Soil and water conservation techniques based land degradation neutrality: a need-based solution for degraded lands in Indian perspective

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Land degradation neutrality (LDN) adopted in 2015 as target 15.3 of sustainable development goals (SDGs), is a challenge as well as opportunity in the present world to restore the degraded lands. Soil and water conservation (SWC) techniques in the form of bio-engineering measures have vast potential to attain LDN in sustainable manner. India has already announced a LDN target of 26 mha and is fully determined to meet the target by 2030. Therefore, this article proposes and recommends incorporation of SWC measures in effective ways at policy level as key to the success of LDN.

Keywords: Degraded land restoration, ecosystem services, LDN, SDGs, SWC techniques.

LAND is the functionally or topographically distinct fraction of Earth's surface which is not covered by water[1]. Land supports human race by providing multiple functions directly and indirectly. It sustains an enormous number of ecosystem services, of which provisional services lead[2]. Globally, land resources are facing severe risk due to anthropogenic activities including industrialization and urbanization and land-use changes in unsustainable manners. Land degradation has emerged as one of the critical environmental problems in the past few years and most of the regions of the world are being or have been affected by this problem to some or more extent[3]. It is a severe environmental problem affecting the globe negatively[4]. The degree and severity of land degradation are expanding day by day globally[5]. It includes degradation of soil resources as well as temporary or everlasting decline in the structure, density and land-cover composition of vegetation[6]. The loss of vegetation due to degradation in forest areas is responsible for loss of fuel, fodder and grazing land and adversely affects the springs which are the main sources of water in the hilly areas[7]. Land degradation results directly in monetary loss and loss of ecosystem services in the form of declined upper and lower ground storage of carbon in vegetation and soil which is the driver for climate change, loss of biodiversity and several other environmental consequences.

The insufficiency of land resources to produce to feed the population and meet their energy needs are driving the nations to integrate their priorities with international treaties and protocols. Loss of the natural production capacity of soil due to land degradation is an universal apprehension for sustaining life on Earth, food security, conserving biodiversity and indigenous population, climate change mitigation and adaptation. Avoiding, reducing and reversing land degradation are essential for retrieval of nature based food, fodder fuel and, fibre and ecosystem services in a sustainable mode[8].

Land degradation negatively affects livelihoods of people around the world, and the area of degraded land covers around more than quarter of the Earth's geographical area (excluding ice land area). About 1.3 to 3.2 billion global populations of developing countries are affected by land degradation[9]. As per the global assessment of human-induced soil degradation, 15% of the global land is degraded. In Europe, Asia, Africa and North America, the percentage of degraded land is 25, 18, 16 and 5 respectively[10]. The main agent for land degradation is soil erosion which affects the global degraded area by 83% (in North America 99% and in Europe 61%). Other agents include nutrient depletion which affects global land degradation by 4% (South America by 28%), salinity which affects degradation by less than 4% (West Asia by 16%), and chemical contamination which affects global land degradation by about 1% (Europe by 8%)[10].

According to literature about 120.72 mha land area is subjected to a variety of land degradation out of 328.73 mha of geographical area of India, in which both cultivated and non-cultivated area of land are included. The extent of land degradation due to water erosion, chemical degradation, salinization/alkalization and acidification, wind erosion, physical degradation (due to water logging, industrial waste and mining) is 82.57, 24.68, 12.4 and 1.07 mha respectively[11]. Even the soil resources are being eroded at a rate of about 5334 million tonnes yearly, of which 29% is permanently lost into the sea[12,13], 10% deposited into reservoirs which results in decline in the capacity of reservoir by 1–2%, and the remaining 61% displaced from one geographical position to another[14]. According to estimates, productive top soil is being lost at a rate of 6000 million tonnes with an additional loss of major nutrients (NPK) in the range of 5.37–8.4 million tonnes yearly[15]. About 30% of India's land is already degraded or facing degradation[16]. About 3.2 billion global population are affected by land degradation[17]. Around 95%, i.e. 1.33 billion global population affected by land degradation belongs to developing countries[18].

