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Major Aspects of Land Degradation and Its Management from Various Methods: A General Review

Rahul Verma[1], Priya Kushwaha[2], Amit Kumar Singh*[3], Pallavi Dixit[4]

[1]Research Associate, Department of Botany, University of Lucknow, Lucknow, Uttar Pradesh, India
[2]Research Scholar, Department of Botany, University of Lucknow, Lucknow-226007, Uttar Pradesh, India
*[3]Assistant Professor, Department of Botany, University of Lucknow, Lucknow, Uttar Pradesh, India
[4]Associate Professor, Department of Botany, Mahila Vidyalaya Degree College, Lucknow-226018, Uttar Pradesh, India

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ABSTRACT

Land is an important component for any country, which provides food, shelter, fiber, and many other things that are essential for living beings. Land is a non-renewable natural resource that is degraded day by day by different types of natural and manmade practices. Land degradation is caused by different factors, including climate, natural, and anthropogenic activity can deteriorate land quality and degrade the land for agricultural practices. The agricultural sector is directly affected by land quality, which impacts agricultural production. Due to rapid changes in climatic conditions, deforestation at high risk, the desertification process, soil erosion, salinization or alkalization of soil, water logging, and depletion of organic carbon in soil are the major components of land degradation across the world. Management of land for different methods which are important to manage the activity of these components, and properly managing all the factors is responsible for soil degradation. Management of land by various methods, by covering the land with crop residue, using alternative fuel, replanting trees, and making different policies regarding land degradation. Organic farming is an important component in controlling land degradation. This review focuses on different types of soil degradation methods and their effect on crop productivity and the environment, and how it is managed by various methods.

Keywords: Land degradation, Climate change, Agriculture, Environment, Soil management.

I. INTRODUCTION

The land degradation being a high-risk problem worldwide (Turner et al, 2016), there is a lack of a reliable and acceptable global map regarding the extent and problem of land degradation (Gibbs & Sakmon, 2015; Van der Esch et al., 2017). There are various reasons explaining land degradation by using which type of data base (Herrick et al., 2019) and what types of methodologies are used to measure the land degraded area (Prince et al., 2018) are conceptual, however land degradation is the degradation of productivity of the soil, there are many types of views regarding the spatial and temporal scale at which type of land degradation occurs (Warren, 2002), and how this can be the land area is quantified and mapped.

The 3rd edition of the Atlas of desertification includes a global map of the productive land area changing from 1999 - 2013, which is one of the most convenient representations of soil degradation across the world (Cherlet et al., 2018). Over the period, nearly 20 percent of the land area on a global level shows signs of losing its productivity, whereas about 20 % of the land area shows an increased productivity rate. The productivity of land area showed characteristics like the forest land area showing an increasing pattern of productivity, while range lands showed a more declining pattern than an increasing trend. These land productivity assessments, however, do not identify trends of climatic change nor due to some other external or internal factors. All these studies about vegetation growth in different areas on the global scale showed that they are regionally differentiated in two ways that is, increasing or decreasing vegetation growth. When comparing the vegetation growth with the climate variables, Schut et al. (2015) found that there a very less areas (1-2 %) where increases in vegetation growth were independent of climate change factors; positive type of vegetation growth is primarily dependent on climatic factors.

A comprehensive type of treatment methods available for the treatment of land degradation conceptual discussion is mentioned by various recent reports on the soil degradation from the 'Inter-governmental science policy platforms' on biodiversity and ecosystem services (Montanarella et al., 2020). A review based observation attempt to mapping the global land degradation area, based on experts opinions, observations by satellite, bio-physical models, and a database provided by the abandoned agricultural land area, suggests that nearly < 10 Mkm^2 to 60 Mkm^2 (corresponding to the 8 to 45 % of the ice-free land area) have been degraded globally (Gibbs & Salmon, 2015). The global assessment of land degradation uses has shown a trend as a proxy for land degradation and improvement from 1983 to 2006, with updated data available in 2011 (Bai et al., 2008 & 2015). These studies, based on very coarse resolution type of satellite data used (with a resolution of 8 km), and this data indicates that between 22 % and 24 % of the global ice-free land areas are subjected to a downward movement of trend, while near about 16 % of the data showed an increasing trend. This study also suggested that, contrary to earlier assessments (Middleton and Thomas, 1997), dry land area is not the most affected region. Another study suggested a similar type of approach for the period of 1981 to 2006, suggesting that nearly 29 % of the global land is subjected to 'land degradation hotspots', which are areas suffering from an acute type of land degradation and need particular attention to avoid degradation. These land-degraded hotspots areas were distributed in the agricultural and agro-ecological regions all over the world and the number of people affected, and Le et al., (2016), estimated about 3.2 billion people are directly indirectly affected by land degradation, while Barbier and Hochard (2018) estimated that and about 1.33 billion peoples are affected, of which 95 % peoples are affected only from the developing countries.

