



Soil Degradation: A Major Problem in India

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Soil degradation in India affects approximately 147 million hectares of land. The main causes include water erosion (94 Mha), acidification (16 Mha), flooding (14 Mha), wind erosion (9 Mha), salinity (6 Mha), and a combination of factors impacting 7 Mha with only 2.4% of the world's land area, India is home to 12% of the world's cattle and 18% of its human population, making this a very serious issue. India has the second-highest agricultural output in the world despite having a small proportion of land. About 50% of the nation's workforce is employed in agriculture, forestry, and fisheries, which provide 17% of the GDP. Soil deterioration has both natural and man-made causes. Earthquakes, tsunamis, droughts, avalanches, landslides, volcanic eruptions, floods, tornadoes, and wildfires are examples of natural causes. Land clearing and deforestation, unsuitable farming methods, poor handling of industrial effluents and wastes, excessive grazing, negligent forest management, surface mining, urban sprawl, and commercial/industrial development are all examples of human-induced soil degradation. Excessive tillage and heavy machinery use, excessive and uneven use of inorganic fertilizers, poor irrigation and water management methods, excessive use of pesticides, insufficient crop residue and/or organic carbon inputs, and poor crop cycle planning are examples of inappropriate agricultural practices. Land scarcity, a decrease in the amount of land available per person, economic pressure on land, land tenancy, poverty, and population growth are some of the underlying societal factors of soil degradation in India (Ranjan, *et al.*, 2018).

Sources of land degradation

Although land degradation is not being sufficiently addressed, it is crucial to increase awareness so that future land management choices can result in more resilient and sustainable agricultural systems. The reporting area is 304.9 Mha of India's total land area (328.7 Mha), of which 264.5 Mha are utilized for pasture, forestry, agricultural, and other biomass production. Numerous organizations have previously reviewed the degree and severity of soil deterioration in the nation. The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP, 2004) estimates that around 146.8 Mha is degraded. The most significant degradation issue in India is water erosion, which causes topsoil loss and terrain distortion. According to an initial approximation analysis of the available data on soil loss, the average rate of soil erosion was around 16.4 tons per hectare per year, which translated into an annual total of 5.3 billion tons of soil loss nationwide (Dhruvanarayan, 1983). Ten percent of the total eroded soil is deposited in reservoirs, sixty-one percent is simply moved from one location to another, and about twenty-nine percent is lost forever to the sea.

In India's rainfed and irrigated regions, soil degradation has grown to be a significant issue. Degraded lands are costing India enormous sums of money. Declining agricultural production, intense land usage, shifting cropping patterns, heavy input consumption, and diminishing profit are all indicators of this cost (Reddy, 2003) used the National Remote Sensing Agency (NRSA) dataset to estimate the output loss in India in 1988–1989 at Rupees (Rs) 68 billion. An estimated Rs 8 billion was lost due to salinization, alkalinization, and waterlogging. According to a recent thorough study on the effects of water erosion on crop productivity, soil erosion caused by water resulted in an annual crop output loss of 13.4 Mt in cereal, oil seeds, and pulse crops, which is equivalent to almost US\$162 billion (Sharda et al.,2010).

Other human-induced land degradation activities include land clearing and negligent forest management, deforestation, overgrazing, improper handling of industrial effluents and wastes, surface mining, and industrial development, in addition to poor agricultural practices that resulted in soil degradation.

Overgrazing, Deforestation and Careless Forest Management

Eight Indian states today have more than 20% wasteland due to degradation brought on by overgrazing and deforestation. Cutting above the allowed limit for silviculture, unsustainable fuelwood and fodder extraction, agricultural encroachment into forest lands, forest fires, and overgrazing all contribute to the loss of vegetation and subject the land to degradation pressures. In contrast to a sustainable threshold level of 5 animals per hectare, a population of 467 million cattle graze on 11 Mha of grasslands, meaning an average of 42 head per hectare of land (Sahay, 2015.). In arid areas, high animal density leads to overgrazing, which reduces infiltration and speeds up runoff and soil erosion. Overgrazing causes soil loss that is 3–18 times higher at the macroscale and 5–41 times higher at the mesoscale (Sharma, 2023). Deforestation and soil degradation resulted from the 1990s tendency of cultivation on slopes (MOEF, 1999). One of the main causes of wind and water erosion is the depletion of the natural woody cover of trees and bushes. This happens because there is an excessive amount of strain on forest lands because the country's per capita forest area is only 0.08 ha compared to the 0.47 ha needed to meet necessities.

