12 Soil Issues and Future Perspective

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Abstract

In the previous chapters, it has been pointed out that the soils of Nepal are young due to active geology and weathering. Being fragile and loosely aggregated, soils of the plain, hill, and mountain regions are on the verge of degradation and thus require proper care and management. With continued cultivation, low prioritization by government soil conservation programs, and weak policy regulations coupled with natural forces, the soils of Nepal face many challenges. In this chapter, we discuss the issues of Nepalese soils that are either inherent, overlooked, and emergent or likely to emerge soon. These issues were envisioned based on a review of all the chapters of this book, other relevant literature, our own on-the-ground observations, and personal communications with concerned stakeholders. There are numerous soil issues that have arisen due to a lack of proper land management strategy. Soil erosion, soil acidity, flooding, and nutrient depletion are year-round problems. Soil organic carbon depletion is an emerging issue in the Tarai region due to an imbalanced organic input-output ratio. Similarly, soil compaction in the Tarai is another emerging issue due to a multitude of factors such as heavy tilling equipment, a low level of soil organic carbon, frequent flooding-drying cycles, continuous use of chemical fertilizer, and less residue recycling. Cropland abandonment is an emerging issue in the Hills, and land degradation is pronounced in the first five years in this abandoned cropland. Vegetation succession in abandoned land later reduces degradation to some extent, but studies are still required to examine how soil properties are changing in abandoned cropland. In addition, very few studies have been carried out in soil biodiversity, soil pollution, and landscape-scale biogeochemical cycling of nutrients in Nepal. There are numerous potentialities camouflaged in Nepalese soil that are both challenges and opportunities for present and future generations which is discussed in this chapter.

Keywords

Challenges • Nepal • Opportunities • Soil issues • Soil perspective

12.1 Introduction

The United Nations Food and Agriculture Organization identified ten major soil threats in its voluntary guidelines for sustainable soil management (Baritz et al. 2018): soil erosion, low soil organic matter content, imbalanced soil nutrients and cycles, soil salinization and alkalinisation, soil contamination, soil acidification, soil biodiversity loss, soil sealing, soil compaction, and depleting soil moisture. Apart from soil salinization, these threats are prevalent in the soils of Nepal on different scales (Table 12.1). Further, new issues regarding soil are arising in Nepal; for instance, abandoned agricultural soil, shallow rooting depth due to erosion and rock outcrops, microplastic pollution, soil biodiversity change, and pesticide soil pollution, among others.

The government of Nepal has endorsed some of these soil issues in national policy documents. The National Agriculture Policy (NAP) 2004 in Nepal included in the Agriculture Perspective Plan (APP 1995–2015) is a cornerstone shaping agriculture strategies and policies in the country. The policy mostly focused on increasing agricultural production through agricultural input (seed and fertilizer) maximization and identified soil issues such as erosion, nutrient mining, and chemical pollution by agrochemicals as key problems of land degradation requiring attention. At present, the Agriculture Development Strategy (ADS 2015–2035), a

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Table 12.1 Major soil threats of Nepal