The mapping of the human footprint on the world level has been attempted multiple times (Cucek et al., 2012), but in some cases, they confuse how many types of humans impact the planet with the land degradation, environmental degradation, and some other major environmental-related issues caused by human beings. Human impact on climate is not equivalent to land degradation, but information regarding the human footprint provides useful mapping data of the potential for non-climatic drivers of land degradation. Borelli et al (2017) attempt to understand the trends of soil erosion models on land degradation and global vegetation all around the world. The world has suggested that land erosion generally occurs in areas of expansion of crop expansion, particularly in sub-Saharan Africa, South America, and Southeast Asia.

Soils include nearly 1500 GT of organic carbon (median across 28 different estimates by Scharlemann et al., 2014), which is 1.8 times more carbon content than is available in the atmosphere (Ciais et al., 2013) and 2.3 to 3.3 times higher than water is held by the terrestrial vegetation of the world (Ciais et al., 2013). That's why land degradation, including land conversion, leads to soil carbon losses, and has the potential to impact the atmospheric concentration of Carbon dioxide substantially. When cultivating the natural ecosystem for different uses, they lose the soil carbon captured from the soil that has accumulated in soil over a long period. The loss of carbon amount from the soil depends on which type of natural vegetation is present, and how the soil practices are managed. The estimated magnitude of the carbon loss varies from area to area, but figures between 20 % and 59 % have been reported in several studies (Guo & Gifford, 2002; Li et al., 2012; Poeplau & Don, 2015). The comprehensive amount of soil carbon is lost because of land degradation practices after the conversion is hard to assess due to so many types of variation in the local conditions and management.

II. EFFECT OF LAND DEGRADATION ON AGRICULTURE

Land degradation is a huge worldwide problem due to its antagonistic influence the agricultural production. It also has a bad effect on ecological circumstances and nutritional safety. The Ecological system is also affected by soil degradation, because nonstop soil degradation is now far from getting categorized: it creates problematic conditions for ecological growth, it has adverse effects on the socio-economic circumstances, and on agriculture. Degradation of land by various types is the regular outcome of atrophic aspects, which affects crop production. In the framework of crop production, land degradation marks a gap between land excellence and land usage (Beinroth et al., 1994). On the global scale, above 20 % of agricultural land area, 30 % of plantations, and 10 % of savannas are directly affected by land degradation, such degradation is caused by human activities like unsustainable land management and environmental deviations (Bai and Dent, 2006).

Recent studies suggest that about 10 to 12 million hectares of agricultural land are permanently lost on an annual basis due to salinization and soil erosion, and many other land degradation factors. Land degradation affects the yield of crop production, which may develop a more significant relation with the yield growth and loss in the future, as the yield rates are projected to drop below nearly 1 % annually in the coming decades. This phenomenon is more severe in arid and semi-arid regions because of resource combination, lack of infrastructure, and economic factors (Hamdy and Aly, 2014). About 50 % of agricultural land areas are going to be degraded from moderately to severely. Loss of agricultural land affects about 1.5 billion humans on a global scale, 15 billion tons of soil disappear every year, and about 12 million hectares are lost due to desertification and drought.

