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Soil Degradation

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1. Introduction

The rise and fall of ancient civilizations were in direct proportion to the wise use or misuse respectively of the natural resources, in particular, land and water resources. Land is the finite resource which is devoted to the largest primary "Private Industry" namely, "agriculture". But unfortunately land is the least cared; most neglected and misused resource by almost everyone, either knowingly or unknowingly. The results are obvious and for everyone to see in the form of degradation and declining productivity of our resource base. The situation demands everyone's attention and immediate correction.

The pressure on our finite land resources is tremendous at present due to increasing population and competing demands of various land uses. The decreasing land-man ratio and continued dependence of a high proportion of the population on agriculture in developing nations is a matter of grave concern. That is why we are witnessing high rate of unemployment and under employment in the rural areas. Under such circumstances, the extent of unemployment can rise alarmingly unless measures are taken to either increase the intensity of land use or shift a significant proportion of the human resource out of agriculture to non-agricultural activities, or both, and both are not likely to happen that easily in the developing countries.

It is obvious that the population pressure, both human and cattle, and competing demands and needs of the society exerts tremendous pressure on the limited and shrinking land resources like soil, water, forests, vegetation, bio-diversity etc. Due to this pressure, there is severe degradation of the resources and large-scale change in the land use and land cover. Apart from this, particularly of late, there is a significant diversion of farm lands and water resources to non- agricultural purposes, exerting further strain on the already shrinking land and fast-depleting water resources.

Due to the population pressure in most developing nations, the existing forest areas are facing deforestation, cutting beyond the silviculturally permissible limit, unsustainable fuel wood and fodder extraction, shifting cultivation, encroachment into forest lands, forest fires and over grazing. These changes affect drastically the vegetation, rainfall and sedimentation levels in the lakes and reservoirs, hydrological cycle, bio-diversity and ultimately the land use. All such issues are now being widely discussed under the broad heading "global climate change". In spite of concerted efforts by the governments to check deforestation, large forest areas are already degraded and the remaining areas are in various stages of

degradation. This has been conclusively proved through number of studies based on satellite imageries taken at regular intervals (Vasisht et al., 2003).
The land use dynamics in cultivated areas is unique and different than that is observed in the forest areas. Factors and processes like introduction of irrigation, topography, climate, floods and droughts, market fluctuations, input-output levels, price fluctuations, government policies, lifestyle changes and severity of degradation etc affect the types of crops grown, system of cultivation and input management in different regions of the globe (Lal & Stewart 1990).

Fig. 1. Forest fires have the devastating effect on all the elements of ecosystem including soil

Most of the times, the choice of the crops is not based on the suitability of the area, resulting in either over exploitation or under utilization of the soil, water and other resources. This leads to degradation of the land resources and ultimately to change in the land use pattern itself. A case in hand is the development of severe salinity in the Indo-Gangetic Plains and command areas in the Deccan Plateau of India due to uncontrolled and unscientific irrigation which has changed dramatically the land use of the area from multiple cropping to almost a single crop in about 11 m ha area (Suraj Bhan et al., 2001). If we consider the case of India, the latest estimate indicates that soil erosion, salinity and alkalinity, water logging and declining soil fertility has affected about 57 per cent (187.8 m ha) of the land resources in the country, threatening the sustainability of the resource base(Table 1).
Land resource includes soil, water, bio-diversity, climate etc. Soil is the most important component among all, as any effect on it, directly influences and changes other components

also. Soil degradation is the loss of actual or potential productivity and utility of soils. It implies a decline in soils inherent capacity to produce economic goods and perform environmental regulating functions (Anthony Young 1998). Among the functions, agricultural productivity and environmental regulatory capacity depend on soil quality and relevant properties. Soil degradation is the temporary or permanent lowering of the productive capacity of land as a result of human actions or non-action. It covers the various forms of soil degradation, including erosion and fertility decline, adverse impacts on water resources, deforestation and forest degradation and lowering of the productive capacity of pastures etc. Loss of biodiversity and human-induced climatic change also has effects, direct and indirect, on productive potential of land resources (Pathak, 2010).

1.1 The global extent of soil degradation

Global Assessment of Soil Degradation (GLASOD) was the first attempt to estimate the severity and extent of soil degradation on a world basis (Oldman, 1988). A key feature of this study was that the degrees of severity were defined not in physical terms, as soil loss, nutrient decline, but on the basis of effects upon agricultural production. This was done because it allowed comparison between different types of degradation.

1.2 Degree of soil degradation

Four categories to express degree of soil degradation are recognized. The categorization was in terms of agricultural suitability, declined productivity and biotic functions. These are:

1. Slight: The terrain has somewhat reduced agricultural suitability, but is suitable for local farming systems: restoration to full productivity feasible: original biotic functions largely intact.
2. Moderate: The terrain has greatly reduced in agricultural productivity, but is still suitable for local farming systems: needs major improvements to restore productivity; original biotic functions partially destroyed.
3. Strong: the terrain is non-reclaimable (at farm level) and requires major engineering works for terrain restoration: original biotic functions largely destroyed.
4. Extreme: The terrain is irreclaimable and beyond restoration: original biotic functions fully destroyed.

Degradation type	Area affected (m.ha)	Percent
Water Erosion	148.9	45.3
Wind Erosion	13.5	4.1
Chemical Deterioration (loss of nutrients, salinisation)	13.8	4.2
Physical Deterioration (Water logging)	11.6	3.5
Total affected area	187.7	57.0
Land not fit for Agriculture	18.2	5.5
Total Geographical Area	328.7	100.0

(Majhi et al 2010)

Table 1. Extent of Land Degradation in India

It is critically important whether a type of degradation is reversible, and if so over how long and at what cost. Earlier approaches to soil degradation, from productivity or agronomic point of view have now evolved to an environmental one in the last decades. The environmental point of view enables other degradation processes to be accepted, not only those processes affecting soils intrinsic characteristics (changes of the physical, chemical, biological soil properties, or agricultural use), but also those processes due to externalities. Universally known degradation processes are soil erosion, compaction, alkalinization, salinization, pollution, acidification, nutrient depletion and organic matter loss (USDA, 1998).

Out of a world land area of 13000 M ha, 4300 M ha are deserts, mountains, rock outcrops, or ice-covered, leaving a balance of 8700 M ha of usable land, meaning land with potential for cultivation, grazing, or forestry. For developing countries, about 1500 M ha or 25%of usable land are affected to some degree by degradation. The percentage degraded is highest in Africa and Asia, and lowest in South and Central America. About half the area of arable land and a quarter that of permanent pastures is degraded. Water erosion is given as the most widespread dominant type of degradation, with 836 M ha in developing countries, followed by wind erosion affecting 456 M ha, soil chemical and physical degradation 241 M ha, and salinization and water logging 836 M ha (Oldman, 1988).

More reliance can be placed on the estimates of strong and extreme degradation. The definitions imply that these refer to land that is largely destroyed, and probably abandoned from agricultural use. Moreover, since they refer to gullies, hillsides stripped off soil, salinized patches, and the like, such degradation is relatively easy to recognize and assess in semi-quantitative terms. The total world area of strongly degraded land is 305 M ha, of which 224 M ha is due to water erosion and 21 M ha to salinization. About 95%of this is in developing countries. The conservative estimates suggest that current loss due to degradation maybe more than 5 M ha per year. The 21 M ha of severely salinized land, probably representing saline patches that have been abandoned, is also largely in the tropics. It amounts to over 10 %of the irrigated area in developing countries and is steadily increasing as investments in soil conservation/reclamation programs are not forthcoming on expected lines.

	Usable land M ha	All degrees of degradation		Strong and extreme Degradation	
		M ha	%	M ha	%
Africa	663	494	30	129	8
Asia	779	748	27	109	4
South/Central America	714	306	18	48	3
Developing countries	656	548	25	286	5
Developed countries	555	417	16	43	2

(Source: Oldman, 1988).

Table 2. Global Assessment of Soil Degradation (GLASOD)

If it is assumed that most of this loss has taken place over the last 60 years, probably at an accelerating rate, the current loss becomes at least 5 M ha per year, or 0.3% of usable land of developing countries. An area of about 1500 M ha, or 25% of usable land in developing countries, has been affected by soil degradation of some kind, to a degree which appreciably (10 % of land) or greatly (15 % of land) reduces its productivity. About 300 M ha. or 5 % of usable land in developing countries have been so severely degraded, mainly by erosion, that for practical purposes they can be regarded as lost.