Urban Growth, Industrialization and Mining

Large tracts of land are gradually being taken away from agriculture, forestry, grassland and grazing, and underused regions with wild vegetation due to an expansion in industrialization, urbanization, and infrastructure development. Because it modifies a region's socioeconomic characteristics and changes the soil's physical, chemical, and biological characteristics, opencast mining is of special concern. Water shortage as a result of the lowering of the water table, soil contamination, partial or complete loss of flora and fauna, pollution of the air and water, and acid mine drainage are all negative repercussions of mining. Rich topsoil and plants are significantly lost when overburden is removed from a mine area (Sahu and Dash, 2011). Typically, overburden removal is accomplished by blasting or using excavators, which produces a significant amount of waste (soil, debris, and other stuff). Compared to underground mines, open-pit miners generate eight to ten times as much waste (Anon, 2006). The extent and importance of mining's environmental impact vary from mineral to mineral, as does the surrounding environment's capacity to absorb the detrimental impacts linked to the location of mineral deposits and the scale of mining operations. Large amounts of waste, overburden, tailings, and slimes are produced by mineral production, and a significant amount of land is degraded.

Natural and Social Sources of land Degradation

Earthquakes, tsunamis, droughts, landslide, avalanches, volcanic eruptions, floods, tornadoes, and wildfires are examples of natural causes of land degradation. Land scarcity, a decrease in the amount of land available per person, economic pressure on land, land tenancy, poverty, and population growth are some of the underlying societal factors of soil degradation.

Land Shortage, Land Fragmentation and Poor Economy

Small land holdings are common in India, especially in areas that receive rainfall. Approximately 50% of agricultural output is produced on 80% of farmers' holdings, which are ≤ 2 ha. Between 1970 and 2000, the average size of land holdings decreased from 2.3 ha to 1.3 ha, with 0.32 hectares of land per person in 2001 (Mythili, 2014). Farmers who own small land holdings face extreme financial strain. The application of green manuring or soil conservation structures is constrained by labor, land, and capital resources due to this demand. Therefore, non-sustainable land management practices are a direct cause of deterioration when poverty and land scarcity are combined. Inappropriate crop rotations and uneven fertilizer application are two more direct causes of land degradation that stem from this (FAO,1994).

Land degradation is still a major issue despite the Indian government's numerous initiatives. The National Land Use and Development Council in 1985, the National Wasteland Development Board in 1985, the National Watershed Development Projects for Rainfed Areas in 1985–1986, the Reclamation and Development of Alkali and Acid Soil in 1985–1986, the National Land Use Policy in 1988, the Integrated Wasteland Development Project in 1989–1990, the Constitution (74th Amendment) Act in 1992 (Regulation of Land Use). According to the United Nations Environmental Programme (UNEP), human activity and climate change have caused prolonged or frequent droughts that have exacerbated land degradation during the past 20 years. Increasing population:land ratios (the agricultural sector's GDP share decreased from 35% in 1981 to 13% in 2012), institutional and market failures, externality, and tenurial systems—insecure property rights—were further underlying factors.

Population Increase

India is home to about 16% of the world's human population and nearly 20% of its cattle, although making up only 2.5% of the world's land area. India's limited land resources are being severely strained by steady growth in both the human and livestock populations as well as the pervasiveness of poverty. Growing urban populations lead to urban sprawl. Urban sprawl is a result of infrastructure needs such as transportation, water and sewage facilities, housing, schools, commerce, health, and recreation, all of which rise with urban population (Braman *et al.*, 2014).