Agro-ecological region	Soil threats	Severity	References
Tarai	Low soil organic carbon—more than 95% croplands are below the critical level of soil organic carbon concentration (i.e., 2%)	High	(Yadav et. al. 2000; Ojha et al. 2019)
	Soil acidification in the Eastern region (more than 55% cropping area is affected by soil acidity) and soil alkalinity in the Western region	High to moderate	(Bajracharya and Sherchan 2009; Brown et al. 2006; Gautam and Chettri 2020)
	Soil sealing and compaction (due to heavy tillage equipment, low organic inputs, less residue recycling, and continuous use of chemical fertilizer)	Moderate	(Shrestha and Kafle 2020; Takeshima and Justice 2020)
	Flooding and sedimentation	High	(Dingle et al. 2020; Kafle et al. 2020)
	Nutrient imbalance	Moderate	(Regmi et. al. 2002; Brown et al. 2006; Karna and Bauer 2020)
	Lowered water table	Low to moderate	(Gautam and Prajapati 2014; Nepal et al. 2021)
	Arsenic toxicity in ground water (used as drinking and irrigation water)	Moderate	(Maharjan et al. 2007; Thakur et al. 2010)
Siwaliks/ Mid-Hills	High rate of natural erosion due to sloping terrain and fragile geology	High	(West et al. 2015)
	Soil nutrient mining due to erosion, less input, and no residue recycling	Moderate	(Chalise et al. 2019, 2020)
	Depletion of spring water sources (used as drinking and irrigation water)	Moderate to high	(Adhikari et al. 2020; Thapa et al. 2020)
	Low quality of organic manure (only contains 0.3 to 0.7% N)	Moderate	(Gami et. al. 2001; Karki 2003; Maskey and Mihara 2020; Ojha et al. 2014)
	Abandoned croplands (soil properties change in a degraded abandoned land and natural vegetation succession)	High	(Chaudhary et al. 2020; Paudel et al. 2018)
	Microplastic pollution	Low to moderate	(Yukioka et al. 2020)
	Agro-chemical soil pollution	Moderate to high	(Atreya 2008; Bhandari 2014; Pokhrel et al. 2018)
	Low water retention capacity (most soils are sandy loam)	Moderate	(Bajracharya and Sherchan 2009)
High Hills/ Himalayas	Shallow soil depth (rock outcrop)	High	(Baumler and Zech 1994)
	Microplastic pollution	Low to Moderate	(Napper et al. 2020)
	Rooting depth limitation	High	(Sitaula et al. 2004)
	Slow decomposition of soil organic matter due to low temperature and low soil moisture	High	(Drollinger et al. 2017; Sitaula et al. 2004)
	Low soil nutrient status	Moderate to high	(Drollinger et al. 2017)
	Glacial and wind erosion	Moderate	(Gabet et al. 2008; Wagnon et al. 2013)
	Soil pollution (toxic trace elements, persistent organic pollution, poly-aromatic hydrocarbons) in the upper Himalayas	Low to moderate	(Guzzella et al. 2011; Tripathee et al. 2018, 2016)

long-term strategy by the Nepal government to increase agricultural productivity and sustainability, identifies soil sustainability as a key indicator of sustainable agriculture growth, though many aspects of the soil threats listed in Table 12.1 are overlooked in the ADS. Thus, policy reform and intensive soil conservation programs should be a national priority.

12.2 Soil Issues/Threats Frame

Different soil threats result from either being overlooked or exist as inherent or emerging threats in the soil system (Fig. 12.1). These issues need to be addressed in government developmental and research programs and might require reforming the existing policy supported by research findings.

12.2.1 Inherent Issues

Some of the soil issues have arisen due to inherent soil characteristics. These issues can be attributed mostly due to natural causes, but human interventions accelerate the problem. These soil issues have been identified at a national scale and are widely reported in government and research reports.

Soil erosion: Due to steep topography, soil erosion is one of the inherent soil issues of Nepal. The natural rate of soil erosion is higher than the accelerated rate of soil erosion (West et al. 2015), and forestland is more degraded than cropland in Nepal (Chalise et al. 2019). This is one of the most discussed soil issues, and policymakers are well informed about it. Recent studies have shown that rates of erosion are increasing which requires proper care and management (Chalise et al. 2019). This scenario demands effective soil conservation work in the affected areas.

Soil acidity and alkalinity: These issues particularly arise due to the acidic/alkaline nature of parent materials. However, the imbalanced use of chemical fertilizer also accelerates the soil acidity, seen particularly in the Tarai region. Refer to Chaps. 7 and 8 for the cause and remedies of soil acidity and alkalinity issues in Nepal.

Flooding and sedimentation: Every year flooding and sedimentation degrades thousands of hectares of fertile land in the Tarai region. This is a year-round problem that is widely