2. Causes of soil degradation

The causes of soil degradation are made up of natural hazards, direct causes, and underlying causes. Taking soil erosion by water as an example, the natural hazards include steep slopes, impermeable or poorly structured soils, and high intensities of rainfall. The direct causes are unsuitable management practices, such as cultivation without conservation measures, or overgrazing etc. The underlying causes are the reasons why such practices are adopted, such as the cultivation of slopes because the landless poor need food and non-adoption of conservation measures because farmers lack security of tenure (Hassan & Rao, 2001).

Water erosion was attributed more or less equally to deforestation, agricultural activities like the cultivation of land naturally at risk without adequate conservation measures and overgrazing. Wind erosion is primarily due to overgrazing and to a lesser degree, over cutting of vegetation. Soil chemical and physical degradation result primarily from faulty agricultural practices. The deterioration of soil physical properties occurs when farmers try to maintain crop yields by fertilizer use alone, without measures to maintain organic matter (Butterworth et al., 2003).

The direct causes of soil degradation like salinization are due to mismanagement of irrigation schemes and lowering of groundwater through extraction in excess of recharge (Singh et al., 1992). Adverse changes in river flow and sediment load are off-site consequence of forest clearance and erosion. Deforestation is resorted mostly for agricultural use than by felling for timber. Forest degradation is normally due to over cutting for fuel wood, domestic timber and fodder. Selective extraction of the best species in commercial logging is also another major cause for forest land degradation.

2.1 Economic and social reasons

Soil degradation need not be viewed as a consequence of failure by farmers to adopt conservation practices, or deforestation. It is only part of the picture and the root of the problem lies in economic and social circumstances. We need to view the situation from a socio-political stance, seeking for changes in the social structure and state polices, programs and developmental interventions, if measures to combat land degradation are to be successful (Greval & Dogra 2002, Srivastava et al., 2002).

Land tenure is rightly seen as a basic obstacle in sustainable management of land resources. It is natural that farmers are reluctant to invest in conservation measures if their future rights to use the land are not secure. Two kinds of property rights lead to this situation, insecure forms of tenancy and open access resources. Tenancy as such is not to blame, provided that there is legal security of tenure. In the 1980s, following a World Conference on Agrarian Reform and Rural Development (WCARRD), there was an impetus on reform of land tenure. Land reform programs were attempted in many countries, with limited success owing to opposition by strong vested interests (FAO, 1988).

Fig. 2. Cultivation on steep slopes without adequate conservation structures: cause for degradation of natural resources

Land shortage, brought about by population explosion has become a fundamental cause of degradation. Once farms are too small to support their children and all the good land is taken up for crop production activities, migration to sloping, semi-arid, or other areas with high natural hazards takes place. Frequently this will require clearance of forest. Soil conservation is normally applied on a participatory basis, through the approach of land husbandry. Forests, which serve the needs of local people for food, fodder and fuel wood, are more likely to be conserved, if responsibility for their management is given to the village or community

2.2 Vicious cycle of population, poverty and land degradation

A chain of cause and effect links direct and indirect causes of land degradation. The driving force is an increase in population dependent on limited land resources base. This produces land shortage leading to small farms, low production per person, increasing landlessness and in consequence, poverty. Land shortage and poverty together lead to non-sustainable land management practices, the direct causes of degradation. Poor or landless farmers are led to clear forest, cultivate steep slopes, overgraze village common lands like pastures or make short-term unbalanced fertilizer applications. These non-sustainable management practices lead to land degradation, causing lower productivity and lower responses to inputs. This has the effect of increasing the land shortage, thus completing the cycle.

Only the poor by no means cause land degradation. Irresponsible rich farmers sometimes exploit the land, but by and large farmers with secure tenure and capital are more likely to conserve natural resources. When natural disasters occur, rich farmers can turn to alternative sources of income, or borrow and repay in better years. These alternatives are not open to the poor (Srivastatva et al., 2002).

Fig. 3. Salinization of most fertile black soils due to excessive irrigation in India

In the past, rural populations had access to adequate land to meet their needs. When a disaster occurred, whether of natural origin or war, there were spare resources to fall back upon. They could take new land into cultivation, kill livestock, which fed upon natural pastures or go into forest and extract roots or hunt wildlife. Because of land shortage, these options are no longer available. Farmers are surrounded by other farmland, such common rangeland as exists is often degraded, and over large areas no forest remains. The options open are to work on the farms of others, non-agricultural occupations, enforced migration to the cities or ultimately dependence on famine relief. Many African nations face exactly the same situations even now (Young, 1998).

If we consider the case of India, the limited land area which is equal to only 2.5 per cent of the world's geographical area. It supports approximately 16 per cent of the world's human population and 20 per cent of the world's livestock population. The population of India has already crossed one billion mark and is still growing at the rate of about two per cent. This exponential growth of population (36.1 crores in 1951 to 102.7 crores in 2001) and dependence of more than 60 per cent of the population for their livelihood on agriculture and allied activities exerts tremendous pressure on the limited land resources of the country. At present, the per capita availability of land is only 0.15 ha, which will be further reduced to less than 0.07 ha in 2050 with an expected population of about two billion (Grewal & Dogra, 2001).

Hence the stress on limited land resources is going to increase day by day. Governments need to address the issues with all the seriousness. The link between population, poverty and soil degradation is now widely recognized. FAO reports 'A lack of control over resources, population growth and inequity are all contributing to the degradation of the region's resources**.** In turn, environmental degradation perpetuates poverty, as the poorest attempt to survive on a diminishing resource base'**.** Through force of circumstances, it is the poor who take the major role in the causal nexus between land shortage, population increase and land degradation. Thus rapid population growth can exacerbate the mutually reinforcing effects of poverty and environmental damage of which the poor are both victims and agents. Hence, in such nations population control needs to be taken on top priority to protect the natural resources base besides other socio-economic conflicts (FAO, 1988).

3. Processes and causes of soil degradation (Table 3)

Two processes lead to the loss of soil's capacity to perform its functions: those that change their physical, chemical and biological properties (intrinsic processes) and those that prevent their use by other causes (extrinsic processes)(Antony Young 1998).

Intrinsic processes
Degradation of the Physical fertility
Compaction
Crusting
Structural degradation
Soil loss: Water and Wind erosion
Mining
Urbanization of agricultural lands
Land movements by civil engineering for infrastructure projects
Excess water/waterlogging
Degradation of Chemical fertility
Loss of nutrient: Leaching
Extraction by plants (nutrient mining)
Run off loss of nutrients
Immobilization of nutrients
Acidification
Salinization
Sodification; alkalinization
Pollution
Degradation of biological fertility
Loss of organic matter
Extrinsic processes
Loss of accessibility: damage of roads etc.
Conversion to risk areas: Natural disasters etc.
Climate fluctuations
Inadequate agricultural policies
Illiteracy
Human induced degradations like degradation due to brick making, sand extractions etc.

Table 3. Soil Degradation processes

3.1 Soil erosion

Soil erosion is the detachment or breaking away of soil particles from a land surface by some erosive agent, most commonly water or wind, and subsequent transportation of the detached particles to another location. Erosion is a natural process and is a critical factor in soil formation from rock parent material. Human activities are responsible for greatly

Fig. 4. Cultivation of crops not suited to the land (ginger in place of paddy): a cause for soil degradation

Fig. 5. Uncontrolled grazing by livestock: a cause for degradation

accelerating erosion rates, usually by reducing or eliminating plant and residue cover. However, once productive agricultural soils have been formed over periods of thousands or millions of years, erosion of the soil material is then usually very low or negligible because of the impacts of protective natural plant and residue cover. This exposes the soil to wind and water erosion forces, weakening the soil cohesive forces by tillage disturbance, and increasing the erosive agents, particularly by activities that increase surface runoff. Soil erosion is a serious problem and major cause for the declining productivity, particularly in the rainfed areas world over. If we consider the case of India, almost the entire rainfed area in the country, covering an area of about 70 m ha, is affected by severe sheet and rill erosion. Loss of topsoil is one of the major factors for the low and unstable crop yields obtained in the semi-arid and sub-humid subtropics of India (Sehgal & Abrol, 1994).

Fig. 6. Forest clearing for rubber cultivation: steep slopes and high rainfall in Kerala state (Southern India) makes the soil most vulnerable for severe erosion losses.

