Short Communication

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Land Degradation Neutrality: Indian Examples

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Discussions around climate change at times ignore soils, even though the major soil-forming factor is the climate (Bhattacharyya *et al.* 2014). Because land mass is fixed in quantity, there is an ever-increasing competition to control the fixed quantity of land resources in terms of their services for living organisms. This brings huge pressure on carrying capacity of land. The land area is dwindling due to many reasons, particularly due to natural and anthropogenic degradation (Bhattacharyya 2014). Therefore, it is imperative to save our motherland by focusing on land degradation neutrality (LDN), whereby the finite land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems. Since the land and/or soil degradation can cause social problems leading to poverty and malnutrition, the implementation of LDN requires the involvement of multi-stakeholders with adequate support from the national and regional governments.

The target audiences are individuals / organizations in positions of influence to improve or transform land management practices and land use planning at different scales. For Indian conditions, this might include i) Each citizen, ii) The farmers (do's and don'ts), iii) Government organizations (implementation), iv) non-government organizations (NGOs), v) Universities (academia) with special reference to agricultural universities, and, vi) Research institutes (councils).

Indian examples

Indian perspective for LDN might consider the recommended doses of management practices of the national agricultural research system, which maintains the rice-wheat cropping system with special reference to the Indo-Gangetic Plains (Bhattacharyya *et al.*2004), the process of natural degradation of land and soils in the drier tracts of India and can also deliver multiple benefits from soil organic carbon (Chivhane and Bhattacharyya 2010; Banwart *et al.* 2014; van Noordwijk *et al.* 2015).

The soils of the semi-arid tropics (SAT), in general, are calcareous and sodic either at the subsoil regions or throughout the soil depth (Bhattacharyya *et al.* 2016a). The presence of pedogenic calcium carbonate (lime nodules: $CaCO_3$: PC) that can only be distinguished from pedorelict calcium carbonate as nonpedogenic carbonates (NPC) by the soil thin section studies, is very common in major soils of the SAT regions of India (alluvial soils of the Indo-Gangetic Plains, ferruginous soils and shrink-swell soils) under SAT (Bhattacharyya *et al.* 2016a, 2016b). Under SAT environments, water loss through evapotranspiration is considered the primary mechanism in the precipitation of PC, while temperature plays an important role in controlling the water flow in the soil. The formation of pedogenic calcium carbonate results in the concomitant development of sodicity in soils. However, the development of sodicity is not realized yet in desert soils due to their sandy textural class, ensuring better leaching of bicarbonates, and therefore pedogenic calcium carbonate is generally observed at greater depth. In the loamy and clayey textured soils, the leaching of bicarbonates is slow; therefore, pedogenic calcium carbonate and sodicity develop in the upper horizons. Such pedogenic processes are common in tropical, ferruginous, clayey, and smectite-rich mineral soils (Alfisols) in India. The formation of pedogenic calcium carbonate in these soils is observed due to the influence

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of the present semi-arid climate in these soils making these Alfisols calcareous, unlike their counterparts in the humid tropical climate. The PCs in such soils are mainly concentrated as lubinites formed only when the soil solution is supersaturated with calcium carbonate in semi-arid environments. Therefore, soil texture has a vital role in accumulating carbonates in addition to the arid climate.

Soil inorganic carbon (SIC) sequestration as pedogenic calcium carbonate in soils impairs soil quality and productivity. The formation of pedogenic calcium carbonate in arid climate increases the pH (making these soils alkaline) and the relative abundance of Na^+ ions in both soil exchange sites and solution. Excess Na^+ ions cause dispersion of the fine clay particles. The formation of pedogenic calcium carbonate creates a chemical environment conducive to facilitating the deflocculation of clays which translocate down the depth of soils. Therefore, the formation of pedogenic calcium carbonate and the clay illuviation (downward movement of clay in the profile) are two concurrent and contemporary pedogenic events, resulting in increased sodium concentration which increases ESP and pH with depth. The formation of PC with concomitant development of ESP in sub soils ultimately impairs the hydraulic properties of soils and modifies the microstructure of soils. The formation of pedogenic calcium carbonate in alluvial (129 kg ha^{-1} yr^{-1}), shrink-swell (37.5 kg ha^{-1} yr^{-1}) and red ferruginous (30 kg ha^{-1} yr^{-1}) soils of semi-arid climate is the major reason for soil/land degradation which requires immediate attention for addressing issues of LDN in Indian perspective.