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Land degradation neutrality (LDN) is a state where the land degradation process is in a steady state or there is no further loss of degree of productivity of soil, as well as the existing degraded land is restored and reclaimed[19].

Presently, land restoration and reversal of land degradation is getting passable consideration from researchers, policymakers and conservationists to conserve soil resources. As a result of which, LDN was adopted as 15.3 target of goal 15 of 'life on land' under sustainable development goals (SDGs) of United Nations Convention to Combat Desertification (UNCCD) in Conference of Parties (COP-12) in October 2015 (ref. 19). Adoption and implementation of LDN in the Rio+20 product document 'The future we want', emphasized on the importance and conservation of nature and natural resources. Avoiding, reducing and reversing land degradation are vital in the present context of SDGs and betterment of humankind. The three main indicators of LDN are land cover and land cover change (LCC), land productivity in the form of net primary productivity (NPP) and soil organic carbon (SOC)[5,9].

LDN offers challenge as well as opportunity for the overall development of the world to address SDGs and reversal of degraded land into restored and sustained land. LDN is a long-term goal that has the potential to meet the needs of global population in future. LDN signifies policies and practices related to land management at national as well as local levels. It is an inimitable opportunity in the way of sustainability, restoring degraded areas and utilizing degraded lands for profit of mankind in feasible manner. It tactically puts efforts to avoid, reduce and reverse land degradation process which directly involves in conserving, managing, restoring and rehabilitating land in land-use planning.

There are several approaches suggested by researchers for restoration and rehabilitation of degraded lands. During the course of restoration and rehabilitation, some of the key points to consider in planning and execution are severity damage, ultimate target of restoration process, and resources available including funds. Improving the quality of degraded lands and ecosystems is the prime goal of any nation in the context of feeding their population, safeguarding their environment and meeting international goals of sustainability. The main aim of restoring degraded landscape is to speed up the natural inbuilt processes of land so as to amplify natural productivity, increase ecosystem services and reduce the rate of environmental losses and consequences[20].

Managing and restoring degraded lands are the focal points of LDN. The key components to restore and manage degraded lands are identifying the cause and target, stabilizing site, ecological reconstruction, monitoring and evaluation[21]. The main components of managing degraded land are biology (in consultation with chemistry), engineering and integration of both, i.e. bio-engineering. The role of soil and water conservation techniques is vital in establishing the vegetation and long-term water management planning in crops. Agroforestry, horticulture, grasses, shrubs and agronomy crops can rely on SWC techniques on degraded lands. Depending upon the class of degraded soil, different vegetation and soil management practices can be applied. In different biological practices, agroforestry, crop rotations, cover crops, zero or reduced tillage, residue management, vegetative barriers, mulch, shelter belts, inter cropping, biofertilizers, etc. are imperative[22]. Biological practice means establishing direct link between soil interfaces, working to condition the media, making the soil media altered towards restoration and rehabilitation. The modified soil media becomes healthy in terms of physical, chemical and biological aspects providing more productivity.

The engineering techniques are applied based on the severity and class of degradation, topography and climate of the specific locations[23]. Some techniques include trenching, bunding, terracing, contour wattling, crib structures, geo-textiles including geo-jute, loose boulder/stone/check dams, gabion structures, spur, brushwood check dams, and conservation bench terrace[24]. These techniques work in combination with biological measures which in turn provide tangible as well as intangible benefits in the form of ecosystem services.

Implementing SWC based policy helps in soil and water conservation in terms of quality and quantity, livelihood security, biodiversity protection, climate change mitigation and adaptation, and land resources restoration. The neutral degraded lands would guide towards amplified NPP for agriculture and forests, creating better cash flow and GDP for a nation. A conceptual framework of SWC based LDN for environmental sustainability is given in Figure 1. SWC based LDN avoid, reduce and reverse the harshness of land degradation process through ecological restoration in a natural way and eventually sustain and improve ecosystem services[25]. The past global implications of SWC measures on degraded lands are represented in Table 1. SWC based LDN works on the principle of ecologically functioning to improve the three main indicators of LDN, i.e. LCC, NPP and SOC[5,9]. SOC is universally used as an indicator of combined form of soil physics, chemistry and biology owing to its heath[26].

