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Soil Erosion: Cause, Affect and Remedies

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Abstract—*Soil erosion leading to change in cropping and agricultural productivity and vice versa is threatening the agricultural sustainability of many countries, especially the developing and least developed countries with scare land resources. Soil degradation is "the decline in soil's productivity through adverse changes in nutrient status and soil organic matter, structural attributes and concentrations of electrolytes and toxic chemical (Blaikie and Brookfield, 1987). These problems are partly due to natural cycle of events and mostly because of irrational human interventions. In this paper, an attempt has been made to review the nature and kind of soil degradation in India and its possible remedies to improve the situations.*

1. INTRODUCTION

Soil erosion is a global phenomenon caused by a variety of factors or processes, which include soil erosion by water/wind, deterioration in physical, chemical and biological or economic properties of the soil and long-term loss of natural vegetation. It is estimated that about 2 billion ha area in the world that once was biologically productive is now affected by various forms of land degradation (Oldeman, 1991). About 5-7 million ha of arable land of the world is lost annually through land degradation (Lal and Stewart, 1992). Globally, land degradation affects about one-sixth of the world's population, 70 percent of all dry lands (about 3.6 billion ha) and one-quarter of the total land area of the world. The continental percentage of land degradation is highest in Asia (37%) followed by Africa (25%), South America (14%), Europe (11%), North America (4%) and Central America (3%), the world total being 15 percent. Atlas of India (2005) prepared by Ministry of Rural Development using IRS-LISS III data, 55.27 Mha or 17.45% area of the country is degraded.

Table 1: Degraded lands in India

Type	Area (M ha)
Gullied lands	1.90
Land with or without scrub	18.80
Waterlogged	0.97
Saline/alkali	1.20
Shifting Cultivation	1.88
Degraded forest and agricultural*land under forest	12.66
Degraded pastures/plantation	2.15
Sands	3.40
Mining and industrial wastelands	0.20
Barren/stony/snow covered	12.11
Total	**55.27**

2. OBJECTIVES

The objectives of this article are to:

i. To examine the cause of soil erosion in India.

ii. To evaluate the impact of soil ersion.

iii. To critically analyze the strategies for combating land degradation.

3. METHODOLOGY

This project is the most well-known in the Indian context. Much of the data used for the analysis below was obtained from secondary sources such as published papers, government reports, Journals, and newspaper articles.

4. CAUSES

Degradation of land is a consequence of either natural hazards or direct causes or underlying causes. Natural hazards are the environmental conditions which lead to high susceptibility to erosion such as high intensity storms on steep slopes and soils having less resistance to water erosion, high speed winds, soil fertility decline due to strong leaching in humid climates, acidity or loss of nutrients, waterlogging etc. The underlying causes are the factors indirectly responsible for land degradation such as population pressures, land shortage, tenancy rights, economic pressures and poverty. Land shortage and poverty together lead to no sustainable land management and consequently land degradation.

5. IMPACTS OF LAND DEGRADATION

Land-degradation impacts are felt by the agricultural industry. Thus, the economic and social effects of land degradation are felt most by the people involved in agriculture. For example, in relation to soil, in the short term the economic and social effects may come from the reduced capacity of the soil to sustain plant growth for crops or pasture, resulting in reduced yields. Most agricultural practices lead to natural vegetation being replaced by plants more suited to the agricultural systems. This occurs either through direct clearing and replacement of native vegetation by overgrazing, by changes

in water availability and salinization, or simply by the failure of the native species to recruit new individuals to replace those that die. Although land clearing was seen as essential to grow food and fiber, it has opened our land resource to damage by erosion, destroyed soil structure and changed soil chemistry and caused a loss of biodiversity and other problems.

