15 Land Degradation Neutrality in Coastal India: Case of Mobius' Strip Linking Pedodiversity and Biodiversity

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Abstract

Land degradation neutrality (LDN) seems to be scale-sensitive depending on various requirements. Although pedodiversity and biodiversity appear to be non-converging, however, appropriate scale used to collect both soil and biodiversity data may help to comment better on this mobius relation. Pedodiversity and biodiversity are both important while adopting LDN methodology. Since land use is dynamic therefore LDN, pedodiversity and biodiversity should be considered holistically to suggest sustainable land use planning for addressing various developmental goals. Present attempt addresses a few such issues with Konkan, Maharashtra, India, as mode.

Keywords

Land degradation neutrality (LDN) · Pedodiversity · Biodiversity · Mobius · Land use planning · Konkan

15.1 Land Degradation Neutrality (LDN)

Discussions around climate change seldom refer to soil, even though the major soil forming factor is climate. Because land mass is fixed in quantity, there is an ever-increasing competition to control land resources in terms of their services for the living organisms. Land area is dwindling due to many reasons. The main reason is its degradation, both natural and anthropogenic. It seems, therefore, logical, to save our motherland and focus on LDN whereby the amount and quality of land resources, necessary to support ecosystem functions and services and to enhance food security,

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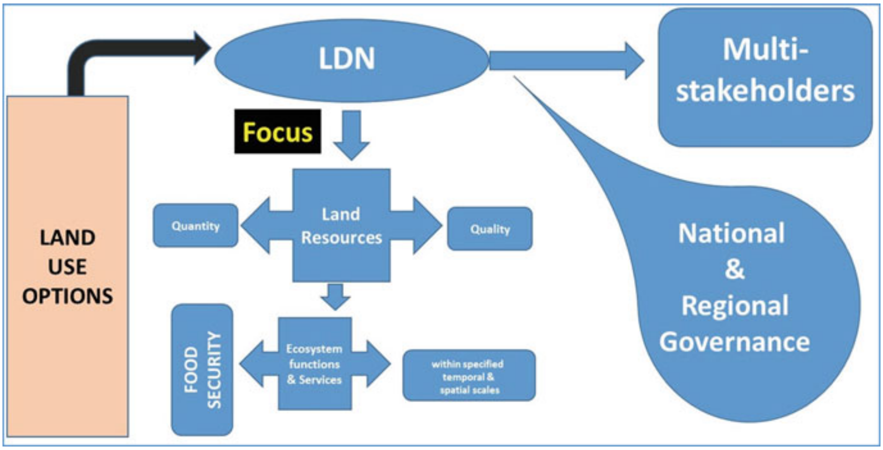

Fig. 15.1 LDN and land options: a schematic diagram (Bhattacharyya et al. 2020)

remain stable or increase within specified temporal and spatial scales and ecosystems. Three case studies, one in high rainfall areas and the two in the semi-arid tropics (SAT), are showcased to address the LDN. These observations can act as model land use options to further LDN in similar areas in other parts of the world including India. Such steps to adopt LDN policies will render land resources to be protected and restored for promoting sustainable use of terrestrial ecosystems including forests since these procedures help reversing land/soil degradation and to combat climate change. Major soil (and landscape) forming factor is climate (Jenny 1941), and therefore, the issues of climate change always involve soils/lands; so far its effect on terrestrial ecosystem is concerned.

LDN assists to keep the land resources stable and may also improve its quality within specified temporal and spatial scales and ecosystems. Since land and/or soil degradation has the potential to cause social problems leading to poverty and malnutrition, the implementation of LDN requires involvement of multi-stakeholders with adequate support of the national and regional governments (Fig. 15.1).

LDN is directly related to land use and land use is related to quality of land/soils which is diverse in nature. This diversity of soil termed as pedodiversity is linked to biodiversity to determine the present and suggested land use. Therefore, to achieve LDN there should be a mutual convergence of pedodiversity and biodiversity to realize its (LDN) success. Do pedodiversity and biodiversity really converge? The present effort delves in this direction citing selected studies in coastal Maharashtra, India.

15.2 Achieving LDN

LDN could be achieved by balancing degradation for which major requirement is the information on soil and land. Soil resource inventory for the entire country (Bhattacharyya et al. 2009), details of soil information system, and other information are available (Bhattacharyya et al. 2021a, b). These datasets provide various case studies in different ecosystems of the country which act as model for replicating in similar situations.