During UNCCD COP 14, India announced a LDN target of 26 mha from 2019 to 2030 (ref. 27). From 2019 to 2021 India took over COP presidency towards contributing effective involvement and implementation. Government of India (GoI) has already initiated few schemes to achieve LDN such as Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), National Rural Employment Guarantee Scheme (NREGA), Soil Health Card Scheme, Namami Gange, Rashtriya Krishi Vikas Yojana and National Afforestation Programme which are having vast potential to achieve LDN. There is a need to integrate schemes of land and water management with SWC techniques. Conservative estimation tells that costs of degradation are

Table 1. Implications of soil and water conservation (SWC) measures on degraded lands in different countries

Type of degraded land	SWC measures	Country	Implication	Reference
Steep slopes of hills	Crescent bund and coconut husk	India	Cumulative yield of cashew was increased by 32–35%	30
Mixed calcareous, hyperthermic, and falls under Fluventic Ustochrepts	Bench terracing, trenches	India	Carbon stocks were significantly increased in bench terracing and trenching	31
Hypothermic family of typic Haplustepts with clay loam texture soil	Staggered contour trenches, continuous contour trenches, stone mulch, vegetative barriers	India	Soil loss and runoff was reduced by 97% and 91%, compared to bare soil. Over the period of 6 years, contour staggered trenching produced significantly higher yield (8.83 Mg ha^{-1}) of *Emblica officinalis*	32
Very deep sandy loam, poor in fertility and SOC	Vegetative filter strips, grassed water courses, grassed buffer strips	India	Grass filter strips reduced the sediment concentration in the runoff water by six times (from 4.2 to 0.65 g/l)	33
Regosoils with poorly structural and heavily erodible	Brush check dams	France	The average volumes of sediment trapped ranged from 0.10 to 0.95 m^3 yr^{-1} per gully over the three years	34
Rugged, dissected mountains, deep valley	Stone bund, soil bund and bench terracing	Ethiopia	Positive correlation was found between stone bunds and soil bunds	35
Undulating terrain, steep slopes, fragile environment and erratic rainfall	Stone bunds	Ethiopia	Soil loss by sheet and rill erosion decreased by 68% and positive impact of stone bunds on crop yield mostly concentrated around the stone bunds	36
Slopy land	Tied ridging (TR)	Kenya	Tied ridging reduced sediment yield by 94% compared to the conventional tillage	37
Gully eroded area	Vegetation (tree + shrub) with terracing	China	*Platycladus orientalis*, *Hippophae rhamnoides* with terracing resulted in significant soil carbon sequestration relative to abandoned cropland	38
Cambisol and calcic	Terracing for *in situ* moisture conservation	China	Soil moisture was reported 13.7% higher than that in the slope and canopy transpiration and increased by 9.1% at terrace treatments	39
Sloping erosion prone area	Water harvesting technique	Tunisia	Catchment-to-cropping ratio (CCR) more than 10 decrease and reduces runoff towards downstream area	40
Laterite soil with fluvial sandy gravel	Check dams, channel protection	Nepal	Sisso, bamboo and pine with Napier grass system. Napier grass is effective for erosion control and improving top soil fertility	41

2.54% of GDP which is a huge loss for nation like India. India will require about 14.4 billion USD to meet the SDGs by 2030 (ref. 16). The cost of sequestrating carbon using degraded land restoration and degraded forest restoration is estimated to be 51 and 61 USD per tonne of carbon sequestration respectively[28]. India is firmly determined towards attaining the SDGs. It has already increased its tree and forest cover by 0.8 mha during the period of 2015 to 2017. The total carbon stock in forest is approximated to be 7082 million tonnes. There is an enhancement of 38 million tonnes in the nation's carbon stock during 2015 to 2017 (ref. 29). With these positive signs of sustainability, India is also planning to move forward towards achieving the LDN. Further, GoI has announced and initiated the process to set up a Centre of Excellence for Sustainable Land Management at the Indian Council of Forestry Research and Education (ICFRE), Dehradun, in order to provide all the technical support to the Ministry of Environment, Forest and Climate Change, in achieving the LDN targets. This Centre also envisages south–south cooperation to enable India to share its experiences on sustainable land management with other party countries.

