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Achieving Land Degradation Neutrality: An Old Problem with New Urgency

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Abstract: It is generally spoken that history repeats itself. The same is the case with the rise and fall of many civilizations including the Indus valley civilization. But we should learn lessons from the historical past for developing strategies and plans to reverse the trend of land degradation. During the Neolithic period, nearly 8000-4000 BCE, agro-pastoral and shifting cultivation were the normal ways of livelihood options. However, resource utilization was in harmony with nature, and resource sharing among the several social strata was extremely cordial. In the early Holocene soil erosion was very slow. During the middle Holocene, soil erosion rate was lower because luxurious vegetation cover protected the soil from water erosion, although the precipitation was high. However, the first major notification occurred at the end of the bronze age (or 1000 BCE) when post-Vedic people introduced the iron plough and started cultivation by burning down forest lands. The continuing degradation of land and soils is a severe threat to the provision of ecosystem services and economic development in India and globally. Although a natural process, soil erosion has been accelerated by human activity through the large-scale conversion of natural ecosystems into agricultural land and other sectors. In an ideal situation, the erosion level should be contained within the permissible limit specified for a given location which ranges between 2.5 to 12.5 t ha^{-1} yr^{-1}. Once this threshold is crossed, the inherent fertility of the land begins to fall. In India, agricultural expansion and its associated intensification through mechanical ploughing, irrigation and application of fertilisers and chemicals have led to a set of adverse impacts that threatens not only agricultural productivity but also the sustainability of the wider environment. These adverse impacts may become a more considerable problem under the changing environment of the 21^{st} century, as climate change is expected to impact the extent, frequency and magnitude of soil erosion in a number of ways. The most direct of these impacts are changes in the erosive characteristics of rainfall. More aggressiveness of rainfall is projected in the form of more intense precipitation events over the coming decades. Hence, about 66 M ha area in our country under the erosion class of 5-10 t ha^{-1} yr^{-1} that covers mostly croplands will be additionally affected by higher rates of erosion exceeding the critical limits (permissible limits) due to climate-induced changes in rainfall. India has set a target of achieving 26 M ha of land neutrality by 2030. Policies will not be successful unless the economies of millions of peasants are improved who are still living either just at or below the subsistence level. The underlying dilemma is whether the political and administrative power should be decentralized first or whether the resources should be intensively utilized first. The article highlights the urgency in addressing the land degradation problem by developing strategies for achieving land degradation neutrality and designing sustainable land management.

Key words: *Holocene, ecosystem services, sustainable land management, climate change*

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Introduction

Land degradation especially soil erosion is looked as a major environmental problem in India affecting about 83 million ha area. The relationship between soil erosion and land degradation starts from a nondegraded steady state, however, several drivers and pressures accelerate it. Historically, such drivers were deforestation, shifting cultivation, overcutting of vegetation, over-ploughing of land along with population pressure and climate change. Since prehistoric time, humans also realized that worsening land degradation caused by human activities is undermining the well-being of humanity and in recent time a new approach has been taken to achieve land degradation neutrality by 2030.

Land is nature's most precious gift to mankind. It is the most fundamental of natural resources which provided all of the food, feed, fiber, and shelter, for the human race and its civilization to thrive on this planet (more than 99% of the world's food supply comes from the land). However, the land is under tremendous stress due to the ever-increasing biotic pressures. Furthermore, the degradation of cropland, water, energy and biological resources, that are vital for sustainable agriculture production, continues unabated (Mandal and Giri 2021).