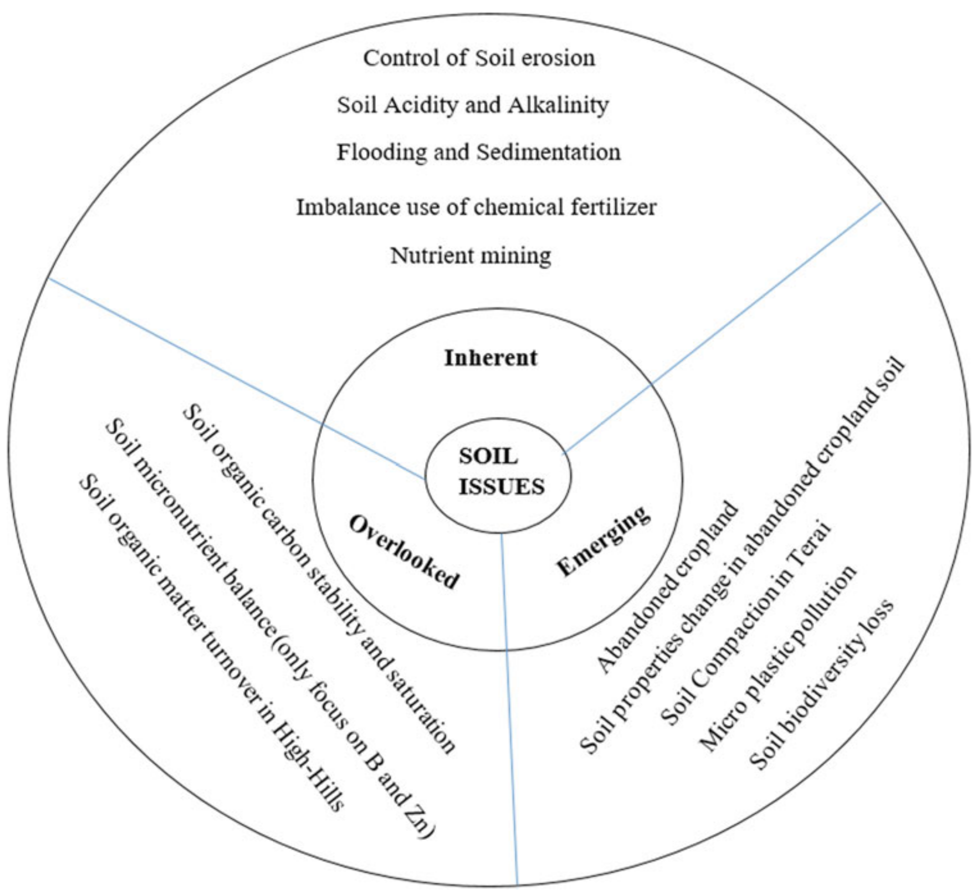

Fig. 12.1 Framing of soil threats or soil issues within the Nepalese perspective

reported in several studies and reports. The re-utilization of flooded or sediment-covered land is our prime concern. Most often than not, it is impossible to prevent floods, however, we need to develop strategies for the restoration of these lands.

Plant nutrient imbalance and nutrient mining: There is heavy nutrient mining in Nepalese soils due to continuous cropping without applying the recommended fertilizer amount in the field crops. Fertility management practices by farmers either rely only on chemical input or insufficient manure with low nutrient quality. This further deepens the nutrient imbalance in the field and triggers nutrient mining. Refer to Chap. 8 for the cause of soil fertility imbalance and its management through integrated nutrient management strategies.

12.2.2 Overlooked Issues

Soil organic carbon stability and saturation: The importance of SOC has recently been identified in the Agriculture Development Strategy (ADS 2015 to 2035). Previously, the Agriculture Perspective Plan (APP 1995 to 2015) had been endorsed by the government, which primarily focused on the chemical fertilizer distribution system and chemical fertilizer subsidy scheme and failed to integrate organic fertilizers into the subsidy program. Due to increased focus on chemical fertilizer and insufficient replenishment of organic fertilizer lost due to tillage or soil organic matter (SOM) oxidation, the SOM level of the cropland sharply declined to near 1% (ADS 2015). This decline has now been recognized in the ADS, which has set a target of increasing the level of SOM to 4% in 10 years' time as a key sustainability indicator. The target of reaching 4% SOM in 10 years is not supported by any study, and for this, we need to investigate the SOC sequestration potential of soils by studying the SOC saturation point of different soil types across agro-ecozones. The SOC saturation potential of Nepalese soil is still unknown, and thus, ADS overlooked the SOC sequestration capacity of these soils.