Land Degradation Neutrality (LDN) is achieved if further degradation is balanced by reversal of degradation, elsewhere, in the same land type, by restoration or rehabilitation. A land resource inventory is the pre-requisite to assess the extent and remedy of LDN. Two case studies are mentioned here to address the LDN, one in high rainfall areas and the other in the semi-arid tropics in India (SAT). These observations can act as models to further LDN in similar regions in other parts of India and elsewhere.

Model I (Humid tropical areas in India)

Spatially-associated red (Alfisols) and black soils (Vertisols and their intergrades) (Bhattacharyya *et al.* 2014, 2015) as distinct entities are common in the Western Ghats and Konkan, Maharashtra (Bhattacharyya *et al.* 2019). These soils are often referred to as laterites. The terms 'red' and 'laterite' have led to controversial opinions. Contrary to the general belief that such soils are difficult to grow crops, these associated soils in Konkan, Maharashtra, are cultivated profitably for various agricultural and horticultural crops besides forestry with appropriate conservation measures. Out of many horticultural crops, the Alphonso variety of mango is one of the most popular and preferred crops for planting in Konkan, grown on these associated soils, often referred to as laterites.

Konkan has an area of 0.3 million ha under laterites, which are formed due to exposure of red soils over time to convert them into a chunk of hard material. These areas, locally known as *jambha katal*, are usually kept fallow. Some of these areas have profitably been utilized for Alphonso mango cultivation using the scientific methods and the wisdom of local farmers. It seems probable that after the initial drudgery of establishment in the hard rock, these trees receive a consistent supply of nutrition from the calcium (Ca)-rich zeolitized basalts. Ca-rich zeolites are present in the sand fractions to the tune of 2-3%. It is quite probable that the hard basalts and their weathered counterparts (*murram*) should contain more zeolites in providing nutrition to the young mango plants. Earlier studies on the mineralogical make-up of the weathering rinds of basalt indicated the presence of Ca-rich smectite minerals, even in a relatively hard basaltic rock. Such examples provide two-fold benefits: the expansion of cultivable areas under horticulture (mango) and the profitable use of otherwise unutilized fallow lands. Knowledge of geology and soil minerals can help the natural resource managers combat land degradation (Bhattacharyya *et al.* 2019).

Model II (Semi arid tropical, SAT, areas in India)

The NARS has been doing an excellent job for many years in the SAT regions of India (Bhattacharyya *et al.* 2016b). As for which, the soils in the SAT region are showing resilience in spite of a hostile pedo-environment (Bhattacharyya *et al.* 2015); otherwise, these soils could have been infertile and perhaps irreparable. This was demonstrated with red-black soil association in the SAT to understand the reduction of soil quality due to chemical soil degradation.

People talk about soils and their uses and abuses; people rarely talk about the fate of soils/minerals in case we follow the same set of agricultural management practices. Can we predict the fate of our soils in the future? With the help of a soil and mineral information system, can we predict future soils and landscape scenarios using various predictive models (Bhattacharyya *et al.* 2014)? Can we foresee the soils of tomorrow using the soils/soil mineral database? With temporal changes, using carbonate minerals in soils of the SAT, changes in soil properties for future are projected. Two probable scenarios were considered, such as business as usual (BAU) and the management intervention. Usually, carbonate minerals start forming pedogenically in the sub-surface. If the pedogenic carbonate formation process in soils continues at the existing rates mentioned above, these minerals will gradually engulf the entire profile with increased aridity. This process results in poor drainage and very high bulk density, making these SAT soils highly alkaline, completely impervious, and extremely hard to be useful for crop production. Soils with such lands will look barren, without much vegetation left on them (Figure 1, on the left). Fortunately, these soils have tremendous resilience (Bhattacharyya *et al.* 2015) and respond to management interventions. Appropriate management practices bring these degraded soils back to normalcy, making the agriculturally productive. Such model examples can help to make land degradation neutrality possible in many areas of SAT, India as shown in the figure 1(on the right) (Bhattacharyya *et al.* 2015, 2016b) with lush green vegetation.