'Land degradation' is a complex expression of natural processes. It covers a group of biophysical mechanisms, each of which may result in a reduction in the functional capability or quality of the land. It also embraces a series of socio-economic outcomes, any one of which may affect the livelihood and wellbeing of humans. Specifically, it is now usually defined as the partial or permanent reduction in the productive capacity of the land including its main land uses such as rainfed arable, irrigated, grassland, and agro-forestry. Capacity and potential are, however, vague to measure: they involve many other issues of identification of environmental change and long-term effects on society. Consequently, land degradation is more usually perceived in terms of its symptoms and biophysical process, from the scenically dramatic (gullies and badlands) to the often invisible (sheet erosion by water, loss in soil physical structure). Other definitions of land degradation abound, and many authors find difficulty distinguishing between it and desertification. Desertification and land degradation are two terms commonly associated with losses of vegetation cover and ecosystem productivity. Desertification refers to the land degradation in arid, semi-arid, and sub-humid areas resulting from various factors, including climatic variations and human activities. When land degradation happens in the world's drylands, it often creates desert-like conditions. Globally, 24% of the land is degrading. About 2 billion people directly depend on these degrading areas. Globally, land degradation affects about one-sixth of the world's population, 70 per cent 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 per cent. Data on of land degradation status and its impact on land productivity is given in table 1. However, considering the severity of land degradation that reduces the productivity and sustainability of landscapes and of the primary renewable natural resource components, especially the soil and vegetation, many researchers and policy planners viewed it as a serious global environmental problem.

Table 1. Degradation status of global land and its impact on land productivity

Degradation category	Amount of land affected (million ha)	Lost production (per cent)
Total usable land	8,735	
Not degraded	6,770	0
Degraded	1,965	
-lightly	650	5
-moderately	904	18
-strongly	411	50

There is little doubt that soil erosion has a detrimental effect on soil resources and will continue to have detrimental effects on global soil resources. Despite claims that during the past 50 years soil loss by erosion has been a serious problem, the current and potential future consequences of this loss are not known. Inferences made from the synchronicity of soil erosion events and societal changes are not based on quantitative assessments of the impact of soil erosion on agricultural productivity. Likewise, the analogy between the collapse of ancient societies and the risks facing modern society is based on assumptions that have not been tested. Hence, the extent to which soil erosion is indeed a significant threat to the agricultural productivity of modern societies remains a subject for debate.

Historical context of land degradation

Soil erosion is not new, perhaps the phenomenon of erosion is as old as the formation of the earth itself. Although part of the erosion is attributed to natural causes, there is ample evidence that a significant proportion of erosion is caused by human activities in the form of increasing encroachment of forests, deforestation overgrazing of rangelands, and expansion of agricultural land. Since, the dawn of the civilisation, land, and water have been the basic elements of the life support system on our planet. The great civilization flourished where these resources available in plenty and they declined or perished with their depletion. Civilizations, therefore, learned to respect these resources and found the best way of using them. Respect for soil is best depicted in the Hindu mythological concept of Panchbhutas these are soil, air, fire, water, and sky that constitute the most fundamental state of divine process.

Historically, three major human-induced erosion peaks can be identified in India. The first period between 1000 and 3000 years ago, occurred because of excessive timber cutting and expanded cultivation (Mandal and Giri 2021). Human impact on forest clearance have been reported through pollen study in Garhwal Himalayan Lake between 2000 BC and 480 BC when the post-Harappa migrants reached to foothills and Yamuna Ganges Doab. In the region of Kumaon Himalaya, an iron smelting site at Uleni (Almora district) dated 1022-826 BC and Tehri Garhwal was discovered. Large track of north India and Peninsular India were brought under intensive cultivation during 500 BCE and CE 300. Even the large surplus of agricultural products would have promoted large trade within the territory and overseas by Maurya and Kushanas in the north and Chalukyas and Sangam in the peninsula. Surely, this land transformation significantly contributed to soil erosion. Since, Alexander's invasion (326 BC), the gradual disappearance of forest in the Indian sub-continent is indicated in some areas. Expansion of agriculture into forested land and marginal grasslands was the dominant factor determining erosion. During the Mughal period, cropping intensity further increased with a mixture of subsistence agriculture and commercial crops.

From the historical connotation, Hsuan Tsang the famous Chinese scholar in the 7th century AD, explained about the extensive forest in the Gangetic valley. Bank of

Yamuna was also wooded during the campaigns of Mahmud of Gazni in the 11th century AD. Nine hundred years later, Ain-E-Akbari, likewise mentioned royal forests near Punjab, Haryana and western Uttar Pradesh regions of India. In the 13th century the dense track of forested land between Delhi and Badaun was removed by the order of Allaudin to make passage for traders and travellers. Soil history with the human is both cultural and intellectual, what people believe about soils influences what they do with them, either they conserve and nurture them, or they abuse and abandon them. What people understand and misunderstand about soils is thus a necessary part of any history of the nexus between soil and society.