Micronutrients: Micronutrient use has now been realized in vegetable-based farming systems, but the focus is only on B and Zn (Shrestha et al. 2020a, b). Andersen (2007) and Panday et al. (2018) identified B, Zn, and Mo as deficient in Nepalese soils and limiting agricultural production. Since then, most studies have focused on these three micronutrients. However, there are other soil micronutrients such as Fe, Cu, Co, Ni, and Mn that also require extensive study in Nepal and should be included in future plant nutrient management research and programs.

Soil organic matter management in the High Hills: The regional distribution of organic matter seems to be higher in the High Hills, but low temperature and less soil moisture retard the decomposition rate. Low decomposition results in less availability of plant nutrients and is linked to low soil fertility and productivity. Research is needed to find ways to increase the decomposition rate to make nutrients available from the organic matter in the soil, including the rate of mineralisation from organic and inorganic sources.

12.2.3 Emerging Issues

Abandoned cropland: Of the 27% cultivable areas of the country, around one-third of the land is abandoned (Gautam 2004). Cropland abandonment is now an emerging and alarming problem in Nepal due to internal migration and labor out-migration (Ojha et al. 2017; Sunam and McCarthy 2016), causing significant land degradation problems, including soil fertility decline, soil organic matter reduction, gully erosion, mass movement, loss of topsoil, and vegetation cover reduction, all of which arise in the first few years of abandonment (Chaudhary et al. 2020; Jaquet et al. 2015; Khanal and Watanabe 2006). Similarly, the abandoned land goes to secondary natural succession after few years (Pathak 2015). As such, an extensive study is necessary to understand the changes in soil properties that occur with the passage of time in abandoned land, along with the ecosystem co-benefits of secondary natural succession. Also, retrospective and prospective econometric studies are necessary to understand the impact of abandoned cropland on food security along with proper re-utilization pathways.

Soil compaction in Tarai: Soil compaction in Tarai results from the introduction of heavy machinery for agricultural operation (Takeshima and Justice 2020). In addition, low levels of soil organic carbon, no or low residue recycling, and continuous use of chemical fertilizers further trigger soil compaction. Low carbon in soil reduces the bulk density, low residue recycling lowers soil organic matter, and continuous use of chemical fertilizer increases soil cementation. All of these factors coupled with the weight and drag force of heavy equipment result in massive soil structure and hence soil compaction. Compact soil restricts plant root growth and causes low infiltration, low microbial activity, and low acquisition of plant nutrients, which directly retards crop productivity. This issue is scantly reported in technical reports, and thus a widescale survey on soil compaction in the Tarai is necessary to understand the extent of the compaction.

Microplastic pollution: In the last decade, there has been a shift to a vegetable-based cropping system from a rice–wheat cropping system in Nepal (Shrestha et al. 2020b). Plastic mulching is common in vegetable farming and is commercially growing (Atreya et al. 2019). Plastic mulching is an effective measure to control weeds, temperature, and soil-borne pathogens. However, the improper management of plastic can lead to microplastic pollution. Some of the studies report traces of microplastic in the higher elevations of Nepal (Napper et al. 2020), and hence, future studies should examine the spatial extent of microplastic pollution in different eco-zones in Nepal.

Soil pollution (*Heavy metals, pesticide pollution, and organic pollutants*): Insecticides were first introduced to Nepal in 1954 when the Malaria Eradication Program was launched (Aryal et al. 2016; Sharma et al. 2012). Thereafter, many types of insecticides, fungicides, and herbicides have been imported. The highest amount of plant protective chemicals is applied to vegetable crops, including cereal crops. Recognized intensively vegetable-cultivated pockets in Nepal are Thimi of Bhaktapur, Nallah of Banepa, Kabhre, Panchkhal Valley of Kabhre, Trishuli of Nuwakot, and Naubishe of Dhading. These pockets supply vegetables to the Kathmandu valley. Later, Bara, Makawanpur, and many districts of the Tarai adopted vegetable farming to supply Kathmandu, Pokhara, and other densely populated cities. These vegetable-growing farmers have been using both organic and inorganic pesticides on their crops, including organochlorines, organophosphates, carbamates, formamidines, thiocyanates, organoioctines, dinitrophenol, synthetic pyrethroids, and many types of antibiotics, fungicides, and herbicides. When sprayed onto plants, 99.99% of these chemicals are washed onto the soil (Pimentel 1995). When the sprayed chemicals fall onto the ground they affect the beneficial microorganisms that are available on the soil surface. They can also enter the soil when the treated plant residues are incorporated into the soils. Some of these chemicals, in the form of dust or granules, are applied directly to the soil (Edwards 1966). The spray also enters the plant through leaf cuticles and the stomata (Mitra and Raghu 1998).