5.1. Water Erosion

The states of Nagaland, Meghalaya, Arunachal Pradesh, Assam, Chhatisgarh and Jharkhand have more than 60% of their total geographical area beyond the permissible rate of 10 t/ha. Similarly, more than 40% area in the states of Uttar Pradesh, Uttarakhand, Madhya Pradesh and Manipur is affected by erosion rate exceeding the permissible limit About 125 Mha area in the country suffers from water erosion rate of more than 10 t/ha either exclusively or in conjunction with other land degradation problems like salinity, acidity etc.

5.2. Wind Erosion

Wind erosion is prevalent in arid and semi-arid regions of the country covering an area of about 28,600 km2 in the states of Rajasthan, Haryana, Gujarat and Punjab. About 68% of the affected area is covered by sand dunes and sandy plains. It has been estimated that out of 208751 km2 mapped area of Western Rajasthan, 30% is slightly affected by land degradation, while 41% is moderately, 16% severely and 5% very severely affected (Narain and Kar, 2006). Decreasing rainfall gradient and increasing wind strength from east to west are responsible for the spatial variability in sand reactivation pattern.

5.3. Waterlogging, Salinization and Acidification

The problems of waterlogging and salinization in the irrigated command areas of arid and semi-arid regions are a global phenomenon, mainly associated with canal irrigation systems. About 10-33 percent of irrigated lands in various countries are adversely affected by the problems of waterlogging and salinization. The soils which are both waterlogged and salt affected are called waterlogged saline soils.

5.4. Floods and Droughts

Occurrence of floods, droughts and other climatological extremes is a common feature in many parts of the country. These natural disasters cause widespread land degradation apart from heavy monetary losses and a serious setback to economic development of the country. It has been estimated that 8 major river valleys spread over 40 Mha area of the country covering 260 million population are affected by floods.

Besides environmental degradation, poverty and marginalization are other major factors which force the poor to live in threatened and exposed conditions. About 60% of total flood prone area in the country lies in Indo-Gangetic basin which supports 40% of India's population with 60 Mha cultivable land. The Brahmaputra basin is also critical as it experiences frequent floods within the same year thus seriously affecting all developmental activities. The incidence of floods is not restricted to humid and subhumid regions but have also caused extensive damage in the desert districts of Rajasthan and Gujarat in the recent years.

5.5. Vegetation Degradation

The areas which are most affected by vegetation degradation include pasture lands and open forests. The average grazing intensity in India is about 42 animals per ha of land against the threshold level of 5 animals per ha (Sahay, 2000). An estimated 100 million cow units graze in forest lands against a sustainable level of 31 million per annum (MoEF, 1999) affecting approximately 78% of India's forests.

5.6. Depletion of Soil Organic Matter

The organic matter content in India varies with soil texture, climate, rainfall, moisture, tillage, crop residue management, land use, application of fertilizers and cropping systems. The organic matter content is generally low under Indian conditions due to tropical and sub-tropical climate. Comprehensive data on status of organic matter during different time scales is largely missing. In Tamil Nadu state, organic matter reduced from 1.20 in1971 to 0.78 percent in 2002. In the cultivated fields, it rarely exceeds 1 percent except in few soils of hilly region (Table 12). High soil organic carbon (SOC) (> 1 percent) can be accumulated in red and laterite soils of humid tropical and hill and mountain soils having humid temperate climate. Desert soils are the poorest in SOC contents.

Table 2: Organic carbon in surface layer of important soil groups in India

S. No.	Soil group	Organic carbon (%)
1	Deep black soils	0.3 – 0.8
2	Red and laterite soils	0.7 – 6.5
3	Alluvial Soils	0.3 – 1.1
4	Hill and mountain soils	4.0 – 8.0
5	Desert Soils	0.3-0.6
6	Coastal alluvial soils	0.5 –0.9

The SOC in the degraded soils can be improved by adopting the following measures:

- Conservation tillage utilizing crop residues
- Growing leguminous cover crops to enhance biodiversity and produce quality residue for incorporation in soils
- Adding N, P, K and all deficient nutrients to accelerate the process of humification to convert organic residues to humus besides optimizing production.
- Adding organic manures (FYM, Compost, and vermin-compost) under IPNS.