Target audiences for LDN include individuals/organizations which may influence for improving or transforming land management practices and land use planning at different scales. For Indian situations, this may well include (i) each and every citizen, (ii) the farmers (do's and don'ts), (iii) government organizations (implementation: land use for agriculture a state subject, conflict of interest!), (iv) nongovernmental organizations (NGOs), (v) universities (academia with special reference to agricultural universities (Bhattacharyya et al. 2018a, b; 2021c), and (vi) research institutes (Councils etc.).

15.3 Soil Diversity

It has long been recognized that biodiversity can be the mechanism behind the performance of an ecosystem, particularly in communities of aboveground organisms. In soils below ground, however, the functioning of biodiversity is not well understood. Soils are highly diverse. It has been estimated that 1 g of soil contains up to one billion bacteria cells consisting of tens of thousands of taxa, up to 200 million fungal hyphae, and a wide range of mites, nematodes, earthworms, and arthropods. Besides, soils contain minerals many of which act as modifiers to control the quality of soils affecting its ecosystem service. Among many parameters soil formation is controlled by climate and parent materials (rock systems) which vary in different ecosystems to give rise to different soils and bio diversity. Most of such soil diversity parameters are hidden beneath the earth surface which requires expert knowledge of scientists (pedologists, earth scientists, and others) to decode nature's signatures. Soil diversity is thus intimately linked to aboveground biodiversity. Diversity is widely considered as synonymous to difference. Various factors cause differences in soils. These could be natural and/or anthropogenic. To understand the diversity of soils, the knowledge on the potential of soil resources and its limitations, different kinds of methods used for management of these soils either for agriculture and non-agriculture purposes is vital (Bhattacharyya 2021a).

15.3.1 Soil Diversity in Coastal India: Konkan, Maharashtra

Konkan, Maharashtra in India is different from other parts of Maharashtra and also from India in terms of variation in geology, climate, soils, and environment (Fig. 15.2). Konkan covers an area of nearly 30 lakh hectares and represents a

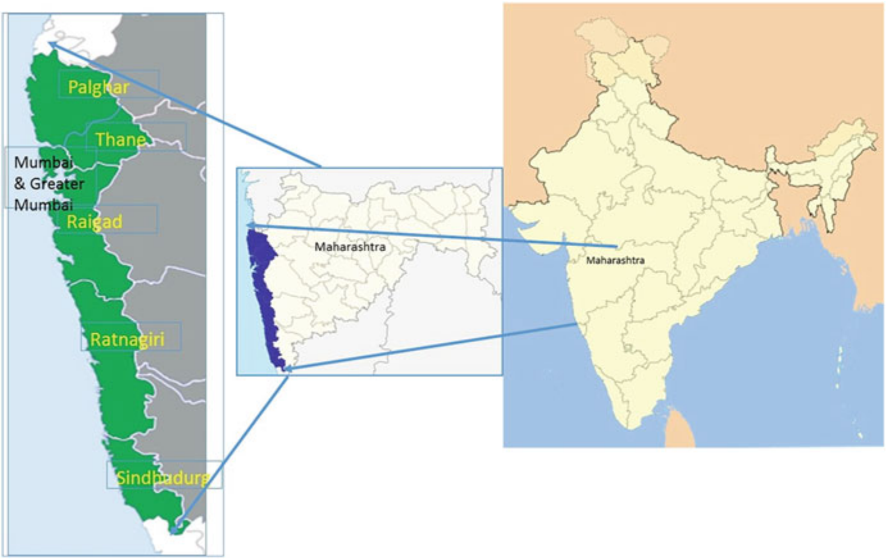

Fig. 15.2 Study area in coastal (Konkan) Maharashtra, India

coast line of 720 km stretching south of Gujarat to north of Goa. This basaltic terrain receives an average rainfall of 2500–4000 mm. The northern part of Konkan comprising of part of Raigad, Thane, and Palghar bear some similarity of typical basaltic landscape like central Maharashtra and Vidarbha. This might be due to the fact that Palghar and Thane are on lower elevation and has more breadth (distance between Arabian sea and the Western Ghats) resulting in the formation and persistence of deep black soils as is common in other parts of Maharashtra. On the contrary, southern Konkan gradually narrows down south to Goa and represent undulating landscape with steep slopes causing severe soil erosion. This happens in spite of the fact that south Konkan has more vegetation. This is the reason why south Konkan is represented by relatively shallow red soils and at places these soils are deep to be qualified as Alfisols. Coastal ecosystem is vulnerable (Bhattacharyya 2021a, b, Bhattacharyya et al. 2021c). The soil diversity in Konkan, Maharashtra, as a part of huge stretch of Indian coast measuring 7517 km is briefed in the following.