Pesticides, fungicides, and herbicides are increasingly applied to protect crops in Nepal, and it has become a habit for farmers to spray chemicals to protect their plants whether there are pests or diseases infestations. In general, farmers are advised to spray 2–3 times per crop season but farmers have been reported to spray between 2–10 times (Sapkota et al. 2020). Therefore, the surrounding environment of the intensive vegetable-cultivating pockets of Nepal is highly contaminated (Atreya 2008; Bhandari 2014; Pokhrel et al. 2018; Sharma et al. 2012). Obsolete pesticides and persistent organic pollutants are contaminating chemicals that have been brought to the country and kept in storehouses in various places across the country (e.g., Amlekhgunj) rather than being used, and because of unscientific storage methods, some of them have leaked into the soil and the open environment (Shah and Devkota 2009). Residues of these chemicals have been found above the tolerable limits in Nepalese soils (Kafle et al. 2015). More dangerous persistent organic pollutants such as organochlorine pesticides, Polycyclic aromatic hydrocarbons have been found in the soils of Kathmandu valley (Pokhrel et al. 2018). Sharma et al. (2012) mentioned that significant levels of pesticides have been found to contaminate vegetable-cultivating soil. Now is the time to start assessing soil and human health linked to pesticide residue levels in the soil. There is also an urgent need to set national standards/critical limits of soil pollution parameters to monitor our soil health status.

12.3 Future Perspectives

Soil biodiversity map: Occupying merely 0.1% of total global land area, Nepal is 31st in the world and 10th in Asia in terms of natural biodiversity (MoAD 2017). This indicates the richness of biodiversity in Nepal but does not include soil biodiversity. However, this national assessment of biodiversity suggests the potentiality of soil biodiversity richness too. To date, scattered studies have been conducted on soil bacteria, fungi, and earthworms. Most of them are related to soil pathogens that are harmful to crops. Studies related to soil microorganisms are limited to rhizobium cultures and their effect on legume production. However, the availability of different beneficial organisms and their potential needs to be studied and mapped. A national inventory of soil biodiversity is necessary to understand its status.

Establishment of soil study reference sites: The soils of Nepal are young, dynamic, and developing. Nepal could be a potential study site for researchers around the world to study the dynamic soil formation processes of pedogenesis. For this to occur, identifying the reference landscapes and establishing a reference study site is necessary. Inceptisols and Entisols, which are often referred to as young soils, are abundantly available in Nepal, and they undergo biological-physical–chemical changes to develop into other soil types. Researchers can harness the study of these active soil formations. Non-volcanic Andisols are also present in Eastern Nepal (Baumler and Zech 1994), and this presents Nepal as a potential place for the study of the dynamics of soil-forming factors with different soil types.

Soil atlas of Nepal: We need to make soil understandable to the public. A non-technical soil map is necessary to advocate the importance of soil resources to policymakers, farmers, and agro-entrepreneurs. Nepal joined the Global Soil Partnership program of the Food and Agriculture Organization of the United Nations and is now working to prepare the soil atlas of Asia. This atlas is necessary to scale up on a national scale and will be an important national document for planning and public education. It will be an important visual document that provides information about soils in plain language and an important resource for raising awareness to protect the soils.

12.4 Conclusion

Nepal generally has a rich body of policies for addressing general agricultural problems as well as different levels of soil-threatening conditions; however, there exists a wide gap between policy formulation and its implementation. In addition, soil biodiversity and soil micronutrient management, among other issues, were overlooked from a research point of view. Hence, the future of soils in Nepal should depend not only on policy reform and intensive soil conservation programs but on more data and facts that can be produced for evidence-based and effective implementation. All three levels of government—federal, provincial, and local—as well as the communities themselves, should give priority to the future of our soils and our food system.

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