- Adopting soil conservation measures, viz; contour cultivation, contour and graded bunding, terracing etc. to hold humified organic residues along with the soil.
- Maintaining microbial biodiversity which is inherently important to the concept of soil health and transformation of soil organic matter through various soil processes.

5.7. Over Exploitation of Ground Water

Ground water quality is polluted either due to geological factors (arsenic, iron, fluoride etc.) or due to excessive use of agro-chemicals. The occurrence of arsenic in ground water is reported in West Bengal, Bihar, Chhattisgarh, and Assam while high concentrations of iron have been observed mainly in Assam, West Bengal, Orissa, and Chhattisgarh and in Karnataka. Similarly, high levels of fluoride occur in about 200 districts in India. Nitrate pollution occurs in intensively irrigated and high productivity regions due to excessive use of chemical fertilizers in India, especially in states like Punjab, Haryana and Western U.P.

5.8. Degradation Due to Urban and Industrial Wastes and Excessive Use of Agro-Chemicals

Rapid urbanization, industrialization, and agricultural intensification are accompanied by generation of large amounts of solid and liquid wastes. Soil and surface bodies have become logical sinks for Urban Solid Waste (USW), sewage-sludge and industrial effluents (Minhas and Samra, 2004). The per capita generation of solid wastes in India varies from 0.2 to 0.6 kg per day depending upon population size of the city (MUD & PA, 2000). Thus over 450 class I and II cities in India are generating about 57 Mt of solid wastes which are expected to increase to 107 Mt per annum by 2030 (Anonymous, 2003).

5.9. Coastal Erosion

The coastline in India extends from Tamil Nadu to West Bengal in the east and from Kerala to Gujarat in the west. The total coastal length has been reported to vary from 5708 km to 5996 km by various workers (Singh et al., 2004; Joshi, 1995; Ramachandran, 2001). The tidal waves in the Indian Ocean cause considerable soil erosion. Nearly 250 million people live within a distance of 50 km from the coast with a population density of about 880 persons per sq km. The coastline of Tamil Nadu is more affected by storms and depressions especially during November to January (north east monsoon). The state has lost many villages and towns in the past due to sea intrusions..

5.10. Gullies and Ravines

Gullies result from continuous non-judicious use of the land and are defined as advanced form of rill erosion. They generally originate on sloppy lands due to improper management and concentration of flowing water leading to severe erosion hazards. The major factors responsible for formation and development of ravines include severe misuse and management of rainwater and faulty agricultural practices in the upper river catchments resulting in heavy siltation rates and meandering of rivers and backflow of water from adjoining porous strata into the river system leaving behind a network of gullies.

In India, ravines (gullies) occur along the rivers Beas, Yamuna, Ganga, Chambal, Kalisindh, Mahi, Narmada, Sabarmati and their tributaries in the States of Punjab, Uttar Pradesh, Bihar, West Bengal, Rajasthan, Madhya Pradesh and Gujarat .

5.11. Mass Erosion Problems

Landslides, minespoils and torrents are the major mass erosion problems prevailing in various regions of the country, especially in the hill and mountain agro-ecosystems covering Himalayas and Shiwalik region. Due to precipitous slope and high intensity rains, they lead to enormous sedimentation rates affecting productive lands besides loss to life and property. Apart from causing disruption to traffic, they also impair the quality of water resources and in turn the aquatic life in streams and reservoirs.

5.12. Landslides

The hilly regions having steep slopes, fragile ecology, high seismic activity, and intense rainfall conditions are highly susceptible to land sliding. The problem gets further aggravated by excessive deforestation, unscientific cultivation on steep slopes and developmental activities like road construction, buildings construction, mining etc.