The second peak, during the 19th and early 20th centuries, occurred due to European immigrants. Through the establishment of an exportation type of agriculture, the immigrants forced the native population to move and explore the more erodible and marginal lands, while holding the better lands for a marketing economy. The third period, beginning in the early 1920s and extending to the present days occurred mainly with a growing population pressure for more land and food production (Mandal and Giri 2021). This population growth forces farmers to develop new lands for agriculture production and to adopt intensive, non-conserving cropping and management systems which cause spectacular levels of soil erosion. In many regions, the seriousness of the erosion problem has been recognized and effective erosion control measures adopted. In other regions, erosion is still a major crop production impairment and continuously causes extensive sedimentation and water pollution problems. Soil degradation and civilization interact in both directions, meaning erosion-induced land degradation affects human lives and human activities often enhance soil degradation.

Issues and challenges: The urgency now and ahead

Today's global population (7.2 billion) is expected to be around 8 billion by 2030 and 9.2 billion by 2050 (GOS 2011). Most of these increases will happen in sub-Saharan Africa and Asia including India. India's population is likely to reach 1.5 billion by 2030 and 1.8 billion by 2050 (Swaminathan 2009). Therefore, India's cereal production has to be doubled by 2050 in order to meet demand. Similarly, the demand of feeds for livestock and poultry and biofuel production increases. As cereal products are increasingly used as feed for livestock, which is estimated to be 45–50% by 2050 if meat consumption increases (FAO 2003; 2006), finding alternative feed sources is essential for increasing the availability of cereals for human consumption. This poses a big challenge since most of the easily available feed sources have already been fully exploited, although some alternatives still exist.

Without innovations and critical interventions, the global food production system will continue to degrade the environment, the biodiversity, and eventually the world's carrying capacity. The widespread problems associated with the ongoing intensification are topsoil erosion, depletion of soil fertility, soil acidification, and salination. In addition to other forms of degradation, the rates of excessive water extraction for irrigation which in many places exceeds the rates of replenishment, and heavy dependence on fossil fuel energy for the synthesis of fertilisers and pesticides caused severe damage to the ecosystem (GOS 2011). For example, the production of nitrogen fertilisers is highly energy intensive: the roughly fivefold increase in fertiliser price between 2005 and 2008 was strongly influenced by the soaring oil price during this period.

Globally, there will be a competing demand for land for different developmental activities by 2050 (Mandal *et al.* 2021). It is estimated that possible loss in land due to non-farm activities will occupy about 2-8% of cropland. Land degradation may result in the abandonment of 1.5 to 2.5% of cropland. Additionally, cropland will lose productivity due to water scarcity, climate change, and land degradation (Table 2).

Table 2. Causative factors of land pressures and possible production loss by 2050

Cause of possible loss of cropland	
Causal factors	**Possible change by 2050**
Biofuel demand	-2% to -8%
Demand for others	
Non-food crops	-2.5% to -3.5%
Urban build-up	-2.5% to - 4.5%
Land degradation	-1.5% to -2.5%
Possible impact in yields	
Land degradation	-1% to -8%
Water scarcity	-1.7% to -12%
Climate change	-1.0% to -1.5%
Invasive species	-2.0% to -6.0%

Source: Nellemann *et al.* (2009)

The rapidly increasing human population is making the man-to-land ratio more critical over the years. In India, per capita availability of land has fallen drastically from 0.91 ha in 1951 to about 0.32 ha in 2001 against the world average of 2.19 ha. The availability of per capita net sown area has similarly reduced from 0.33 ha in 1951 to 0.14 ha in 2001 and is expected to decline further to 0.09 ha by 2050. According to an estimate, a minimum economic holding size of 2 ha of unirrigated land and 1 ha of irrigated land has been suggested in India for sustaining a family of 5 or 6 persons (NAAS 2009). The decline in the quality of land is of greater concern for the quality of life. Although the quality of nearly 16% of the total land area including cropland, rangeland, and forests is improving, the ISRIC has estimated that out of the 11.5 billion ha of vegetated land on earth, about 25% has undergone human-induced soil degradation, particularly through erosion (GOS 2011). Therefore, it is high time to examine the carrying capacity of the land under cultivation (Singh 2019)