Gullies and ravines are also commonly seen in these areas. Wind erosion is dominant in the western regions of the country and to some extent in the coastal areas. It causes loss of topsoil, terrain deformation, over blowing and shifting of sand dunes. It is estimated that more than 45 per cent of India's geographical area is already affected by serious soil erosion and this proportion is increasing year by year.

It is estimated that the soil forming process needs hundreds of years for the formation of few inches of agriculturally productive soils. Under natural condition, undisturbed by man, equilibrium gets established between the climate of a place and the cover of vegetation that protects the soil layer. A certain amount of erosion does take place even under this natural cover, but it is slow and very limited in nature which is balanced by the soil that is formed by continuous weathering and other soil forming processes. When this balance is upset because of the cultural operations followed or any other reason, the removal of soil takes place at a faster rate than its renewal.

In sheet erosion, the movement of runoff water and eroded soil occurs in thin sheets continuously. When this moving sheet assumes sufficient velocity, its cutting action on the soil gets increased and results in the formation of rills, trenches or gullies. If the velocity of the runoff water is doubled, its energy increases fourfold and its erosive action on the soil is correspondingly increased and its capacity to carry soil particles is increased by 64 times (Government of Madras, 1954). The gullies tend to get deeper and wider with every succeeding rain and eventually cut up the agricultural lands into fragments and making it unfit for cultivation. Gully erosion is more evident and spectacular at the surface but sheet erosion is more dangerous as it is insidious and is seldom noticed before it is too late to remedy its destructive effects on heavy soils.

3.2 Erosion by water

Water erosion results from the removal of soil material by flowing water. The most common types of soil erosion by water are sheet and rill erosion on upland areas, channel and gully erosion in small watersheds and stream channel and bank erosion in larger catchments.

Sheet erosion is caused by the action of rain drops and shallow overland flows that remove a relatively uniform depth (or sheet) of soil. Because of uniform nature of the soil loss, it is often difficult to detect and gauge the extent of damage caused by sheet erosion.

Rill erosion occurs in well-defined and visible flow concentrations or rills. Soil detachment in rills is largely because of flow sheer stress forces acting on the wetted perimeter of the rill channel. Once detached, larger sediment particles move as bed load, rolling and bouncing down slope with the flow, and are almost always in contact with the soil surface. Smaller sediment particles (silts and clays) are much easier to transport and travel in the rill channels as suspended load. Rills are also the major pathways for trans- porting away sediment that is detached by sheet erosion (also known as interrill detachment). By definition, rill channels are small enough to be obliterated by tillage and will not reform in exactly the same location(Hallsworth, 1987).

Losses under dense natural vegetation are likely to be less than 1 t ha^{-1} per year, under well-managed crops or with conservation works it, whilst, for crops such as maize or tobacco on moderate to steep slopes without conservation, rates of the order of 5o t ha^{-1} per year are recorded in the savanna zone and upwards of 100 tin the humid tropics (Hassan & Rao, 2001).

Removal of soil by erosion and its renewal by rock weathering are natural geomorphological processes, so the question arises as to the rate of loss that is acceptable. The basis normally used is called the soil loss tolerance, defined as the maximum rate, which 'will permit a high level of crop productivity to be sustained economically and indefinitely'. Tolerances were established for different soils of the USA, mostly in the range 5-12 t ha^{-1} per year. In the tropics, a value near the top end of this range, about 10 t ha^{-1} per year, is commonly taken as a guideline, because on cropland it is difficult to achieve much below this rate in practice. This is equivalent to losing a soil thickness of o.8 mm per year, or 8 cm per century (USDA, 1988).

This estimate rests on dubious foundations, particularly as regards sustaining production 'indefinitely'. This word implies that it is the rate at which soil is renewed by rock weathering. The latter has not often been measured, but studies of rates of natural erosion show these to be more typically 1t ha^{-1} per year, and it is reasonable to assume that weathering keeps pace with erosion. It may be that 'tolerable' erosion rates will sustain production for one or several generations, but, since they imply loss of nearly one meter of soil in 1000 years, they are not fully sustainable.

Fig. 7. Over grazing and neglect of village common lands leading to severe erosion

Fig. 8. Rill erosion in cultivated black soils

Because direct measurement has proved difficult, the use of modeling has been widespread. This is founded on the universal soil loss equation (USLE), which states that the predicted rate of erosion, in tons per hectare, is equal to the product of five Factors of erosion: rainfall energy, soil resistance, slope angle and length, crop cover, and conservation practices (Sehgal & Abrol, 1994). Based on experiment data, it is employed as a field guide to conservation; having obtained the predicted erosion for a site without conservation, erosion is reduced to the tolerable level by conservation practices as necessary.
It is not sufficient to know the rate of erosion in terms of soil loss. Before the considerable effort and expense of conservation works can be justified, it is necessary to know the effects on plant growth and crop production. An order-of-magnitude calculation illustrates the effect of the loss of plant nutrients. There is clear experimental evidence that concentrations of nutrients in eroded soil are over twice those in the soil from which they are derived, owing to selective removal of fine particles. Assuming that typical topsoil contains 0.2 % nitrogen, erosion of 20 t of soil will remove 80 kg of nitrogen, together with other nutrients. This is equivalent to carrying several bags of fertilizer away from each field every year. There is a further effect from loss of organic matter by erosion, causing degradation of soil physical conditions (Natrajan et al., 2010). There can be no doubt that erosion in excess of 50 t ha^{-1} per year is common where steeply sloping land is farmed without conservation, and that erosion at such a rate has extremely serious consequences for the future.

Fig. 9. Most catastrophic form of erosion: Gully erosion

As one moves from smaller hill slopes to larger fields and watersheds, additional erosion processes come into play, because of the increasing amount of runoff water. Gullies are incised erosion channels that are larger than rills and form in regions of large runoff flow concentration. Ephemeral gullies are a common type of erosion feature in many fields. They are small enough to be tilled over, but re-form in the same location owing to the convergent topography in small catchments. Classical gullies are larger erosion features that cannot normally be tilled across.

Gullies and gully patterns vary widely, V-shaped gullies form in material that is equally or increasingly resistant to erosion with depth, U-shaped gullies form in material that is equally or decreasingly resistant to erosion with depth. As the substratum is washed away, the overlying material loses its support and falls into the gully to be washed away. The cost of restoring the areas affected with such kinds of severe erosion is at least 50 times more than the cost of preventing the events taking place (Young, 1998).

3.3 Erosion by wind

Erosion by wind occurs when wind speed exceeds a certain critical or threshold value. Soil particles can be detached and moved through suspension, saltation, or creep. Suspension usually lifts the smallest soil particles (clays, silts, organic matter) so high into the air mass that they are easily kept in motion and can travel for long distances. Soil particles that move by creep are larger sand grains and aggregates that stay in contact with the soil surface. Almost all times their motion is often through rolling and bouncing. Saltating soil particles are usually moderate in size, and once detached, move in trajectories up into the air and then back down to the soil surface (FAO, 1991).

Fig. 10. Neglected road side water drain forming into a huge gully

Fig. 11. Simple low cost bunding and bund planting can effectively prevent major forms of soil erosion

3.4 Classes of accelerated erosion

In cultivated fields 4 classes of accelerated erosion are identified based on degree of loss of surface layer and its spread over the fields

Class 1: Soils that have lost some, but on the average less than 25 per cent of the A horizon or the upper most 20 cm. Throughout most of the area, the thickness of the surface layer is within the normal range of variability of the uneroded soil.

Class 2: Soils that have lost, on the average, 25 to 75 per cent of the original A horizon or the upper most 20 cm. Throughout most cultivated areas the surface layer consists of a mixture of the original A horizon and material from below. Some areas may have intricate patterns, ranging from uneroded areas to severely eroded small areas.

Class 3: Soils that have lost, one the average, 75 per cent or more of the original A horizon or of the uppermost 20 cm. In most areas material below the original A horizon is exposed at the surface in cultivated areas; the plough layer consists entirely or largely of this material.

Class 4: Soils that have lost all of the original A horizon or the upper most 20 cm. In addition, some or all of the deeper horizons are lost throughout most of the area. The original soil can be identified only in small areas. Some areas may be smooth, but most have an intricate pattern of gullies.