The biodiversity of about 27000 species is lost every year due to land degradation. About 110 countries are at risk regarding the dry land area and less availability of water for agriculture. Approximately 250 million people are directly and indirectly due to loss of soil, and nearly 1 billion are at risk or threatened. El-Sawify and Dangler (1982) reported that land degradation is mainly caused by the loss of soil organic matter and soil nutrients, which reduces crop production. El-Swaify and Cooley (1981) also observed that the major components that reduce crop production are the physical land degradation components within the root zone. The major reasons for increasing soil erosion are urban sprawl of industries, deforestation on a large scale, and unsustainable agricultural practices. Use of tillage implements in agricultural land will damage the top vegetation and cause soil erosion (Angelsen, 2007).

III. EFFECT OF LAND DEGRADATION ON THE ENVIRONMENT

The effect of land degradation on the natural ecosystem and environment is due to the loss of forests on a large scale (Birhanu, 2014). Land degradation also plays a major role in the diminution of livestock in both quantity and quality, thus, the living standard of rural people is affected by any changes in the livestock sector. Land degradation also results in enhancing the unemployment rate and out-migration of human to fulfill their basic needs, where there is less agricultural area and livestock production. Insufficient land available for cultivation leads to a reduction in farm size, which creates disguised unemployment.

Land degradation is an ecological phenomenon that disturbs the arid and semi-arid regions across the world, and it also affects the economic and agricultural nature of agronomic land (Mantel and Engelen, 1997). Land degradation directly and indirectly affects the cultivation, ecosystems, soil productivity, nutritional imbalance, and loss of biodiversity on a large scale (Wasson, 1987). It also affects the biophysical environment by disturbing the land area through anthropogenic or natural processes. Natural sources contain earthquakes, tidal waves, soil erosion and overflow of water, and cyclones. Land degradation from anthropogenic activities mostly significantly affects the environment (Barrow, 1991). Global estimation of land degradation demonstrated that Asia has been extremely affected, but Africa and Europe are slightly influenced (Zika and Erb, 2009). Early historical studies have demonstrated about non-stop effect of volcanic activity leading to the degradation of land and has a great impact on the environment (Leroy et al., 2009).

IV. LAND DEGRADATION CAUSES AND IMPACT

On behalf of a climate change perspective, soil degradation played an essential role in the change in dynamics of atmospheric gases such as Nitrous oxide (N_2O) and methane (CH_4). Nitrous oxide is produced in the soil by microbial activities, and the dynamics are influenced by both management and weather conditions, while methane dynamics are mainly determined by the amount of soil carbon and what extent the soil is subject to waterlogging (Palm et al., 2014).

Land degradation is not adequately addressed for its effect on plant growth and yield of any crop, but it is essential to raise awareness about land degradation so that, in the future, some measurable decisions can lead to a more sustainable and resilient agricultural system all over the world. The total geographical area of India is about 328.7 Mha, of which 304.9 Mha (million hectares) comprises the reporting area, with 264.5 Mha of land used for agricultural purposes, forestry, pasture, and use in other biomass production. The severity and extension of land degradation in the country have been published in the data by many agencies, and the severity of land degradation has been reported by many degrading agents. According to the National Bureau of Soil Survey and Land Use Planning in India, nearly 146.8 Mha of land area is degraded. Major erosion of any particular area is caused by water erosion, and degradation of land area by water erosion is the most serious problem in India, resulting in the loss of the top layer of soil and terrain deformation. Based on the estimation report about the rate of land degradation and existing loss of the top layer of soil average rate is nearly 16.4 tons of soil per hectare per year, resulting in an annual amount of total loss of 5.3 billion tons all over the country. Nearly 29 % of the topsoil eroded by different agents is permanently lost in the sea, while nearly 61 % is transferred from one region to another by different agents, and the remaining 10 % is deposited in different reservoirs across the country.