The concern of land degradation is crucial for any nation in the context of SDGs. Only with firm determination and collective efforts and convergence between different

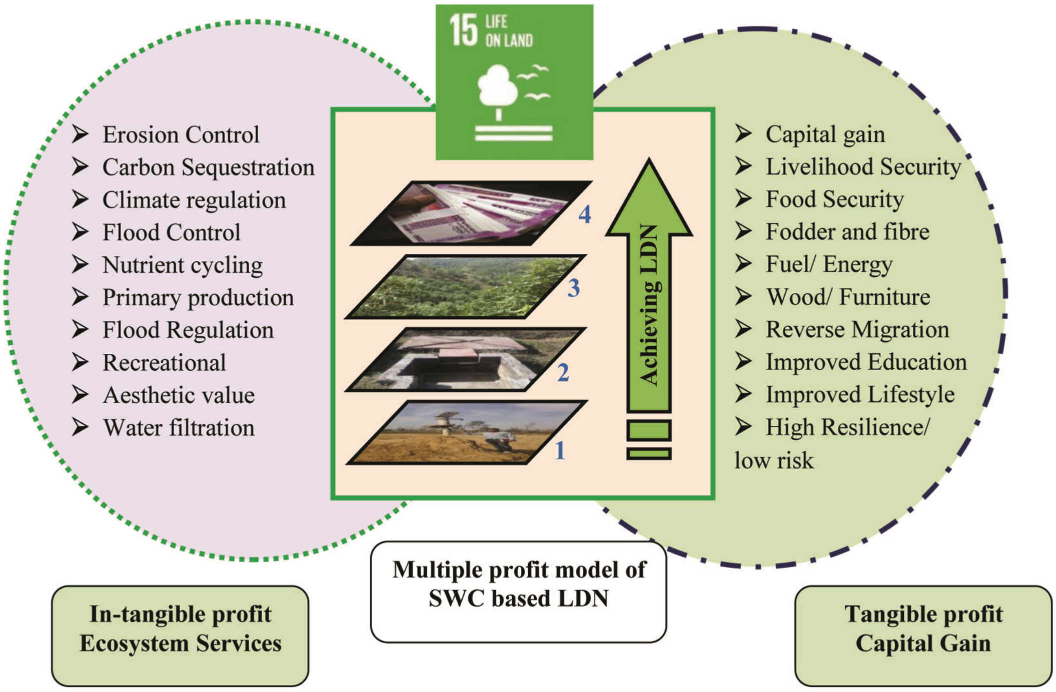

Figure 1. A conceptual framework of soil water conservation (SWC) based land degradation neutrality for environmental sustainability. 1, Degraded land; 2, SWC based bio-engineering measures; 3, Higher yield and nutrient addition to soil (enhanced land cover change, net primary productivity and soil organic carbon); 4, Capital gain.

departments, government and private sectors, non-government organizations and stakeholders, it can be achieved. LDN with integrated systems of biology and engineering with SWC measures at policy level represents an effective way towards achieving SDGs. The integration of LDN targets into nation's own policies and transformation of national targets as well, will enable to fight against national as well as global problems such as climate change and other environmental crisis in a combined mode.

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Mapping of agroforestry systems and *Salix* species in Western Himalaya agroclimatic zone of India

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In the present study, agroforestry was mapped in nine districts from Western Himalayan Region. The agroforestry area in these nine selected districts was estimated to be 332127.55 ha (12.4%). *Salix alba*, an important agroforestry species, accounted for about 12% of total agroforestry area in three districts of Kashmir valley.

Keywords: Agroclimatic zone, agroforestry mapping, object-oriented classification, remote sensing, tree species.

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