Fig. 12. Growing hardy grasses (Pennisetum vahnikere) on farm bunds to conserve soil and water in semi-arid tropics

3.5 Loss of soil structure

Soil structure describes the arrangement of primary particles into aggregates of different sizes and shapes and the associated pore spaces between them. Therefore, a structured soil is heterogeneous; where a degraded, structure less soil is homogeneous. Soil structure significantly influences all processes that take place in the soil. It influences water infiltration (and hence runoff), the movement of water within the soil and the amount of water that can be stored in the soil. Soil structure also determines aeration levels in the soil, which are essential for the oxygen supply to roots, soil fauna and for aerobic microbial activity. Not only the soil structure but also the stability of the structure is of major importance. Structural stability determines the ability of a soil to withstand imposed stresses without changes in its geometric structure and functions. These stresses may be due to rapid wetting, raindrop impact, wheel traffic and excessive tillage(Lal & Stewart, 1990).

Soil physical degradation results when soil aggregates are destroyed by internal or external forces. Internal forces are applied when entrapped air breaks out of soil aggregates upon flooding. External forces appear in the form of rain impact or pressure and sheering for as exerted by animal trampling, wheel traffic and tillage implements.

Depending on the water content, this results either in pulverization or compaction of the soil. Soil physical degradation, however, depends not only on the degrading forces and stresses but also on the stability of a soil to withstand these stresses and its resilience to recover from different levels of short term and long term degradation. Mineral composition of soils also determines its structural stability. Salts like sodium in excess makes the soil vulnerable for destruction of its structure. Supplying adequate soil organic matter and adoption of proper irrigation technologies are essential for maintaining ideal soil structure that is required for the successful production of most crops (Lal & Stewart, 1990).

Fig. 13. Hardy local plant species having commercial value (Agave sps) are essential for successful soil conservation)

3.6 Compaction

Compaction describes the state of "compactness", i.e., bulk density of a soil. Compared with its undisturbed condition, a compacted soil exhibits reduced total pore space, especially because of a drastic reduction of the macrospores, and a pronounced discontinuity of the pore system within the profile. This affects the conductive properties of the soil and reduces its ability to retain air and water. Hence, plants growing under high evaporative demand suffer more from compaction than plants growing under low evaporative demand. Compaction also inhibits root penetration and development, thus affecting nutrient uptake and consequently, plant growth.

The most important cause of compaction is off-road wheel traffic and the use of heavy machinery in mechanized agriculture. Soils with high clay contents and well developed pore systems are generally more compressible than sandy soils. Two main types of soil compaction can be distinguished, namely, the surface layer compaction and subsoil compaction (Government of Madras, 1954).

Surface layer compaction describes the compaction in the upper part of the soil profile, i.e., in arable soils usually the plough layer, Compaction in the surface layer is dynamic and changes significantly over the cropping season, increasing with increasing machinery passes over the field and decreasing again with primary tillage for seed bed preparation for the following season. Adequate tillage effectively reduces soil compaction in the surface layer and its effects.

Sub-soil compaction affects soils beyond the surface layer at depths >30 cm. It is caused by heavy machinery. Swelling-shrinking, freezing-thawing and biological activities can alleviate compaction to a certain extent. Sub-soiling using specially designed equipment can in some cases alleviate sub-soil compaction, but is very energy demanding some times, soils become more dense than it was before sub-soiling because of the destabilization of the soil caused by the mechanical energy input from the sub-soiling operation. Compaction should be considered to be an irreversible, permanent form of degradation.

3.7 Sealing and crusting

Seals and crusts are consequences of rain and flooding on unprotected soil-surfaces. Under the impact of rain drops and the soaking effect of water, the bonds that hold the particles together become weak and the aggregates tend to fall apart. Individual particles become separated. These particles become rearranged and the finer particles tend to be washed into the cavities of the surface. There they form a very thin (1-5 mm) and dense layer that clogs the soil pores and seals the surface. These seals are usually very elastic. Typical characteristics of soil seals are that they do not crack and cannot be removed from the surface.

Fig. 14. Effective use of locally available raw materials like stones and rubbles can reduce the dependence on government aid for soil and water conservation

Soil crusts are formed by the same processes that form seals. They are much thicker than seals (usually 5-20mm) and can be separated easily from the soil surface, and they crack upon drying. Crusts are typically formed on soils with high contents of non swelling clay susceptible to dispersion. Seals that become hard upon drying are also termed crusts. Soils with a high content of fine or very fine sand, or silt are especially prone to sealing and crusting. The presence of exchangeable sodium in the soil can enhance clay dispersion and thus contribute to seal and crust formation.

Fig. 15. Engineering inputs wherever it is absolutely essential to make the projects successful

Fig. 16. Participation of local communities at every stage of soil and water conservation ensures greater success

3.8 Causes and effects of soil physical degradation

The main causes of soil physical degradation are inappropriate land use and soil management practices. All exploitative practices will ultimately lead to degradation and hence reduce soil productivity. In the developing world, land not suitable for cultivation, such as dry lands or steep terrain, is increasingly being cropped. The cultivation and husbandry practices associated with these land use systems are largely responsible for degradation. Ultimately, soil physical degradation leads to reduced plant growth, crop yields, and soil productivity. Soil and water are inseparable when we plan any conservation measure. Hence better husbandry practices to take care of soil, water and crop must go together in any conservation program (Hellin and Haigh, 2002).

4. Soil chemical degradation

Soil chemical degradation is the undesirable change in soil chemical properties such as pH, size and composition of cation exchange complex, contents of organic matter, mineral nutrients and soluble salts. Change in one or more of these properties often have direct or indirect adverse effects on the chemical fertility of soils, which can lead to a decrease in soil productivity(Suraj Bhan et al., 2001).

4.1 Soil pH and soil acidity

Chemically fertile soils have a pH range of 5.5-7.5. Soil pH is determined by the mineralogical make up (clay minerals, various metal oxides and hydroxides, lime etc), organic matter content of the soils and dissolved CO_2 in the aqueous phase. Any measure of pH below 7 is defined as the active acidity, whereas the ability of the soil to maintain a low pH level is referred to as the potential acidity. The active acidity represents the concentration of H^+ ions in the soil solution. Potential acidity includes exchange and titratable acidities where the former constitutes most of the latter in acidic soils. The exchange acidity includes the protons associated with the cation exchange sites on the clay mineral and organic fractions. The exchange acidity as a portion of total acidity varies with the nature of the soil and with the percentage base saturation. There is an equilibrium between active and exchange acidities and as the H^+ ions in soil solution is neutralized, the cation exchange phase brings new H^+ ions into solution. The source of soil acidity is humus, aluminosilicates, hydrous oxides and soluble salts.

Humic matter causes acidity through dissociation of H^+ ions in its carboxylic, phenolic, and similar H^+ ions yielding functional groups. The humic fraction is considered as the weak acid component of the acidity. Furthermore, the complexes of humus with iron and aluminum can produce H^+ ions upon hydrolysis. The charged sites associated with aluminosilicate clay minerals are occupied by various cations present in the solution phase. As the portion of basic cations such as Ca, K, Mg and Na are reduced through leaching or by plant uptake, the portion of the total charge occupied by H^+ ions increases. This process is accompanied by a reduction in pH as the dominating exchangeable H^+ ions controls the solution phase. When the soil pH falls below 6, Al in Octahedral sheets dissociates and is adsorbed in an exchangeable form by clays, thereby increasing the Al saturation. Exchangeable Al is the major cause of exchange acidity. When dissociated from the exchange complex as the Al^{3+} ion, it produces H^+ ions.

Dissolution of soil minerals and application of ammonium fertilizers also can lead to soil acidity. Soil acidity limits the plant growth by toxicity and decreases the macronutrient base cation content. Furthermore, the solubility of Fe, Mn, and Al containing minerals are enhanced at low pH levels and the toxicity of these elements becomes a major problem. The activities of soil organisms, including nitrifying bacteria, are severely restricted at pH levels lower than 5.5. Regular liming of soils with suitable liming materials becomes essential in areas susceptible soil acidity. Regular testing for soil ph needs to be attended in such areas to monitor the acidity levels.