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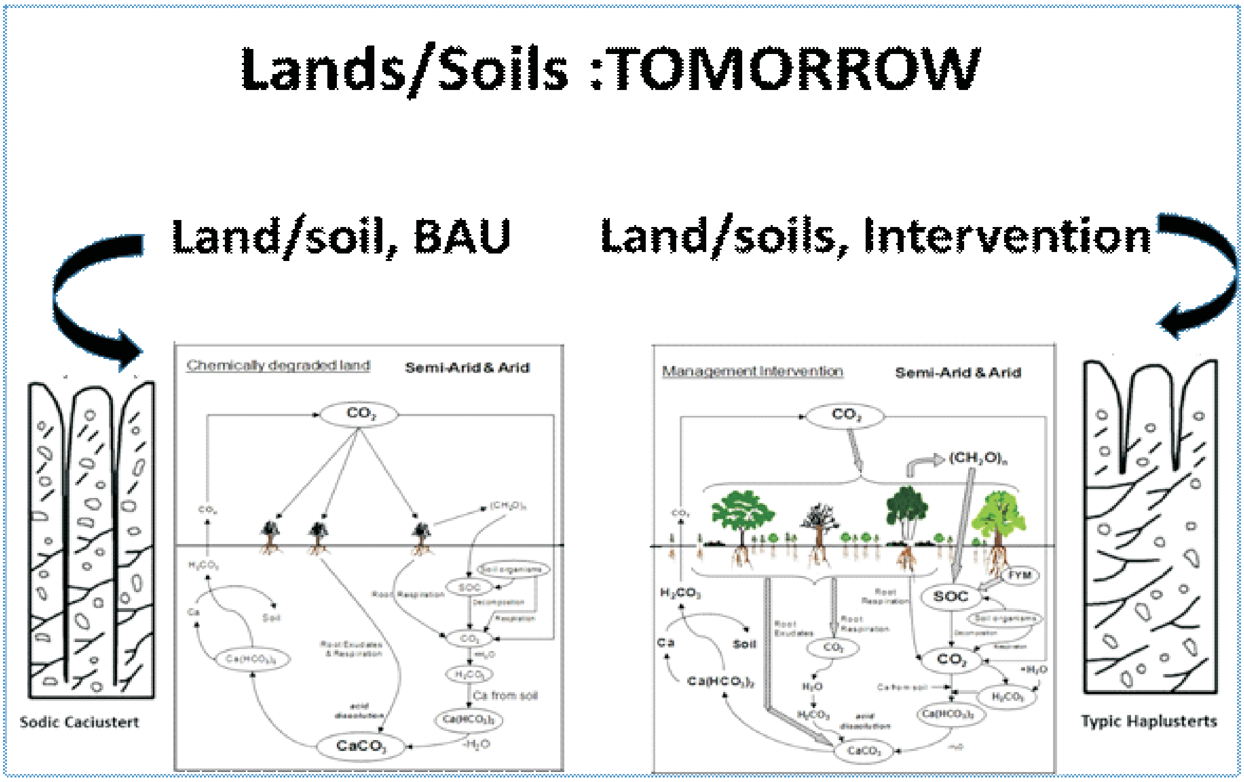

Fig.1. Schematic presentation of degraded soils (highly sodic and calcareous black soils showing very deep cracks extending almost up to 1.5 m depth : Sodic Calciusterts) of tomorrow in SAT, India in absence of management intervention (BAU, Business As Usual). Appropriate management intervention will bring back normalcy in these soils (normal black soils: Typic Haplusterts).