INTERNATIONAL
SOIL AND WATER
CONSERVATION RESEARCH

Soil conservation and ecosystem services

Rattan Lal[1]

Abstract

Accelerated soil erosion, driven by anthropogenic activities such as conversion of natural ecosystems to agroecosystems and mechanical tillage, has numerous adverse impacts on ecosystem services. In addition to degrading soil quality and reducing agronomic/biomass productivity on-site through a decrease in use-efficiency of inputs, off-site impacts of accelerated erosion include eutrophication and contamination, sedimentation of reservoirs and waterways, and emissions of greenhouse gases (e.g., CO_2, CH_4 and N_2O). While advancing food and nutritional security, adoption of restorative land use and recommended management practices are important to strengthening numerous ecosystem services such as improving water quality and renewability, increasing below and above-ground biodiversity, enhancing soil resilience to climate change and extreme events, and mitigating climate change by sequestering C in soil and reducing the emission of CO_2, CH_4 and N_2O. An effective control of accelerated erosion is essential to sustainable development and improving the environment.

Key Words: Gaseous emission, Climate change mitigation, Sustainable development, Accelerated soil erosion, Geologic erosion, Food security, Eutrophication, Sedimentation, Water quality, Biodiversity

1 Introduction

Natural or geological soil erosion is a constructive process with numerous ecological functions: formation of alluvial and Aeolian (loess) soils, weathering of alumino silicates and sequestration of atmospheric CO_2, formation and evolution of the landscape with distinct soil types in relation to landscape position, biogeochemical recycling, etc. Some of the world's most fertile soils (e.g., Indo-Gangetic Plains; the Nile Delta; U.S. Great Plains) have been formed through the slow rate of geologic erosion by water, wind and other agents. However, anthropogenic perturbations have drastically accelerated the process leading to severe negative effects on ecosystem functions and services and adverse transformation/dissection of the landscape.Being a work function, as defined by the product of force (kinetic energy of water and/or wind) and the distance over which the soil is transported, the soil impacted by erosion-induced work is subject to several processes. These include: i) detachment of particles from aggregates or soil mass, ii) entrainment of detached particles, iii) redistribution of soil over the landscape, iv) sedimentation and deposition (or burial) of soil in depressional sites following Stoke's law (settling velocity $\alpha\ r^2$, where r is the radius of the particles), and v) long distance transport of fine particles (colloidal material) and the light (low-density) fraction such as soil organic carbon (SOC) and fine clay. In view of these five processes, soil erosion is a reverse of aggregation (Eq. 1):

Stabilization

$$\text{Clay} \underset{\text{Erosion}}{\overset{\text{Aggr.}}{\rightleftharpoons}} \text{Domain} \underset{\text{Erosion}}{\overset{\text{Aggr.}}{\rightleftharpoons}} \text{Micro-aggregates} \underset{\text{Erosion}}{\overset{\text{Aggr.}}{\rightleftharpoons}} \text{Macro-aggregates} \qquad (1)$$

Where Aggr. refers to aggregation involving flocculation, cementation, and stabilization of floccules into micro and macro-aggregates.

Formation of stable micro-aggregates, according to the hierarchy model (Tisdall and Oades, 1982),

[1] Distinguished University Professor of Soil Science; Director, Carbon Management & Sequestration Center, 210 Kottman Hall, 2021 Coffey Road, The Ohio State University, Columbus, Ohio 43210, USA. Corresponding author: E-mail:LAL.1@osu.edu

encapsulates SOC and other soil organic matter (SOM) within it and physically protects it from microbial/enzymatic attack. In contrast, slaking or disruption of an aggregate exposes hitherto protected SOC/SOM to microbial/enzymatic processes and aggravates the rate of decomposition leading to emission of CO_2 (oxidizing or aerobic conditions), CH_4 (reducing or anaerobic conditions) and N_2O (nitrification/denitrification reactions).

Thus, the objectives of this review article is to describe multi-functions and numerous ecosystem services provisioned and strengthened through adoption of conservation effective measures and restoration of eroded and degraded landscapes.