Even though, in principle globally a substantial additional land could be used for food production, in practice land will come under growing pressure for other uses and loss due to urbanisation, desertification, salinization, and sea level rise. In fact, the possibility of area expansion in India for cultivation is very limited, and sustainable intensification appears to be the only feasible option for realizing self-reliance. To produce 310 million tonnes (Mt) of food grains and 190 Mt of fibres, edible and non-edible oils by 2050 from about 139 Mha of the net sown area is a big challenge for Indian agriculture. Further, it would require average productivity of 3.3 t ha^{-1}. Therefore, good agricultural practices (GAPs) and proven technologies for different regions should be promoted to bridge the yield gaps. The land degradation due to unscientific developmental activities and management of land resources further aggravates the situation worldwide which has been highlighted in table 3.

Table 3. Recent global concerns in land degradation and sustainable development

Year	Milestone
1981	2015 FAO World Soil Charter
1988	Intergovernmental Penal on Climate Change (IPCC)
1992	United Nations Conference on Environmental and Development
	Rio Declaration
	Agenda 21
	Global Environment Facility
	United Nations Convention to Combat Desertification (UNCCD)
	United Nations Framework convention on Climate Change (UNFCCC)
	Convention on Biological Diversity (CBD)
1997	Kyoto Protocol
2000	Millennium Development Goals (MDGs)
2005	Millennium Ecosystem Assessment
2008	UNCCD's Zero Net Land Degradation and Land Degradation Neutrality Initiative
2011	Global Soil Partnership initiated (FAO/European Union)
2012	Rio+20
2015	Sustainable Development Goals (SDGs) and Post-2015 Development Agenda
	Intergovernmental Technical Panel on Soils (ITPS) of the Global Soil Partnership (GSP)
	Land and Soils integrated in the open working group of the Sustainable Development Goals
	Regional Soil Partnerships of the GSP
	International Year of Soils declared by the United Nations General Assembly
	The Economics of Land Degradation
	UNFCCC Paris Agreement
2017	(United Nations Economic and Social Council) United Nations Strategic Plan for Forests 2017-2030
	FAO Voluntary Guidelines for Sustainable Soil Management
2018	UNCCD's Land Degradation Neutrality Fund a Public-private Partnership for Blended Finance

Source: Mandal and Giri (2021)

Pressures on biodiversity

Globally, LULCC has caused unprecedented changes in biodiversity mainly due to complex responses to several human-induced influences in the global environment. The degree of this change is so big (Sala *et al.* 2000) that in some important biomes, the ecosystem processes have been greatly disturbed by irreversible changes and the society's use of natural resources beyond the regeneration capacity. Biodiversity change is now considered one of the important global changes (Sala *et al.* 2000). Deforestation, monoculture, wetland encroachment, and rapid urbanizations altered the structure and compositions of species, and in addition, it created pollution, contamination, and GHG emissions.

Increasing pressure on critical natural resources for survival and the misconception of its renewability have created immense damage to the ecosystem. Managing natural resources under competing and often contrasting demands is a challenge but inevitable for sustainable self-reliance. The challenges are for bigger for population-dense resource-poor countries like India. The economic impact of land degradation has received attention only recently. Valuation of the quality of land is fraught with uncertainty and depends upon the perspective of the analyst. There are two principal choices for valuation: the production or the resource value approaches. The first assesses the impact of land degradation on the value of production lost, usually in market prices of the staple crop. This is a useful device for commercial farming situations, where production foregone is a real loss to the land user. The greater cost of farming the land or the increased investments in fertilizers or irrigation to compensate for land degradation have also been added to the value for lost production.