Degradation of top topmost layer of soil has become a serious environmental problem in both rain-fed and irrigated areas of India. Land degradation in India is very high in comparison with other countries because the rate of land degradation in India is more severe. The documented cost of land degradation is declining crop productivity, land use intensity, change in the crop use pattern, using the high amount of input cost and it also affects the profit, and loss of production of India is valued at Rupees 68 billion in 1988-1989 using the National remote sensing agency dataset. Some other type of additional losses was estimated to cost nearly 8 billion, resulting in salinization, alkalization, and water logging. After some time, a comprehensive study made on the impact of water erosion on crop production, and the data is revealed that soil erosion due to water flow resulted in an annual crop production loss is 13.4 Mt in cereal crops, oil seed, and pulse crops are equivalent to the $162 of U .S. dollars. Apart from the above defective and damaged agricultural activities that lead to land degradation, some other human-induced activities that lead to land degradation include- cleaning of land, careless management of forest area, deforestation, improper management of industrial effluent and effluent, surface mining and industrial developmental activities that also play a leading role in soil degradation.

One of the major reasons for soil degradation is excessive pressure on the land to meet the competing demands of the growing population for food, fodder, and fiber. Various types of human activity are responsible for land degradation, such as the introduction of large-scale canals for irrigation purposes, deforestation, and faulty land use leads to the acceleration of soil degradation through salinization, flooding, drought, erosion, and waterlogging. These processes reduce agricultural production and lead to agricultural security. The emission of greenhouse gases into the atmosphere from various sources, resulting the global warming, is the major reason for soil degradation. Some other causes of land degradation due to direct and indirect human interventions are deforestation and removal of natural vegetation, overgrazing, agriculture-related activities, and over-exploitation of the vegetation for domestic purposes. Some major threats to land degradation and its management are as follows:

Soil erosion:

The major and most important natural resource degradation is soil erosion. Generally, in comparison to plain and undulating terrain, mountainous regions experience more severe soil erosion. Soil management in an appropriate manner, such to the location, like tilling along the slope, and a lack of crop cover on the land area during rainfall time are the major responsible agents of soil erosion with the consequent loss of their productivity. According to one estimate, more than 85 million hectares of land are subject to wind and water erosion. Because of the various factors like slaking and dispersion, the mechanism of soil structural collapse and degradation varies by climatic factors from one soil type to another. Water is the main and responsible erosion agent of most of the soil erosion contexts in India. Degradation of land by wind action is limited in arid and semi-arid regions in India. Removing the natural vegetation cover resulting from the excessive grazing and the extension of agriculture on the marginal area are the major human-induced factors that accelerate wind erosion. Such type of erosion is involved in the displacement of soil particles by wind action.

Salinization and Alkalinization:

The expansion of land area for irrigation and agricultural purposes is the main objective for achieving self-sufficiency in food production for any country. The net land area used for irrigation in India has increased from 22 million hectares in 1950 to near about more than 51 million hectares in the present day. In most of the land expansion, the area is increased under canal irrigation, leading to a rise in the groundwater table, resulting in the deterioration of soil quality through the accumulation of salt in agricultural land. However, reclamation practices are used day by day to mitigate the salinity of the land area. This type of soil contains a high amount of either different types of soluble salt or exchangeable sodium, both of which affect the crop yield and crop production. Crop production depends on the physicochemical properties and nature of the soil that is present in agricultural fields. Soils affected by alkalization or salinization are classified into three types that are: saline soil, sodic soil, and saline-sodic soil. Salt-affected soils are once again regrouped into two class's namely saline and sodic alkali soils. The alkaline nature of the soil is generally characterized by a high pH value (up to 10.8), a high number of exchangeable sodium percent up to 90, a low amount of organic carbon, poor infiltration quality, and poor fertility status. These types of soils are dominated by sodium carbonate and sodium bicarbonate. On the other side, saline soils have a high electrical conductivity and lower pH values. The dominant salts that are present in the saline nature of soils include chlorides and sulfates, or Na, Ca, and Mg. Similarly, about 25 % of groundwater resources in our country are saline and brackish.

Acidity:

The largest area in our country is covered by the acidic nature of soil belonging to the laterites and various types of latosolic soil, e.g., Ferruginous red soils, ferruginous gravelly red soils, mixed red and black, or red and yellow soils. The acidic nature of the soil is developed in humid and per-humid areas in the states of Assam, other northeast states, West Bengal, Bihar, Odisha, Andhra Pradesh, Kerala, Madhya Pradesh, Karnataka, Maharashtra, and Tamil Nadu. This type of soil is formed due to the excessive leaching of cations with high rainfall conditions, resulting in the lowering of the pH value and loss of soil fertility. Based on the pH value in the acidic nature of the soil, it's classified as strongly acidic (pH < 4.5), moderately acidic (pH 4.5-5.5), slightly acidic (pH 5.5 - 6.5), and non-acidic (pH > 6.5).