Agricultural Activities Leading to Land Degradation in India

"The majority of India's arable land has been farmed for hundreds of years, and it was at its most impoverished point many years ago. In this regard, it is important to keep in mind that the majority of India is limited by a lack of combined nitrogen (The Royal Commission on Agriculture in India Report) (RCAI,1928). A technological advancement brought about by the Green Revolution resulted in the introduction of short-duration, high-yielding cultivars that enabled accelerate land use within a year by expanding the area under irrigation and significantly increasing the use of chemicals like pesticides and fertilizers. nearly the past 50 years, India's agricultural output has grown from 50 Mt to nearly 250 Mt. However, this had further repercussions, such as pollution of the environment and a decline in plant biodiversity. Farmers' food and livelihood security are directly and negatively impacted by widespread land degradation brought on by improper farming practices. In essence, degradation is brought on by either waterlogging, which causes soil salinization, or erosion, which causes topsoil to be lost due to wind and water. According to (Maheswarappa *et al.*, 2011) (i) the C-sustainability index was high in 1960 and represented the lowest input usage before the Green Revolution began, and (ii) the C-sustainability index declined because of increased C-based inputs, where there is a linear relationship between C inputs and C outputs. Depending on the land use, crops grown, and management techniques used, agricultural activities and practices can contribute to land degradation in a variety of ways. Urban sprawl and commercial development, overgrazing, excessive irrigation, overdrafting (the process of extracting groundwater beyond the safe yield of the aquifer), cultivation in fragile deserts and marginal sloping lands without any conservation measures, land clearing through clear

cutting and deforestation, agricultural depletion of soil nutrients through poor farming practices, and land pollution, including the disposal of industrial waste on arable lands, are some common causes of land degradation by agriculture.

Low and Imbalanced Fertilization

In India, intensive farming methods have essentially extracted minerals from the soil, especially when it comes to rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.). In comparison to a target ratio of 4:2:1, the already unbalanced consumption ratio of 6.2:4:1 (N: P: K) in 1990 to 1991 has expanded to 7:2.7:1 in 2000–2001 and 5:2:1 in 2009–2010. The number of elements deficient in Indian soils rose from one (N) in 1950 to nine (N, P, K, S, B, Cu, Fe, Mn, and Zn) in 2005–2006 as food grain output expanded over time. Even though fertilizer use has multiplied multiple times, most regions of the nation still have low overall fertilizer use. Zn deficit is widespread across the nation, followed by deficiencies in S, Fe, Cu, Mn, and B. Growing crops extract about 20 Mt of the three key nutrients annually (Tandon, 1992), but the proportional input from inorganic fertilizers and organic manures is insufficient to meet this harvest. According to a different estimate, the difference between nutrient additions and removals over the previous 50 years has been 8 to 10 Mt N + P₂O₅ + K₂O annually (Tandon, 1992). Another factor contributing to soil fertility depletion is nutrient loss from soil erosion, which results in an annual loss of 8 Mt of plant nutrients through 5.3 billion tons of soil loss (Prasad, 2000).

Excessive Tillage and Use of Heavy Machinery

Numerous soil and environmental issues are brought on by excessive tillage, the use of large harvesting equipment, and inadequate soil conservation techniques. Limited soil life and poor soil structure are caused by a decline in soil organic matter (SOM). Soil puddling for paddy rice has detrimental effects on soil biology and deteriorates the physical characteristics of the soil (Hobbs, 2008). Inadequate crop establishment and waterlogging following irrigation are caused by inadequate soil physical conditions. Over the previous forty years, irrigated cropland has doubled from 19% to 38% of the total planted area due to intensive agriculture. A large portion of this water has been taken from scarce groundwater supplies. Waterlogging and salinization are examples of soil degradation issues that have been further exacerbated by improper canal irrigation use and upkeep. Heavy N fertilizer use has caused excess nitrate to seep into groundwater. The primary causes of greenhouse gas (GHG) emissions from agricultural systems are excessive fertilizer applications, indiscriminate irrigation, and needless tillage for planting and land preparation.