Impact of climate change on land resource

As predicted, global warming will intensify the hydrologic cycle resulting in more intense rains, frequent floods and droughts, shifting of rainy season towards winter and significant reduction in mass of glaciers causing more flow in the initial few decades but substantially reduced flows thereafter. The deforestation, desertification and soil erosion are also disrupting the carbon cycle between pedosphere and atmosphere resulting in decline of soil carbon stock especially of soil organic carbon thus deteriorating chemical, hydrological and biological environment of the soil. Crop yields would get reduced due to low soil organic carbon especially if it is below one per cent. Similarly, phytomass productivity on non-arable lands would also decline due to degradation of pasture lands and forest areas. Efforts are, therefore, needed to reverse the trend of declining soil organic carbon to sustain and enhance productivity under all types of primary production systems.

Projections of monsoon rainfall pattern over the Indian subcontinent indicate that by 2050, a 10% increase in the amount and 10% increase in the intensity of rainfall are very likely due to climate change, leading to increase in erosive power of rainfall. Based on the results of Sharda and Ojasvi (2006), it is projected that a 1% increase in rainfall intensity may increase the rainfall erosivity by 2.0%. By 2050, the erosion rates of water erosion class 5-10 t ha^{-1} yr^{-1} are expected to increase to more than 10 t ha^{-1} yr^{-1}. Hence, about 66 M ha area in our country under the erosion class of 5-10 t ha^{-1} yr^{-1} that covers mostly croplands will be additionally affected by higher rates of erosion due to climate induced changes in rainfall. This will result in significant increase in water erosion affected land degradation area from the current levels unless ameliorative measures are taken (Mandal *et al.* 2020; Mandal *et al.* 2021).

The Dilemma

The real dilemma is that the existing food system depends extensively on non-renewable resources and consumes at rates far exceeding their replenishment. On the other hand, all such practices release greenhouse gases, nitrates and other contaminants into the environment. Unless the footprint of food system on the environment is reduced, the capacity of the earth to produce food for all will be compromised with grave implications for food security in near future. Sustainability need for all sectors of the food system, from production to consumption, and in education, governance and research must be addressed properly. One of the daunting tasks is to fulfil the demand of the society by 2050 without degrading the natural resources (Mandal *et al.* 2021). Converting these challenges to opportunities is the key for self-reliance what India is aiming at.

Strategies for achieving land degradation neutrality

Due to financial constraints, it is neither desirable nor feasible to treat the entire landscape area to achieve the intended objectives. In such situations, partial/critical area treatment in a watershed may have triggering effect in creating a favourable environment by dissipating the impact of degrading forces and improving the moisture regimes which in turn could accelerate the process of natural ecological succession and various hydro-geomorphic changes. The importance of the concept of prioritization of erosion risk areas/ critical areas was validated in two watersheds namely, *Sukhomajri and Fakot* representing lower and middle Himalayan regions of India (Sharda and Mandal 2018). It was noticed that out of 4207 ha catchment area of Sukhna lake, only about 80 ha area covering Sukhomajri watershed was critical area contributing significantly to sediment yield. Therefore, by treating about 50% of the critical area, the soil loss reduced drastically by about 80% from 150 t ha^{-1} to 20 t ha^{-1}. Interestingly, the soil erosion in the entire catchment could be brought down within the permissible/targeted soil loss value (ranging between 7.5 and 10.0 t $ha^{-1}yr^{-1}$) by treating only 69% of the critical area thus saving on both time and cost.

Soil and Water Conservation technologies have the potential not only to reduce land degradation but also to address simultaneously global concern of water scarcity, land use conflicts, climate change, biodiversity conservation and forest alleviation (Biswas *et al.* 2021). Central and State governments have set an ambitious target to construct lakhs of farm ponds and wells in rainwater-scarce areas of the country through various programmes like PMKSY, MNRGES and watershed development. However, lack of geo-spatially distributed information on rainwater harvesting (RWH) and conservation practices limit the presentation of a holistic picture on the effectiveness of land protection measures, impact of construction of water bodies and watershed management (Naitam *et al.* 2021).