15.3.2 Soil Diversity: Its Quantification

The soil diversity index (SDI) was assessed using the concept of occurrence of soil family (Soil Survey Staff 2014) per unit area (Bhattacharyya et al. 2013). To estimate the pedodiversity indices (PDI), various measures were used. The area of a taxon (Soil Survey Staff 2014) in each map unit was calculated by multiplying the component percentage of the taxon by the area of the map unit (Bhattacharyya et al. 2009). The total area of each taxon from all the states and Union Territories were extracted from the existing database. PDI were calculated based on the area abundance of the taxa for India, for zones and for various states of India. Three types of indices were considered in this study: richness (S) (number of soil taxa), and diversity (H') (considers both richness and evenness into account or, in other words, the higher the richness and evenness, the higher the diversity) (Guo et al. 2003). Shannon’s diversity index (H') (Shannon and Weaver 1949; Magurran 1988) is also estimated to find out pedodiversity following Eq. 15.1:

$$H' = -\sum_{i}^{S} p_i \times \ln\ (p_i) \qquad (15.1)$$

where S is taxa richness; p_i is the proportion of ith taxa; p_i is estimated by n_i/N, where n_i is the area covered by ith taxa; and N is the total area studied. Shannon diversity index (H') was estimated at different levels of soil taxa following US Soil Taxonomy such as orders, suborders, great groups, subgroups, and soil families (Soil Survey Staff 2014).

Besides, Simpson’s index of dominance (D_s) was also estimated to assess the dominance using Eq. 15.2:

$$Ds = \sum \{p_i(p_i - 1)\}/\{N(N-1)\} \qquad (15.2)$$

where p_i and N are parameters as mentioned above.

15.3.2.1 Taxon Richness

The total number of soil orders found in Konkan region is four, i.e., Entisols, Inceptisols, Alfisols, and Vertisols. Vertisols are reported in the northern districts of Raigad and Thane only. Similarly, Alfisols are not reported in the northernmost district of Thane. Thirteen soil subgroups are found in Konkan region. Raigad (10) district has the highest number of soil subgroups followed by Ratnagiri (9), Thane (8), and Sindhudurg (5). Of the 33 soil series identified in Konkan region, Ratnagiri (23) had highest taxon richness followed by Sindhudurg (17) and Raigad and Thane (15 each) (Bhattacharyya et al. 2020).

15.3.2.2 Shannon Diversity

At the taxonomic level of soil series, the diversity (H': Shannon diversity index) was maximum in Ratnagiri district followed by Sindhudurg, Thane, and Raigad (Fig. 15.3), whereas at the level of soil suborder, the diversity was maximum in Thane district followed by Raigad, Ratnagiri, and Sindhudurg (Fig. 15.4). And as expected, exactly opposite trends were found in terms of taxa dominance (Simpson’s index) for both the taxonomic levels (Figs. 15.5 and 15.6).

The soil diversity obviously increases as lower levels in soil taxonomy (Soil Survey Staff 2014) are explored. This is corresponding to an earlier study at the national level in Indian (Fig. 15.7; Bhattacharyya 2016). Interestingly, the diversity

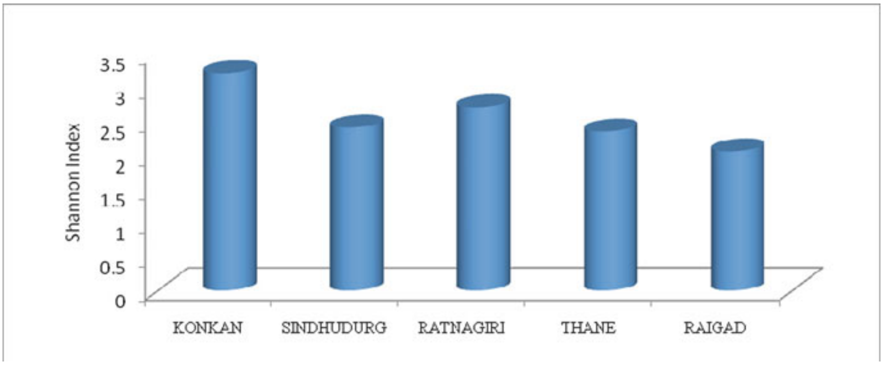

Fig. 15.3 Shannon diversity index (H') in different districts of Konkan region and for the region at the taxonomic level of soil series