2 On-site and off-site effects of accelerated erosion

Being a complex transformational process, accelerated soil erosion has numerous on-site and off-site impacts. On-site impacts are those that occur at the site of erosion. In contrast, off-site impacts are those that occur where sediments (eroded material) are being carried to and deposited (Fig. 1).

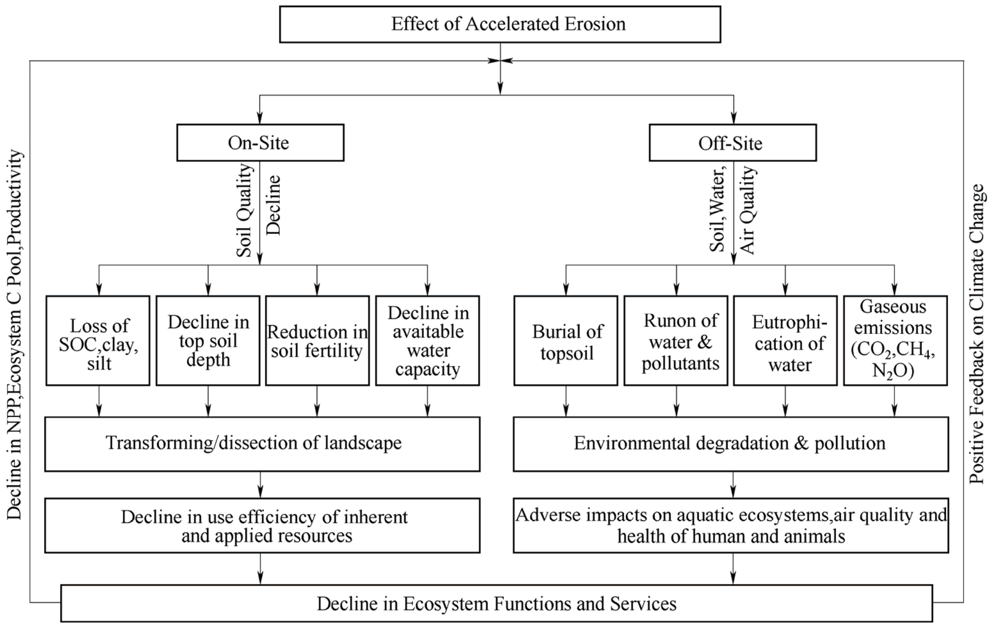

Fig. 1 Adverse effects of accelerated erosion on ecosystem functions and services

Principal among on-site impacts are decline in soil quality because of the loss of key soil constituents (e.g., SOC, clay, and silt), reduction in available water capacity and nutrient reserves, truncation of soil profile and shallowing of topsoil depth, decline of use-efficiency of inherent and applied resources and depletion of ecosystem C pool. Among off-site impacts are burial of topsoil, runon of agricultural chemicals, contamination/eutrophication of natural waters, inundation, anaerobiosis and emission of greenhouse gases (GHGs). Combined, on-site and off-site impacts of accelerated erosion curtail ecosystem functions and services, reduce biomass/agronomic productivity, and create positive feedback to climate change by aggravating emissions of CO_2, CH_4, and N_2O. While some sediment-born C may be buried and protected (Van Ooste et al., 2007), the net effect is increase in the gaseous emission with positive feedback to climate change (Lal, 2003). Numerous goods and services provided by soil (Blum et al., 2004) are severely curtailed when soil is prone to accelerated erosion. In contrast, therefore, adoption of conservation-effective measures has numerous ecological benefits by improving ecosystem functions and services.

2.1 *Accelerated erosion and fate of soil carbon*

Erosion-induced transport and redistribution of C over the landscape disrupt the C cycle at multiple scales (Table 1; Ito, 2007; Kuhn et al., 2009). Transport, redistribution and deposition affect SOC dynamics (Cheng et al., 2010; Haring et al., 2013a; Harper et al., 2010; Nie et al., 2013; Page et al., 2004; Wiaux et al., 2014; Zhang and Li, 2013; Ran et al., 2014).However, some of it is buried (Chaopriche and Marin-Spiotta, 2014; Hoffman et al., 2013; Ran et al., 2014) and is partially protected against decompositional processes.