Identification of hot-spot regions and prioritization

Rates of soil erosion in excess of rates of soil loss tolerance limit are a recipe for disaster and there is a clear need for improved understanding of soil loss tolerance for the formulation of appropriate soil conservation strategies. In ideal situation, the erosion level should be contained within the permissible limit (T-value) specified for a given location (Mandal *et al.* 2006; Mandal *et al*. 2010) which ranges between 2.5 to 12.5 t ha^{-1} yr^{-1}. Once this threshold is crossed, the inherent fertility of the land begins to fall. The second Green Revolution, needed to feed the global projected population of 9.2 billion by 2050, must be based on sustainable management of soil and water resources. Assignment of site-specific T-values (Fig. 1) will help to identify the soil erosion vulnerable zones in India. (Mandal and Sharda 2011). The hot-spot areas needs to be prioritized based upon the difference between the prevailing erosion rates and the permissible erosion limits.

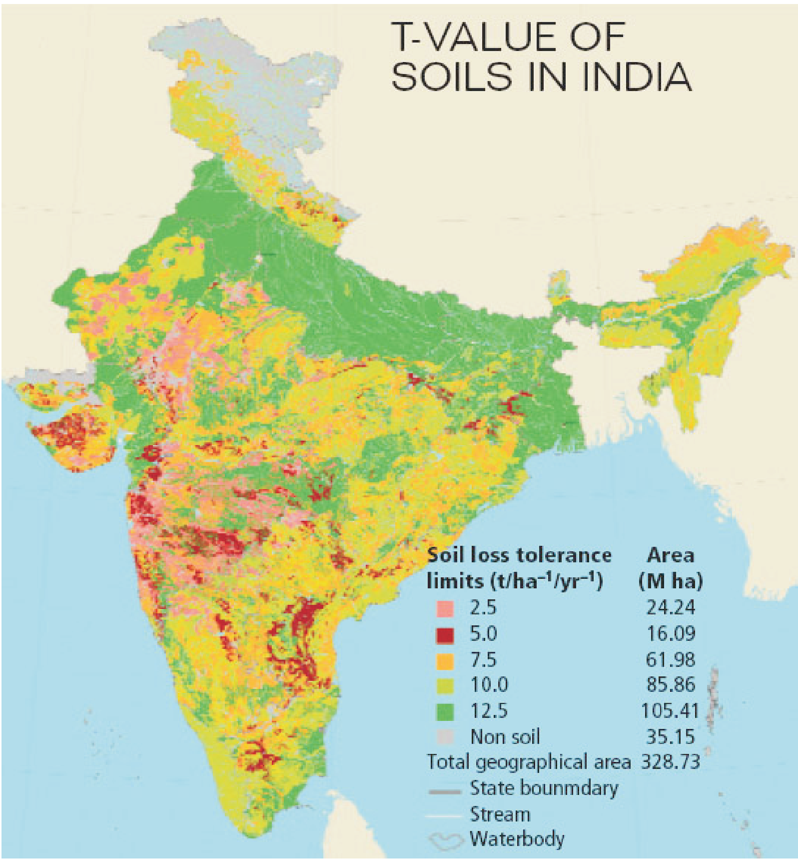

Figure 1. Geo-spatial distribution of permissible limits of soil erosion (T-value) in India.
Source: Mandal and Sharda (2011)