4.2 Salinity

Salinity is a common problem in arid and semi arid regions where evapo-transpiration exceeds rainfall. Under these conditions, there is not enough water to wash the soluble salts down the profile below the rooting zone. Thus, soluble salts originating from various sources accumulate in the soil profile at certain depths known as the salic horizon or at the soil surface, depending on the water regime. If not washed from the soil profile to a drainage system by the leaching fraction of water, the concentration of chloride, sulfate, carbonate and bicarbonate salts of Na may increase in the soil profile and cause salinity in a very short period. Salinization in its broad sense covers all types of degradation brought about by increase of salts in the soil. It thus includes both the build-up of free salts in the soil, salinization in its strict sense, and sodification, the replacement of cations in the clay complex by sodium. It is brought about through incorrect planning and management of canal-based irrigation schemes. Part of the water brought into the area is not used by crops but percolates down to groundwater. This leads to a progressive rise in the groundwater table, and, when this comes close to the surface, dissolved salts accumulate. Patches of salinized soil appear, as more or less circular areas of white, saline soil surrounded by a belt of stunted crop growth. A continued rise leads to water logging (Singh et al., 1992, Datta and Jhong, 2002).

This process happened extensively on the Indus plains of Pakistan; the water table began to reach critical levels in the 1940S, and salinization has since become widespread. A sequence of costly reclamation schemes was necessary to check the rate of land abandonment. It can be prevented by construction of deep drains. Reclamation is a more complex process, involving tube well construction; large-scale pumping to lower the groundwater table, followed by application *of water* much in excess of irrigation requirements in order to leach out salts, a wasteful and expensive procedure ((Datta & Joshi. 1991).

Because salinization is easy to identify', and also takes place on the 'managed' environments of irrigation schemes, estimates of its extent are somewhat less unreliable than those for other forms of degradation, meaning that their range of error is not much above plus or minus 100 %. Another cause of salinity is the absence of drainage system or poor drainage especially in lowlands. A raised water table as a result of an ineffective discharge system is still another cause of salinity. The upward capillary movement of water carrying the dissolved salts, previously present at depth in the rooting zone. The degree of salinity is measured as electrical conductivity of a soil saturation paste or extract and is reported as deci-Siemens per meter (dS/m)(Young, 1998).

The source of soluble salts, besides irrigation water, are mineral weathering, fertilizers, salts used on frozen roads, atmospherics transfer of sea spray, and lateral movement of ground water from salt containing areas. Salinity affects plant growth by affecting water and nutrient uptake and through specific toxicity of Na, Cl and B. The dissolved salts in water increase the osmotic potential, thereby creating the so called physiological drought. Toxicity develops when the ions take up from soil solution accumulate in leaves. As water is lost in transpiration, the concentration of toxic ions increases and causes damage to various degrees, depending on the sensitivity of plants.

Salinity affects the mineral nutrition of plants by reducing the availability and uptake of nutrients through the interaction of Na and Cl with nutrient cations and anions and by interfering with transport of elements within the plant. Leaching with good quality water, providing adequate drainage, adoption of scientific irrigation techniques and growing of salinity tolerant crops are the strategies needed in salinity affected soils. Studies in India have indicated that these areas can be successfully used for inland fisheries and also shrimp cultivation (ICAR, 2008).

4.3 Alkalinity

Addition of salt to soils increases the concentration of Na in the soil solution more than those of Ca and Mg and alters the composition of the exchange phase in favor of Na, because the Na salts are the most soluble salts in nature.

Fig. 17. Providing sub-surface drainage to manage soil salinity/alkalinity

This increase in exchangeable Na (Na_x) is called sodification and soils degraded in this manner are referred to as sodic soils. The measure of sodicity is exchangeable sodium percentage, which is the ratio of Na_x, to cation exchange capacity. This parameter is sometimes expressed as the exchangeable sodium ratio, which is the ratio of Na_x to other exchangeable cations.

If the soil solution contains $CO3^{2-}$ and $HCO3^{-}$ in excess of Ca^{2+} and $Mg^{2+,}$ highly soluble Na salts of these anions hydrolyse and the soil pH rises above 8.5. This process is termed as alkalinization. Sodic soils do not necessarily have high pH, but in well-aerated soils, alkalinization often follows sodicity. Sodicity although a chemical property, has adverse effects on soil structure. As Na_x increases, the binding effects of divalent Ca and Mg ions on clay particles are overcome by the dispersing action of Na ions. Dispersed particles move with water and quickly clog the soil pores, causing drastic reductions in water and air permeability in sodic non saline soils (Sharma et al., 2004). Application of gypsum, leaching with good quality water and proving of adequate drainage and growing of suitable crops are the management techniques needed to tackle these soils (Singh et al., 1992).

4.4 Depletion of soil organic matter

Organic matter is very important to the functioning soil system for various reasons. It increases soil porosity, thereby, increasing infiltration and water holding capacity of the soil, providing more water availability for plants and less runoff that may potentially become contaminated. This may be specifically helpful at mine sites where runoff may become acidic and contain high concentrations of heavy metals. The increased porosity also aids in easing tillage of the soil.

Fig. 18. Success through participatory approach brings smiles and long lasting impact

The organic fraction of the soil accounts for 50 to 90% of the CEC of mineral surface soils. The CEC allows important macronutrient cations (K, Ca, Mg) to be held in exchangeable forms, where they can be easily used by plants. Nitrogen, phosphorous, sulfur, and micronutrients are stored as constituents of soil organic matter, from which they are slowly released by aiding in plant growth. In addition, humic acids (a form of organic matter) accelerate soil mineral decomposition releasing essential macro- and micronutrients as exchangeable cations. In addition, organic matter adds erosion resistance to soils (Anand Swarup, 20110). The establishment of cover on disturbed soil surfaces is a common reclamation strategy. Cover soils facilitate the establishment and growth of vegetation. Many times, finding enough cover soil to cover disturbed surfaces can be difficult and costly. When there is not enough soil on-site to satisfy the demand, surface soils may be hauled in from other designated sites. If surface soils are excavated to recover minerals beneath, the surface soils may be stored until reclamation of the area takes place(Hegde &Daniel, 1994).

In these cases, surface soils may be stored for long periods, during which time, the soils may show reduced biological activity, in part due to bacteria, and invertebrates. Stored surface soils also reveal a loss of organic matter and nutrients. Therefore, organic amendments and fertilization of surface soils that have been in storage for several years are necessary to ensure rapid buildup of microbial populations and initiate nutrient cycling (Rao, 2010).

Fig. 19. Training through field visits and interactions with stakeholders: spreads the soil and water conservation technologies at faster pace

The accumulation of soil organic matter, namely humus, in soils starts with the production of biomass and approaches equilibrium dependent on the effects of factors such as climate, type of vegetation, topography, soil texture, and drainage conditions. At equilibrium, when additions by biomass and removal by mineralization are in balance, organic matter contents range from less than 1% in arid regions to over 20% in organic deposits of cool humid climates. Any change in these factors may disturb the system and a new equilibrium towards depletion of soil organic matter results. A highly disturbing factor in this respect is cultivation. Less organic material is returned to soil at harvest in most cropping systems, and tillage accelerates decomposition of soil organic matter. This process is more rapid in tropical climates. Conversion of forests and grasslands to crop lands promotes rapid decomposition of the organic matter present in soils. Soil erosion is another factor that causes significant reductions in soil organic matter content, first, by decreasing the overall productivity and thus the production of biomass some of which is returned to soil and second, by carrying away the organic matter present in the lighter fraction of the surface soils.

Fig. 20. Planting of leguminous, multi-purpose hardy plant species like Sima rouba in tropical wastelands can restore the soil health at a quicker pace

There are several different types of organic amendments, added for different reasons (Suganya & Sivaswamy, 2006). Mulches are organic materials applied to the surface (not tilled into the soil) primarily to reduce erosion. The more common mulches include paper, wood residues, straw, and native grasses. Surface mulches reduce wind velocities at the soil surface, shield the soil from raindrop impact, reduce evaporation from the soil surface, trap small soil particles on the site, reduce surface soil temperatures, and help prevent soil crusting. Manure, compost, and sewage sludge are other organic amendments generally incorporated into the soil by plowing, chiseling, crimping, or rototilling. These organic amendments benefit the cover soil for the many reasons, such as increased microbial activity, cation exchange capacity (CEC), porosity and water-holding capacity (Anand Swarup 2010).