Crop Residue Burning and Inadequate Organic Matter Inputs

Nearly 3.7 Mha experience nutrient loss and/or SOM depletion, according to NBSS&LUP data (Sehgal and Abrol., 1994). In India, burning crop leftovers for cooking, heating, or just disposal is a widespread issue that adds to SOM loss. About 500 Mt of crop leftovers are produced annually, and about 125 Mt are burned, according to the Ministry of New and Renewable Energy (MNRE, 2009). Uttar Pradesh generates the most crop residue (60 Mt), followed by Punjab (51 Mt) and Maharashtra (46 Mt). Cereals produce 352 Mt of leftovers, followed by fiber crops (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and sugarcane (*Saccharum officinarum*) (12 Mt). The two main cereals that contribute to the production of agricultural residues are rice (34%) and wheat (22%) (NAAS, 2012).

Poor Irrigation and Water Management

The water table has risen in most canal command regions due to poor irrigation system planning and management, as well as groundwater extraction that exceeds recharge capacity. Concerns include non-conjunctive use of surface and ground water resources, inefficient irrigation water usage, poor land development, seepage from unlined water channels, and inadequate drainage. In regions like the Indo-Gangetic Plains (IGP), extensive waterlogging and salinity issues have been linked to canal irrigation expansion (such as the Indira Gandhi Nahar Project, for example). Due to inadequate irrigation and drainage, saline-sodic soils have developed in arid, semi-arid, and sub-humid climates, rendering extensive areas barren. Poor irrigation management causes soil cracking, which results in water bypass flow and

nitrate leaching (Barman *et al.*, 2013). A U-shaped trace is left by improperly closed fissures, which can enlarge and shrink the soil as they dry.

Poor Crop Rotations

Soil erosion on agricultural fields is largely caused by improper crop rotation combined with inadequate soil and water conservation measures. Land degradation has also been caused by the agriculture of marginal lands on steep slopes, in shallow or sandy soils, with laterite crusts, and in dry or semi-arid areas that border deserts. The primary source of increased wind and water erosion has been agricultural production in marginal regions with low SOM because of inappropriate cropping patterns. In dry and semi-arid regions, sandy-soil coastal areas, and the frigid desert regions of Leh in India's far north, wind erosion is a major issue.

Pesticide Overuse and Soil Pollution

When insecticides are used carelessly along with sewage sludge and composted municipal trash, heavy metals and other hazardous materials contaminate the land and water. The use of pesticides, household and municipal garbage, and inappropriate disposal of industrial effluents are the main causes of heavy metal contamination. Significant amounts of heavy metals, which have negative environmental consequences, are also included in some commercial fertilizers. Land degradation is frequently caused by the careless use of agrochemicals, such as pesticides and fertilizers.

Conclusion

Soil degradation remains one of the most critical challenges to sustainable agriculture and environmental stability in India. The combined effects of water and wind erosion, nutrient depletion, salinity, waterlogging, excessive tillage, residue burning, imbalanced fertilizer use, and rapid urbanization continue to reduce soil productivity and threaten food security. As highlighted in the present review, both natural processes and anthropogenic activities are major contributors to land degradation, causing severe economic and ecological losses.

From a 2026 perspective, the focus must shift from problem identification to large-scale restoration and climate-resilient soil management. Greater emphasis should be placed on conservation agriculture, balanced nutrient management, integrated organic amendments, precision irrigation, crop diversification, and residue recycling. The adoption of remote sensing, GIS-based land monitoring, and AI-assisted soil health assessment is expected to play a major role in identifying degraded areas and implementing site-specific reclamation strategies. Government policies should further strengthen watershed management, afforestation, sustainable mining practices, and farmer awareness programs. In the coming years, restoring soil health will be essential not only for improving crop productivity but also for ensuring long-term environmental sustainability, carbon sequestration, and resilience against climate change impacts in India.

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