Soil organic carbon loss:

Alfisols, Ultisols, and Oxisols types of soils are mainly prone from the chemical deterioration of nutrient depletion because of pedogenic processes for the development of soils. The saturation base of such a type of soil is much less, especially in the Ultisols and Oxisols, as compared to the Alfisols. In India, near about 3.7 million hectares of land are degraded from the depletion of organic matter in soils. The area of such type of degraded soil is distributed across the country, ranging from the cultivated areas to sub-tropical belt areas, and it mainly occurs in the shifting cultivation. Removal of in-situ methods of crop residue burning, a very low amount of addition of organic manure, and cultivation on a large scale are the major reasons for the depletion of soil organic carbon from the topmost layer of the soil.

Nutrient Imbalance

The use of different nutrients in balanced proportions is essential for achieving a high crop yield, but the use of nutrients in excessive amounts and imbalanced ratios may pose a risk of pressure on the environment, human health, and the ecosystem. Loss of nutrients from the soil occurs in many types, i.e., emission in the air as ammonia, nitrous oxide, and nitrogen, and discharge from the water through leaching and soil erosion. The nutrient inputs are from the states to the states in our country. The nutrient balance differs among the states, and this is related to the economic development of our country. The wide use of fertilization in the agriculture sector and booming livestock production contributed to the loss of nitrogen in high amounts in the environment. The use of nitrogen inputs and outputs showed a large variation in different types of crop patterns. The highest nutrient inputs and accumulation in cash crop production have been observed. Due to the increasing demand for food in the future, the nutrient loss problem and depletion of organic matter will be more serious risks in the future. Especially occurs in highly intensive cultivated areas of rice-wheat cropping systems in the Indo-Gangetic plains.

V. MANAGEMENT OF LAND DEGRADATION

Growing different types of vegetation cover provided by plants is the best method to stop soil erosion in different areas. The installation of a safeguarding covering, like a blanket, over the soil for the growth of small plants also helps in preventing soil erosion. Construct the wind break material to prevent soil erosion from the speedy wind action in the land area. The management and reclamation of acidic soil including the addition of line and other chemicals in amendments to neutralize the acidity and manipulation of agricultural practices for the optimum crop yield, and cultivation of acid tolerant crops and varieties, and addition of supplement nutrient through the suitable carriers, reclamation of acidic soil through the water management and other agronomic practices. Reclamation of acidic soil from the lime requirement, estimation based on exchangeable acidity, and percentage-based saturation of soil ranges approximately from 3.5 to 15 tons per hectare. Balanced and integrated use of organic and inorganic manure in different crops, using a suitable method of crop residue management, is the best and desirable option for balancing the soil organic carbon in the soils. Irrigation systems may be helpful in land management, i.e., drip irrigation can control land erosion and water erosion. Managing the irrigation water is the most efficient way to control soil erosion. Using the most efficient way of low and high salt water is maintaining the clay soil's productivity. Using different management techniques to avoid soil degradation, such as fencing, use of fertilizers, use of salt and different supplements, burning, and water development, may control the overgrazing by animals and lead to improved soil fertility.

VI. CONCLUSION

Land degradation affects the environment, agriculture, and society in different ways because land degradation impacts human beings, environmental conditions for crop production, and society for livelihood. Land degradation is caused by different types, i.e., water erosion, deforestation, soil compaction, salinization, desertification, water logging, and many other factors. Land degradation becomes more dangerous because it directly or indirectly impacts food security and environmental conditions. So it is important to minimize land degradation and soil loss by using different techniques. This present review concludes that land degradation is managed by the use of integrated application of organic and inorganic fertilizers, promoting drip irrigation techniques to reduce soil and water losses. Furthermore, new policies are required at the government level to reduce soil degradation.

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