Adoption of conservation agriculture, crop rotation with legumes, mixed farming, green manuring, green leaf manuring and application of organic manures like oilcakes, FYM and composts are recommended to maintain adequate soil organic matter (Raj Gupta et al., 2010). In developing nations both the cow dung and the crop residues are extensively used as fuel in rural homes. These activities are also listed as the cause for increased accumulation of green house gases. It was noticed that wherever the program of green energy " Bio-gas technology" is adopted, the health of rural women and soil improved considerably

(Swaminathan, 2011). This simple technology can bring down the green house gas accumulation also to a great extent. Once this technology is adopted, farmers tend to stall feed their animals as they do not wish to lose the cow dung. This activity helps in restoration of vegetation in village common lands and naturally soil health improves and soil degradation decreases/halts. Farmers bring all kinds of farm wastes to their backyard and decompose the wastes using bio-gas slurry. Hence the quantity and quality of production of organic manure increases and its use in farm improves the soil health. When rural kitchens are freed from smoke due to the use of biogas, the health of women folk improves automatically. Hence there is an urgent need to promote this simple technology in very large scale.

4.5 Loss of plant nutrients

Plant nutrient elements are continuously lost from soils by crop removal, erosion, leaching, and volatilization at rates determined by the type of vegetative cover, cropping system and climatic conditions. In intensive agriculture, much larger amounts of nutrients are taken away from soil with little return in crop residues, in many cases exhausting the nutrient reserves in soils (Tiwari, 2010). Basic nutrient cations such as Ca, Mg and K may be leached from soils under acidic conditions. Nutrient depletion and declining fertility is commonly observed in both rainfed and irrigated areas. Highly weathered soils occurring in the high rainfall areas are more prone to loss of fertility and chemical deterioration. According to the Soil Resources Mapping data, in India, about 3.7 m ha of land area is deteriorated due to nutrient loss and/or depletion of organic matter (Sehgal & Abrol 1994). It has been established by many studies that in many regions there is a net negative balance of nutrients and a gradual depletion of organic matter content level in the soils. Since in future the required demand for food production will have to be met through increased intensity of cropping, the problems of maintaining nutrient balance and prevention of emerging nutrient deficiencies will be a major concern in most of the cultivated lands.

Lowering of soil organic matter is the main cause of physical degradation and also affects nutrient supply. Degradation of soil physical structure has substantial affects on plant yield independently of chemical properties. Maintenance of the soil organic matter content is a key feature of management, since this underlies many other properties: resistance to erosion, structure and therefore water-holding capacity, and ability to retain and progressively release nutrients. Recycling of organic material also helps to prevent the development of deficiencies in micronutrients (Rao, 2010). Erosion is itself a cause of fertility decline, through removal of organic matter and nutrients. Even with no erosion, however, fertility decline can be brought about by other processes, notably, nutrient removal in harvest exceeding replacements, by natural processes and fertilizers.

Evidence is accumulating that fertility decline is extremely widespread, particularly in areas that have long been under annual cropping. Indeed, although it is a reversible form of degradation, the total consequences on lowering current agricultural production may be greater than those of erosion (Tiwari, 2010). In the Indian subcontinent, where fertilizers have been in use for 20 years or more since the green revolution, reports of nutrient deficiencies are becoming common. The explanation is that farmers first added nitrogen fertilizer, and obtained a good crop response; after some years, the augmented growth led to exhaustion of soil phosphorus reserves, and phosphate had to be added also; now, the same process is happening with respect to secondary and micronutrients, such as sulphur and zinc. A result of fertility decline is that responses to added fertilizers are now less than formerly. In India, Pakistan, and Bangladesh, rates of increase in fertilizer use have not been matched by crop yields. There are also records from long-term experiments. A striking example is a 33-year experiment in Bihar, India; despite changes to improved varieties, wheat yields declined substantially with nitrogen, phosphorus, and potassium fertilization, whereas they rose with additional farmyard manure (Tiwari, 2008).

4.6 Soil pollution

Soil pollution can result from mining or industrial operations, and from agriculture. Soil and groundwater pollution from agricultural activities has been up to now mainly a problem of temperate countries. As fertilizer and pesticide use increase in the developing world, it will become an increasing problem, calling for technical appraisal and legislative control (Chonkar, 2001).

Ecosystems are threatened by such contaminants and their interactions in the environment. The impact of urbanization and industrialization has been a major factor against the need of preserving the quality of soil, by reducing it via chemical contaminants, use of polluted waters for irrigation, and deposition of harmful particulates to the atmosphere. Ecosystems are threatened by such contaminants and their interactions in the environment. The sources of pollution are: (1) the waste waters; (2) the agricultural wastes, (3) the airborne pollutants, (4) the pesticides, (5) the urban wastes: a) sewage sludge; (b) composts; (c) fly ash; and (6) the industrial wastes: (a) pesticides and fungicides; (b) fertilizers; (c) detergents; and (d) chlorinated solvents.

These sources may cause fatal effects and/or irreversible destructions for human health and the environment. The levels of contamination together with their ability and mobility in decomposition and accumulation of the chemicals in the soil have been scientifically proven to be harmful to animals, plants, and micro-organisms via destroying the natural structure of water, soil and air which is balanced by nature.

Inactivated enzymes are the measure of heavy metal (divalent) toxicity readily reacting with proteins, amines and sulfohydryl (-SH) groups as well as Hg and Cd replacing Zn in metallic enzymes. Metal toxicity is known to decrease cell membranes permeability and change genetic characteristics of cells increasing risks of cancer. Mercury accumulates in fatty tissues as methyl Hg, whereas cadmium replaces calcium in bones and kidneys destroying their excretory function.

Metals such as lead, arsenic, mercury, chromium, cadmium and copper are found at acceptable limits in nature. However, these limits might increase with contamination from agriculture, industrial and infrastructural wastes. For instance, concentration of lead might increase by the gaseous emissions of vehicles and use of garbage compost as a fertilizer together with pesticides. Arsenic is naturally found at a level of 10 ppm in soils and might also increase to 500 ppm with the use of industrial wastes for agricultural applications. Mercury is added to soils by rain and irrigation waters as well as garbage compost. Mercury compounds are highly poisonous for humans and animals. Excess Hg affects the central nervous systems and develops blindness via CH_3 HgCl.

The major source of cadmium contamination in agricultural soils is the excess use of fertilizers with varying amounts of cadmium contents (0.1-90 mg/Kg) depending on the phosphate rock materials utilized in production. Such contaminations in soils will cause a 0.1 mg/kg increase of Cd in 20-30 years. Another significant Cd contamination source is the sewage sludge used in cultivated soils. Cadmium adsorption by organic or inorganic soil compounds (minerals) depends on the soil texture, pH, and Ca together with other elements.

Chromium, the essential element for human and animal diets is not considered essential for plant nutrition with a tolerable level of 100 mg/kg in soils. Chromium is irrevocable in its role in the induction of the effect of insulin and proteins as well as stabilizing nucleic acid structures and activating some enzymes in glucose metabolism. Since pollutants and heavy metals such as persistent chlorinated organic compounds and Hg could cause genetic side effects, great care and effort should be paid to prevent the transportation of the said substances to soil for sustaining biodiversity. Hence, through the sustainable ecosystem concept, the status of pollutants in soil should be monitored permanently.

4.7 Desertification

The term 'desertification' falsely evokes the image of advancing deserts. While a desert is a unique ecosystem, desertified areas are not: they are disrupted ecosystems. Desertification means land degradation, loss of soil fertility and structure as well as the erosion of biodiversity in drought prone areas (Tuboly, 2000). Desertification is a land degradation process and it deals with the gradual conversion of productive land into less productive or unproductive ones. Thus, the problem is a continuous one. The presence or absence of a nearby desert has no direct relation to desertification. It is the excessive abuse of land in any patch or land under arid ecosystem which can initiate desertification process. (Nagarajan, 2000). Land degradation is a more acute problem faced by the farmers in the dryland regions, especially the small and marginal farmers. Soil erosion by runoff is the principal cause of land degradation particularly in the rainfed agro-eco regions of India and Africa. Consequences of land degradation could be more disastrous in arid and semi-arid areas where the ecosystem is very fragile. Rainfall being the only source of sustaining the entire production system, these areas chronically suffers from low food and fodder productivity due to poor, erratic and unevenly distributed rainfall. The process of land degradation is highly dynamic and complex at times. Unfortunately, more often than not, it goes unnoticed by the very people dwelling in such less endowed areas which are already marginalized. The people are characterized by low literacy and awareness levels, poor socio-economic status and have low risk bearing ability (Subba Reddy et. al 2000).