Sustainable land management

According to Inter-Governmental Technical Panel on Soils (ITPS), soil management is sustainable if the supporting, provisioning, regulating and cultural services provided by soils are maintained or enhanced without significantly impairing the soil functions that enable those services or biodiversity. The balance between supporting and provisioning services for plant production, regulating services for water quality and availability; and for atmosphere GHGs composition are of specific concerns. Supporting services include primary production, nutrient cycling and soil formation, while provision services comprise of supply of food, fibre, fuel, timber and water, raw earth materials, habitat and genetic resources. Sustainable Land Management is a knowledge-based procedure that helps to integrate land, water, biodiversity and environmental management (including input and output externalities) to meet rising food and fibre demands while sustaining ecosystem services and livelihoods. Improper land management can lead to land degradation and a significant reduction in the productive and service functions (World Bank 2006). The revolutionary changes are required to redesign and realign the whole production system by incorporating the concept of ecological intensification. Action needs to occur simultaneously on many fronts where more sustainable food production is achieved through investment in existing technology, reversing land degradation, innovation in improving use efficiencies of resources, minimising waste; improving the political and economic governance of the food system to increase productivity and sustainability and social infrastructure (a framework is presented below). According to some researchers, global food availability can be increased as high as 100-180%, which will meet the projected demands while lowering GHG emissions, biodiversity losses, and other environmental problems if all the strategies are taken up through a holistic approach. To achieve sustainable development goals (SDGs) and land degradation neutrality (LDN), synergy should be created among scientific know-how, practical do-how and farmers 'participation.

Recommendations Nations need to protect their soil resources from excessive erosion which may otherwise threaten the productivity of production systems and pollute the water resources and in turn endanger food and environmental security. Following recommendations are made to support the land use planners and policy makers to identify the priority programmes and develop the best manageable policy framework for controlling land degradation.

A comprehensive national knowledge base on land degradation scenario due to various driving forces such as land use changes, construction of water bodies and climate change should be developed and updated for the benefit of various stakeholders. Water infrastructure creating activities under all large scale development programmes must be geo-tagged to present the holistic picture on the effectiveness of land protection measures, construction of water bodies and watershed management. This is more so required to effectively plan and implement national programmes like PMKSY, MNRGES and watershed development.

Out of 4937 large dams in our country, 4485 dams having storage capacity of 1-50 Mm^3 experience a reduction in storage capacity ranging from 0.8% to >2% per year. Estimated life of the majority of these reservoirs is less than 25 years with a range of 8 to 40 years. These reservoirs cater to the domestic, agricultural, and industrial needs of a large number of people. Hence, to prevent high siltation rate in these reservoirs and to preserve the precious water resource, effective land protection measures in their catchments are essentially required. Hence, based on the reservoir sedimentation rates, Ganga, Krishna, Godavari, Narmada, Brahamputra, Mahanadi, Cauvery and Western Ghats and Indus are the river basins which need effective treatment for erosion control in their catchment area to control threats of climate change, land degradation, loss of biodiversity and for sustainable agricultural productivity.

Specifically, the areas of utmost concern are the Himalayan region and the Peninsular India and Peninsular plateau where a considerable area can only afford soil loss ranging from 2.5 to 5.0 t $ha^{-1}yr^{-1}$ only. Among the states, Maharashtra has maximum critical area (47.7%) with a target value of 2.5 t ha^{-1} yr^{-1} followed by Rajasthan (31.6%), Karnataka (13.5%) and Gujarat (12.3%). Identification and execution of site specific best management practices is essentially required in these areas to bring the prevailing erosion rates within the permissible limits which may otherwise adversely affect the crop productivity.

The crops like rainfed paddy (important states Chhattisgarh, Odisha, Assam and Uttar Pradesh), maize (important states Karnataka, Andhra Pradesh, Madhya Pradesh and Maharashtra), soyabean (important states Madhya Pradesh, Maharashtra, Rajasthan and Andhra Pradesh), groundnut (important states Karnataka, Andhra Pradesh, Tamil Nadu and Gujarat), and sorghum (important states Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh) are suffering from maximum production losses due to water erosion and need to be prioritized for taking up soil and water conservation measures on watershed basis in rainfed areas.

Monitoring of data on biophysical, socio-economic and sustainability aspects and estimation of indicators be invariably a part of watershed development project planning to evaluation. Bio-physical indicators include Critical Area Index, Cultivated Land Utilization Index, Water Storage Capacity Utilization Index, Irrigability Index, Livestock Composition Index, and Livestock Production Value Index. Socio-economic indicators include Regular Employment Generation Index and Seasonal Outmigration Ratio. Sustainability indicators include Runoff Conservation Index, Soil loss, Drought Resilience Ratio, Induced Watershed Eco-Index and Carrying Capacity Index. This will help to assess the economic, environmental and livelihood security impacts of the programme in well accepted measurable terms.