5.13. Climate Change Impacts

The analysis of monthly rainfall data for all the 36 subdivisions of the country indicates that contribution of June and August rainfall exhibited significantly increasing trend while contribution of July rainfall showed a decreasing trend (Guhathakurta and Rajeevan, 2006). Thus, a major shift in rainfall pattern both spatially and temporarily has been recorded in the recent years. Analysis of long-term rainfall data for over 1100 stations across India show pockets of deficit rainfall over eastern Madhya Pradesh, Chhatisgarh and North-east region in Central and Eastern India (Subba Rao et al., 2007).

6. STRATEGIES FOR COMBATING LAND DEGRADATION

For evolving effective strategies to check land degradation, it is imperative to assess, characterize and classify different types of degradation problems and develop appropriate technologies to reclaim the degraded areas for their productive utilization. In India, participatory watershed management has been accepted as a tool for all developmental activities with a focus on socio-economic aspects apart from biophysical attributes following ‘bottom up’ participatory approaches.

Common guidelines for watershed development projects have been formulated and implemented since April 1, 2008 for all the concerned ministries.. The following issues need to be addressed on high priority for efficient management of natural resources:

- Integrated land resource management policy is needed to meet the projected phytomass/ biomass demand by accounting for the reclamation of degraded lands and involving all the concerned ministries.
- For sustainable land use management, methodologies need to be developed for optimal land use planning at different scales using modern tools and procedures.
- There is a need to develop and evaluate integrated farming systems in different agro ecological regions of the country to maximize productivity and profitability, input use efficiency, cropping intensity, resource conservation, employment generation, environmental security, and poverty alleviation. It would encompass optimal combination of various enterprises, viz; agriculture, horticulture, livestock, fishery, forestry etc. for different categories of farmers and farming situations to achieve efficient utilization of land and water resources and prevent over exploitation of land.
- For productive utilization of waste/degraded lands, location specific alternate land use systems, viz; agri-horti, horti-pastoral, agri-horti-silvi, agri-silvi-medicinal and silvipastoral need to be developed for scientific planning of land resources following watershed approach.
- The problem soils such as saline and alkali soils should be managed by leaching of excess salts, improving drainage systems, application of gypsum, growing green manures or mulches and tolerant crops and trees as per packages developed and recommended by research organizations.
- Soils polluted by heavy metals or toxic substances and excessive use of agrochemicals can be ameliorated through phytoremediation, bioremediation, manipulating microbial catabolic genes and growing resistant crops.
- To prevent land degradation, conservation agriculture should be promoted to ensure minimum disturbance to the soil, provide permanent cover to the land surface, and select appropriate cropping systems and rotation to achieve higher profitability and environmental security. It would include zero-tillage, residue management, mulching, cover crops, and various soil and water conservation measures.
- Soil management practices like residue incorporation, manuring, reduced tillage, and mulching play a vital role in sequestering carbon in the soil and check CO2 emissions.

Reclamation of degraded soils and ecosystems following watershed approach can enhance the terrestrial C pool, microbial population, and soils net C sinks for higher and sustained productivity.

- Suitable soil quality indicators need to be developed to sustain hydrological, biological and production functions of the soil and prevent deterioration of land resource due to physical, chemical, and biological factors.
- Enabling policy framework is essentially required by enacting suitable legislations to provide for remediation of damaged soils, trans-boundary impact of pollution and cost of land degradation to taxpayers. The polluters must pay for abuse of the land resource through dumping of industrial or domestic wastes, irrigation with poor quality water, excessive use of agro-chemicals; intensive use and over-exploitation of land especially the marginal and fragile ecosystems and non-adoption of appropriate conservation measures during mining and related activities.

7. CONCLUSION

It can be concluded that land degradation is a serious problem in India which need to be tackled because shrinking of land resource base will lead to a substantial decline in food grain production which in turn would hamper the economic growth rate and there would also be unprecedented increase in mortality rate owing to hunger and malnutrition.

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