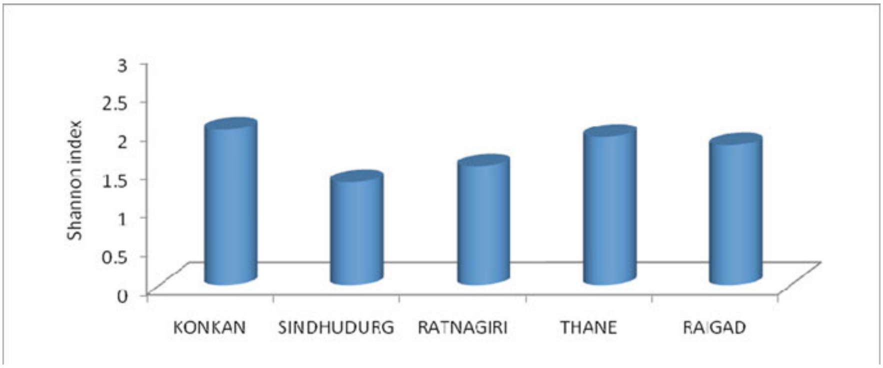

Fig. 15.4 Shannon diversity index (H') in different districts of Konkan region and for the region at the taxonomic level of soil subgroup

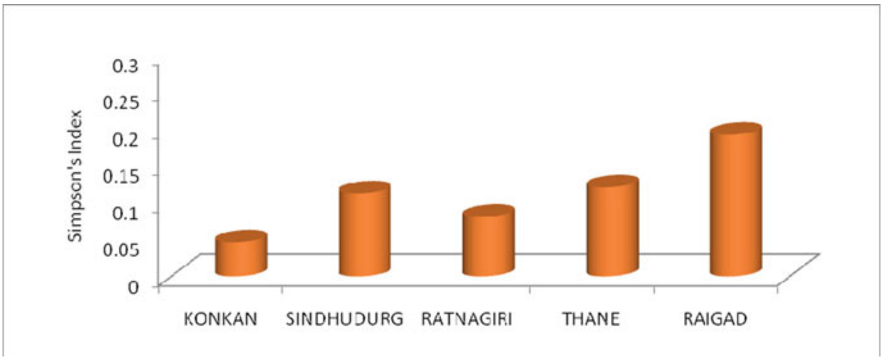

Fig. 15.5 Simpson's index of dominance (D_s) in different districts of Konkan region and for the region at the taxonomic level of soil series

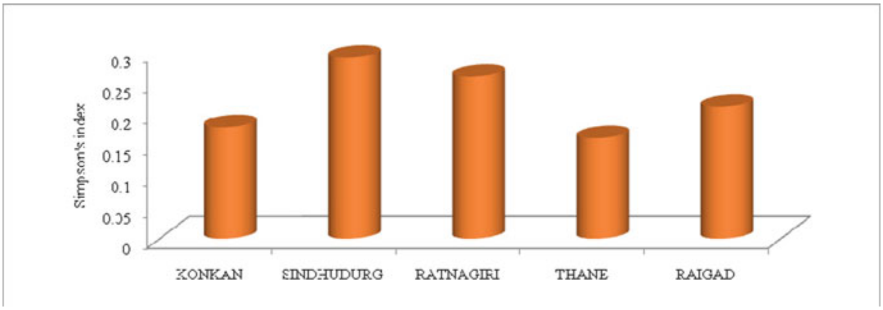

Fig. 15.6 Simpson's index of dominance (D_s) in different districts of Konkan region and for the region at the taxonomic level of soil subgroup

does not increase linearly for Konkan under comparison in the present study. The diversity at subgroup level was highest in Thane district, whereas at the (soil) series level, it was Ratnagiri district that registered the highest value. These findings in corroboration with the earlier national level study (Bhattacharyya 2016) necessitate careful documentation of all taxonomic levels of soil classification which demands a new dimension of research to make an estimate of the number of soil series which can be obtained for the entire country as a whole (Bhattacharyya 2016) using pedo-transfer functions.