A study desertification conducted using remote sensing and ground truthing in Bellary district in Karnataka situated in semi-arid region indicated that nearly 28 percent of total area (8.5 lakh ha) area faced severe desertification, major cause being vegetation degradation, salinization/alkalization and water resources degradation(NBSSLUP, 2005). Some of the other on-field indicators besides the scientific indicators, of the impending crisis are: Dying of older trees due to lack of enough capillary raise of water which indicates falling water tables in the area - for instance, if there is a need to irrigate mango trees and orchards, it is a sure indication of the alarming situation. In brief all the degradation processes together can be termed desertification and it is the final stage of decline of farming assets and consequently the food production potential.

5. Human induced accelerated soil degradation

The excessive demand for construction materials like bricks and sand for infrastructure projects in developing countries like India are causing huge soil degradation in peri-urban environment at an alarming rate. A study conducted at Bangalore, India revealed that sand supply from riverbeds to Bangalore is not able to meet the demand of booming construction sector. Enterprising farmers have taken up extraction of sand by washing surface soils of agricultural fields. Nearly 25 percent of sand supplied is from this source. Study revealed that significant employment and economic gains are realized at an ecological cost. Loss of surface soils, nutrient losses, crop yield losses, siltation of tanks, excessive ground water exploitation and soil erosion are taking place due to sand extraction(Table 4 and 5). Nearly 18000 ha of land which was usually used for growing the staple food of the region, i.e., Finger millet is going out of cultivation for few years to come(Rajendra Hegde et al., 2008).

Mining is another significant economic activity causing unrepairable damage to land resources (Vishwanath, 2002, Bhushan & Hazra, 2008). A case study conducted at Goa state in India indicated that large tracts of pristine forests of western ghats were lost to mining and the accumulation of mining wastes in the nearby paddy fields in the valleys have destroyed the highly productive soils. The economic and ecological damage is very long lasting. Such a development has lead to social conflicts between miners and farmers. Mining has both on site and off site ecological damage. Mining in Goa is done by open cast method which necessitates the removal of overburden overlying the iron ore formations. On an average about 2.5 to 3 tons of mining waste has to be excavated so as to produce a tone of iron ore. The average annual production of iron ore is about 15 to 16 million tones, in the process removal of which about 40 to 50 million tones of mining waste is generated. Such a huge quantity of mining waste creates a problem for its storage thereby causing severe environmental pollution.

Damage to the environment is mainly done by the reject dumps, pumping out of muddy waters from the working pits including those where the mining operations have gone below the water table, and slimes from the beneficiation plant. The damage is more evidenced during monsoon where the rain water carries the washed out material from the waste dumps to the adjoining low-lying agricultural fields and water streams. It is stated that the slimes and silts, which enter the agricultural field are of such character that they get hardened on drying. The washed out material from the dumps and the flow of slimes from the beneficial plants besides polluting the water causes siltation of water- ways, especially during monsoon. Such silting of water ways over the years may trigger years even flooding of the adjacent fields and inhabitated areas, especially during monsoon.

Desurfacing of farm lands for brick industry is another source of soil degradation. Thousand of ha of lands are losing their productive potential due to unscientific extraction of soils (Grewal & Kuhad , 2002). Recently technology of using fly ash for brick production has been evolved which may help in reducing the soil degradation to some extent (Kathuria, 2006).

Purposeful conversion of productive farming lands in to shrimp farming or urban development is taking place at a very large scale on coastal zones. In India, Goa a tiny state is a world famous tourist place. The state has low lying 18000 ha of vary productive paddy farming lands called Kazan lands. Slumping revenues from agriculture in Goa has led to breaching the bunds to allow saline water into the fields to raise fish, as this is far more profitable than cultivating paddy has become rampant. It is reported that khazan lands are extensively inundated for as many as 15 years and used for shrimp farming. The growing density of population poses another threat to the khazan lands. Goa's population is concentrated in the Mandovi-Zuari basin, which is also where the khazan lands are situated and almost all urban expansion has taken place at the expense of these lands. Threats to the khazan lands include those arising from general environmental degradation. Deforestation in the upper river catchment areas and mining activity have added to the silt load of the

rivers. The sediment that gets deposited in the estuarine region have resulted in many acres of khazan lands now getting flooded during the monsoon.
The rivers have become heavily polluted near the towns and much of the waste material they carry flows into the khazan lands with the tides. And, this problem is compounded by the petroleum residues from barges, tankers and trawlers in the rivers."The problem is that any expansion that takes place in Goa has to be at the cost of the khazan lands. Good sign is that environmentalists attention is unquestionably focussed on the need to protect the khazan lands -- a valuable Goan heritage.
In every region such human induced degradation are taking place due to non adherence of environmental laws. Comprehensive policy is needed to make these enterprises ecologically tolerable.

	Details	Per lorry load of sand	In one day (1000 lorry loads)	In one year	remarks
1.	Soil used (m^3.)	120	120000	438 lakhs	
2.	Are of land used for soil excavation(ha)	0.04	40	18600	0.3 m depth (normally)
3.	Quantity of water used (litres)	132000	1320 lakhs	48180 million	
4.	Quantity of silt-clay generated (m^3.)	30	30000	11 million	

Table 4. Soil degradation due to sand extraction in peri-urban and rural Bangalore

Nutrient	Units	Surface soil	Sub surface soil	silt	Fertility Depletion/ ha	Fertility depletion /year*	Value of nutrient at present rates (Rs)
N	Kg/ha	319.6	191.8	90.0	127.8	2.38 million	25 million
P_2O_5	Kg/ha	83.7	25.2	11.7	58.5	1.09 million	17.68 million
K_2O	Kg/ha	74.8	158.7	62.1	83.9*	* gained	-
Cu	ppm	0.66	0.3	0.1	0.56	-	-
Fe	ppm	0.38	0.76	0.53	0.15	-	-
Mn	ppm	21.6	14.1	2.96	18.84	-	-
Zn	ppm	18.4	13.13	0.18	18.22	-	-
B.D	g/c.c	1.4	1.7	-	-	-	-

* 18600 ha of land being excavated to a depth of 30 cm in one year.

Table 5. Nutrients content and fertility depletion from surface soil of agricultural fields due to sand extraction

Fig. 21. Human induced accelerated land degradation: sand extraction from agricultural fields

6. Accelerated soil degradation due to climate change phenomenon

Due to climate change factors, various regions of the world are facing unprecedented aberrant weather situations like drought, floods, forest fires etc (Agrawal, 2008, Prasd & Radha, 2008). Role of soil is most significant in buffering the climate change phenomenon as soils and plants hold 3 times more carbon stock than atmosphere (Pathak, 2010).

The unprecedented rains leading to floods in 13 districts of northern Karnataka, India during 2009 was said to be one such event caused due to climate change phenomenon. Very high rainfall received over a short period of time in a region dominated by black soils, resulted in severe losses of crops, soils, soil organic matter and soil nutrients besides destruction of human and livestock lives and farming infrastructure.

The shallow depth and heavy texture of the soil made the situation to aggravate further. An estimate made after the calamity revealed that nearly 287 million tons of top soil, 8 lakh tons of soil nutrients, 39 lakh tons of soil organic matter were washed away. In monetary terms, about 853 crores worth of soil organic matter and 1625 crores worth of plant nutrients were lost from the region during this short period. In addition to this, nearly two-lakh hectares of cultivated fields in the flood affected area were deposited with sand along the river courses. These losses have severe long term implications on crop productivity and rural economy of this region (Natarajan et al., 2010).

7. Consequences of degradation

By definition, the direct consequence of land degradation is reduction in productivity. Where degradation is extreme, there is total loss of the resource. This is temporary in cases such as salinization and deforestation, and for practical purposes permanent in severe erosion. In soil degradation, the results may be lower crop yields, or a need for higher fertilizer inputs to maintain existing yield levels. Soil physical degradation and micronutrients deficiencies cause lower responses to fertilizers. Once the cutting of woodlands for fuel and domestic timber passes their rate of growth, the potential of the resource is reduced, and can only be restored by a radical reduction in cutting, which is economically and socially unpractical

Fig. 22. Large scale mining in India without adhering to environmental laws leading to land degradation(Mining of iron ores in Goa state)

There are three bases to assess the costs of land degradation in economic terms: lost production, replacement cost, and the cost of reclamation (Chinnappa and Nagraj 2007). In lost production, crop yields or other outputs are estimated for non-degraded and degraded land, and then priced. The two situations, with and without degradation, can then be compared. A weakness for the case of soils is the paucity of evidence for the physical reduction in output. A cleared forest has lost the capacity to produce timber for the 20, 30, or 50 years needed for its regrowth, besides which, continued use for agriculture will prevent any such restoration.