It is necessary to adopt a system of land budgeting based on risk and potential analysis to take informed decisions for integrated land management planning following watershed approach. Land reforms, land administration and land acquisition should become more responsive to land quality variations to promote integrated management, planning, implementation and monitoring. Thus, the land reforms policy needs to be revisited to address issues of land tenure, land records and their computerization, digitization of maps, acquisition of land for various purposes besides taking care of critical areas and hotspots. Since land holding size is declining and fragmenting owing to laws of inheritance, a facilitating provision for contract farming and participation of corporate bodies may be included in the policy document. Similarly, mechanism for regulating SEZs should be developed to prevent any adverse impact on prime agricultural land in different regions.

The land management policy should also aim at determining an economically viable size of land holding in different agro-ecological zones of the country to meet the basic needs of average family size of 5 members. To preserve and protect quality and productivity of land resource from pollution and contamination through dumping of garbage and discharge of sewage from settlements and industrial effluents on land and water bodies, appropriate biological measures should be included as an integral component of land development and management activities. Legal incentives and disincentives may be included in the land policy for improving or deteriorating the land quality, respectively from its scientifically assessed use potential.

Policy framework and regulation for sustainable land management: There are several existing policies relating to land use that need to be kept in mind. These include the National Water Policy 2012, National Land Use Policy Outline 1988, National Forest Policy 1988, National Livestock Policy 2013, National Agricultural Policy 2000, National Policy for Farmers 2007, National Policy on Biodiversity 1999 and National Biodiversity Action Plan 2008, and National Environment Policy 2006. Clearly, there is a need to harmonise these policies at the central and state levels, and a mechanism is required that can take a composite view of the land resource base and the competing and conflicting demands thereon.

Conclusion

Historically, soil erosion and land degradation started from a non degraded steady state, however, several drivers and pressures accelerated it. The drivers were deforestation, shifting cultivation, overcutting of vegetation, over-ploughing of land along with population pressure and climate change. Since prehistoric time, humans also realized that worsening land degradation caused by human activities is undermining the well-being of humanity and in recent time a new approach has been taken to achieve land degradation neutrality by 2030. Almost all farming-based cultures in the world have suffered from soil erosion by water with different degree of magnitude varied mainly through time and space.

In general, the studies show that local and regional variations in natural situations, cultural traditions, and socio-economic conditions played a major role in the dynamics and rates of soil erosion in a long-term perspective. The strength and frequency of heavy precipitation events have hardly been investigated yet play an important role with regard to the occurrence of run-off and soil erosion and their long-term effects on ecosystem services. Areas with highly vulnerable soils and inadequately adapted soil management practices have been devastated by soil erosion very quickly, while other sites with less vulnerable soils and well-adapted soil management practices have been farmed over a long period very sustainably. The awareness for the need of soil conservation was different in each culture and period. Soil conservation techniques were obviously not developed until after severe soil erosion with deteriorations to ecosystem services and subsequent socio-economical and political realignments had taken place

In independent India, attention has been paid for controlling soil erosion in different agro-climatic regions of the country. Peasants often appreciate soil conservation measures proposed by various agencies. However, they failed to adopt such measures to effectively control soil erosion because of their fragmented land holdings and poor economic conditions.

Seeking the right intervention for the appropriate target is the major challenge for land managers. There are no shortages of techniques to combat land degradation. However, the heterogeneity of local society, the varying wealth status and resource endowments of local people, and property rights that affect security of tenure, all determine whether a technique is rational and viable for any one household. Future research will have to concentrate on matching solutions to specific environmental situations, societies, and economic demands. A better appreciation of indigenous technologies has already led to rehabilitation projects that combine elements of local knowledge with formal science. Low-cost technologies which use primarily biological means will be the main focus of interest for the most seriously degraded lands. However, ensuring harmony and maintaining a balance with nature is a great challenge in a democratic polity with a fast-expanding market economy. Many renowned historians, ecologists and social scientists have also expressed a similar view.

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