The pedodiversity index (PDI) (H') estimated at the level of soil subgroups and the areal extent of various zones in India (Bhattacharyya et al. 2013) indicates a trend between areas of different zones studied versus pedodiversity (Fig. 15.8). The northeastern, eastern, and southern zones are showing more pedodiversity which support commonly found large biodiversity in these three zones; however, this relation is not in line with the previous results of pedodiversity for the USA (Guo et al. 2003) and the world (Ibañez Marti et al. 1998; MacBratney et al. 2000). This might be due to the fact that PDI has been related with soil subgroups unlike the series used in case of the USA. Pedodiversity (Beckett and Bie 1978) and biodiversity (Kilburn 1966) was reported to have a strong species-area relationship. To justify area dependency of taxa richness, larger scale of mapping and soil datasets for India are required.

Earlier, significantly ($p < 0.01$) higher diversity indices were reported in the soils of relatively moist bioclimate as compared to drier ones (Velmourougane et al. 2014). Besides, higher microbial biomass carbon indicating more diversity was found in soil subgroup, viz., Typic Haplusterts as compared to other subgroups of the same soil (Vertisol) order. Interestingly, areal extent of Typic Haplusterts is much higher than other subgroups in the southern, western, and central zones which signify a close species-area relationship reported by others (Beckett and Bie 1978; Ibañez Marti et al. 1998; MacBratney et al. 2000).