Replacement cost is based on estimating the costs of additional inputs, such as fertilizers, needed to maintain production at the same level as for non-degraded land. This is easier to assess than lost production, and also corresponds to what farmers seek to do. The clearest example of reclamation costs comes from salinization. For Pakistan, the cost of reclaiming 3.3 M ha of salinized land has been estimated at 9 billion (Young, 1998).

For deforestation and erosion, off-site costs resulting from reduction of river base flows and sedimentation of reservoirs must be added. The presently assessed life of eight Indian reservoirs was compared with that anticipated at the time of their design; in four cases, this was 30-40 %. In developed countries, off-site costs of erosion are often assessed as substantially higher than on-site loss of production, although in developing countries the opposite may be the case.

Fig. 23. Mining waste accumulation in paddy fields completely degrading the soil (Goa)

Fig. 24. Sand accumulation on agricultural fields in Nortern Karnataka, India due to floods

Economic analysis requires complex assessments of future production or input changes, and this introduces questions of the discounting of costs and benefits over time. It is possible to estimate the economic costs of degradation on an annual basis. This has been done for the South Asian region. The GLASOD estimates were taken as a starting-point, modified by additional fertility decline. Relative production loss for light, moderate, and strong degradation were assumed to be 5%, 20%, and 75%respectively. These reductions applied to average cereal yields. Fertility loss was also assessed on a nutrient replacement basis. The cost to South Asia of land degradation was estimated as:

Cost, $ billion per year (Young, 1998).

Water erosion (on-site costs only)	5.4
Wind erosion	1.8
Soil fertility decline	0.6-1.2
Salinization	1.5

Recent evidence would reduce the figure for erosion and considerably increase that for fertility decline. The total cost of land degradation to South Asia is about 10 billion a year, which is 7 % the agricultural production of the region. This estimate applies to soil-related forms of degradation, and refers only to on-site costs. The addition of water, forest, and rangeland degradation, together with off-site costs of erosion, would raise this figure substantially.

It is not unreasonable to say that the land degradation that has taken place up to the present is costing developing countries not less than 5%, and more probably nearer 10%, of their total agricultural sector production. Still more tentatively, this rate may be rising by 1% every 5-10 years.

The physical and economic consequences of land degradation are reflected in their effects upon the people. These include: lower and less reliable food supplies; lower incomes, resulting from loss of production or higher inputs; greater risk: degraded land is less resilient, and higher inputs mean that poor farmers are risking more capital; increased labor requirements, as when women walk large distances to collect fuel wood and water; in the case of farm abandonment, increased landlessness and social unrest.

In classical economic theory, 'land' was regarded as a fixed resource, to which factors of labor and capital were applied. With degradation occurring, it becomes a declining resource, and hence labor and capital become less efficient. If most farmers do not know about economic theory, they are well aware of it in practice. Land degradation means they must either accept lower production, or put in greater effort to maintain it at the same level (Chaturvedi , 2010).

The unprecedented rains leading to floods in 13 districts of northern Karnataka, India during 2009 was said to be one such event caused due to climate change phenomenon. Very high rainfall received over a short period of time in a region dominated by black soils, resulted in severe losses of crops, soils, soil organic matter and soil nutrients besides destruction of human and livestock lives and farming infrastructure.

All types of soil degradation can be caused very easily. However, a cure may be either slow and expensive or completely impracticable. Symptoms of degradation of the top soil include crusting, low fertility, etc. These problems can usually be alleviated by increasing the soil organic matter content and the adding calcium compounds such as gypsum or lime if the soil is acidic. Organic matter can be increased by changing crop rotations to include a pasture phase, by keeping plant cover, all the year round, by adding manures, and also by minimizing losses of soil organic matter, which can occur as a result of excessive or high intensity tillage. Organic matter increases soil aggregation and reduces clay dispersion in water. Calcium compounds flocculate the clay, thereby reducing dispersion and increasing soil stability. Clay floccules form the building blocks for larger compound particles such as aggregates. The use of such practices over a number of years can produce a soil structure that is better for agricultural production and is more stable. Compaction damage of top soils is usually not permanent because of the ameliorative effects of tillage, biological activity, and wetting and drying cycles.

Degradation of the sub-soil often occurs through compaction. Sub-soil tillage may make a temporary improvement, but often the soil will recompact to be as bad as or worse than it was before sub-soiling.

Soil salinity can be cured in principle by leaching. However, dry land salinity usually cannot be reversed but may be slowed or halted by planting of deep rooted plants (.e.g, salt tolerant trees) that can transpire enough water to stop further water table rise. Sodicity can be cured by displacing the sodium with calcium. However, this is difficult because sodic soils have an extremely low permeability to water. Displacement and leaching may be accelerated by not using pure water but using water with a high enough electrolyte concentration to keep the clay flocculated and hence the permeability high.

8. Land improvement

Not all changes to land resources are in the direction of degradation. Its converse is land improvement; all relatively permanent increases in productive capacity brought about by human action. Swamp rice cultivation is a special case in which the natural soil profile is radically altered by the formation of a pan, an impermeable horizon which checks loss of water by downward seepage.

Other examples of land improvement are drainage of swamps, terracing, systems of water harvesting, and reclamation of land from the sea. Were it not for land improvement, the productive capacity of Egypt and Pakistan would be a small fraction of its present level. The best-known ease of land reclamation from the sea is the polder system of Netherlands, the only country which, in international statistics, regularly increases its total land area. The leading example in the tropics is Bangladesh, where land productivity and security have been raised by a series of flood control works. More generally, land management which reverses soil fertility decline, for example by raising soil organic matter levels, is a less spectacular but potentially widespread form of land improvement.

Irrigation is the most widespread kind of land improvement; besides its direct action in improvement of water resources, it often leads to an increase in soil organic matter and productivity.

Land improvement also covers the reversal of degradation in its many forms, such as reclamation forestry on eroded hillsides, reclamation of salinized soils by leaching, and rehabilitation of degraded pastures. In resource inventories, it is the balance between degradation and land improvement that gives the net change. Current monitoring of land resource changes is insufficient to be able to say precisely which countries are improving and which degrading their land resources, but the available evidence, not least from field observation, is that the balance is frequently negative. A leading objective of resource management should be to reverse this situation (Srivastava et al., 2002).

9. Conclusions

The extent and severity of various forms of land degradation is alarming at present. This is caused by the excessive pressure on land to meet the competing demands of the growing population for food, fodder, fiber, and urban and industrial uses. If we are to meet the future increased demands and also maintain the productivity of the land, there is no alternative, except to manage and protect our scarce land resources more effectively than at present.

The challenge before us is not only to increase the productivity per unit area, which is steadily declining and showing a fatigue syndrome, but also to prevent or at least reduce the severity of the various forms of degradation, which has reached an alarming proportion. If the situation is not reversed at the earliest, then the sustainability of the already fragile ecosystem will be badly affected, threatening the livelihood security of not only the farmers but also every one. The situation needs immediate attention of all the stakeholders, from policy makers to farmers, involved in the management of the limited land resources of the earth.

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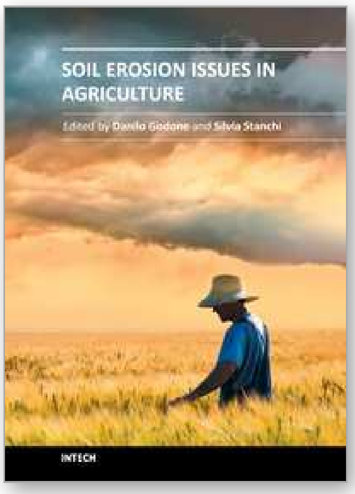

Soil Erosion Issues in Agriculture
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The book deals with several aspects of soil erosion, focusing on its connection with the agricultural world. Chaptersâ€™ topics are various, ranging from irrigation practices to soil nutrient, land use changes or tillage methodologies. The book is subdivided into fourteen chapters, sorted in four sections, grouping different facets of the topic: introductive case studies, erosion management in vineyards, soil erosion issue in dry environments, and erosion control practices. Certainly, due to the extent of the subject, the book is not a comprehensive collection of soil erosion studies, but it aims to supply a sound set of scientific works, concerning the topic. It analyzes different facets of the issue, with various methodologies, and offers a wide series of case studies, solutions, practices, or suggestions to properly face soil erosion and, moreover, may provide new ideas and starting points for future researches.