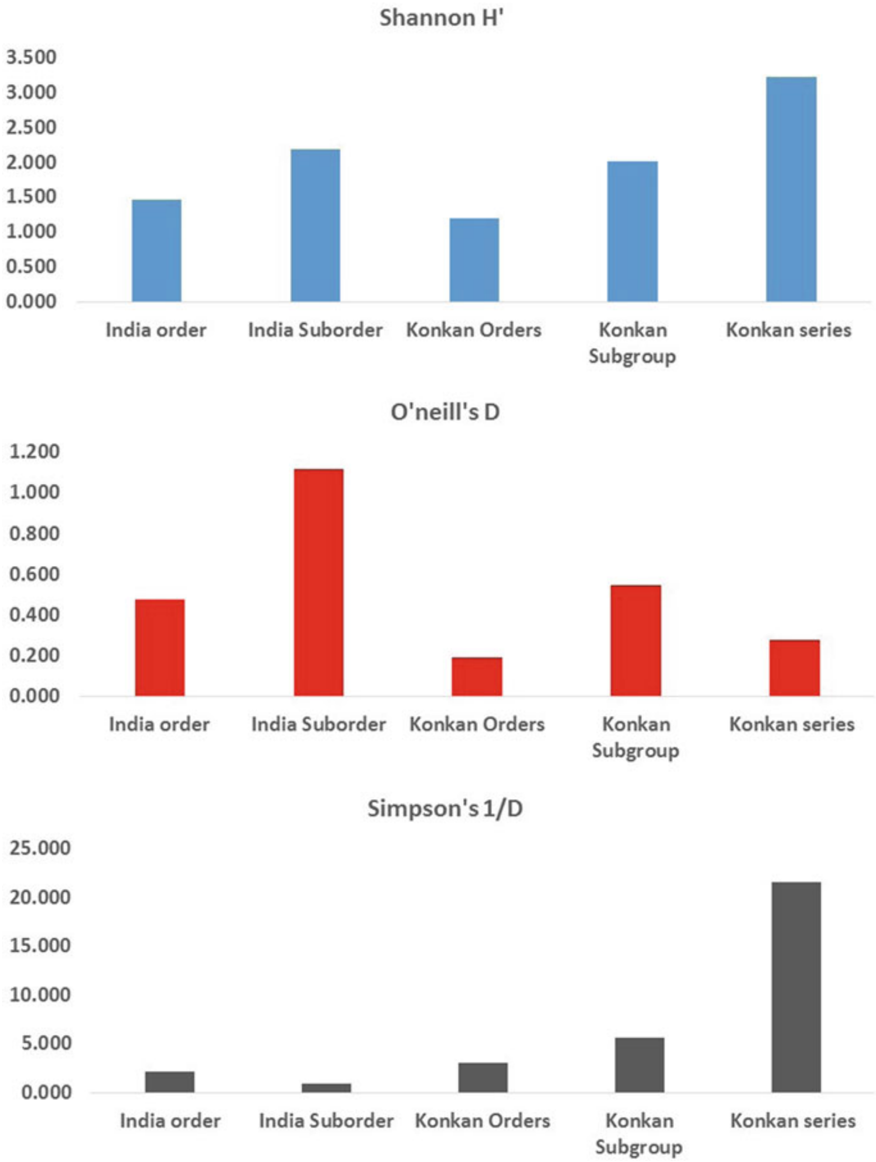

Fig. 15.7 Various parameters of pedodiversity index (PDI) for Indian and Konkan, Maharashtra soils: (**a**) Shannon H' as a measure of PDI; (**b**) O'Neil's D as a measure of relative dominance of one taxon over others; (**c**) Smith's evenness index as a measure of area equitability of the soil taxa; (**d**) Simpson's D, and (**e**) Simpson's 1/D as a measure of relative dominance (the study did not attempt diversity assessment at series level in India)

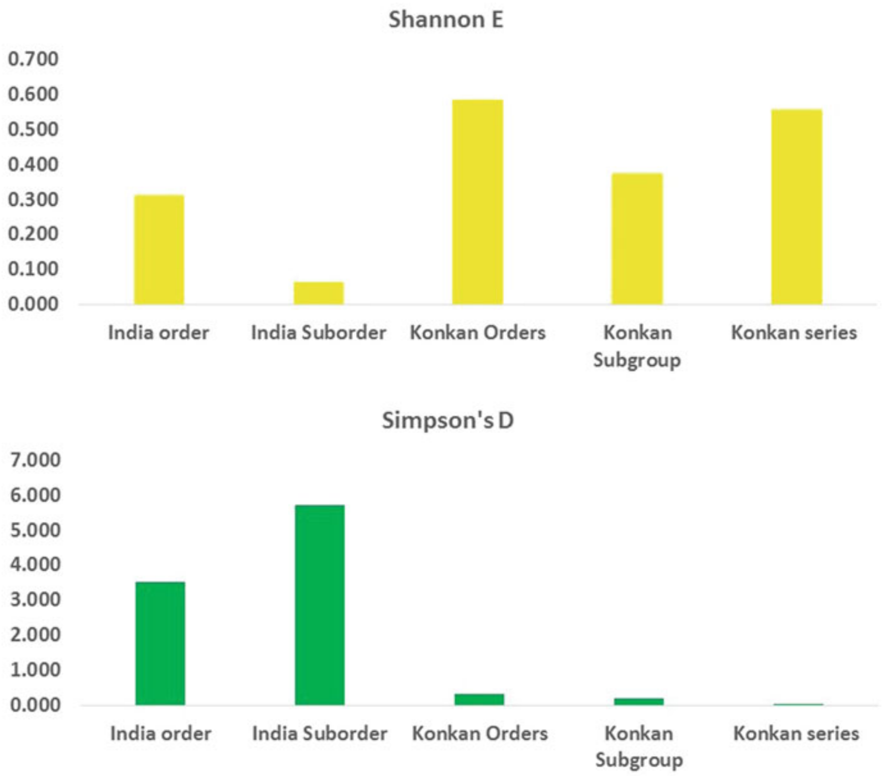

Fig. 15.7 (continued)

15.4 Konkan Biodiversity

Globally, Konkan region is one of the richest in biodiversity. It is part of the Western Ghats-Sri Lanka biodiversity hotspot complex. Recent evidence has indicated that Konkan region has experienced changes in the monsoon since late Pleistocene resulting in the changes in vegetation (Kumaran et al. 2013). These changes in the last 40,000–50,000 years have certainly had implications for the rich biodiversity in this region including the presence of several relic species.

15.4.1 Habitat Diversity

The topography of Konkan is varied and includes coastal lagoons, low-lying valleys, and hills with plateaus, precipitous slopes, and high mountain ridges. The climate also varies across the region from seacoast to mountain crest through coastal hills, middle valleys, and mountain slopes. At the same time, the climate varies from wet

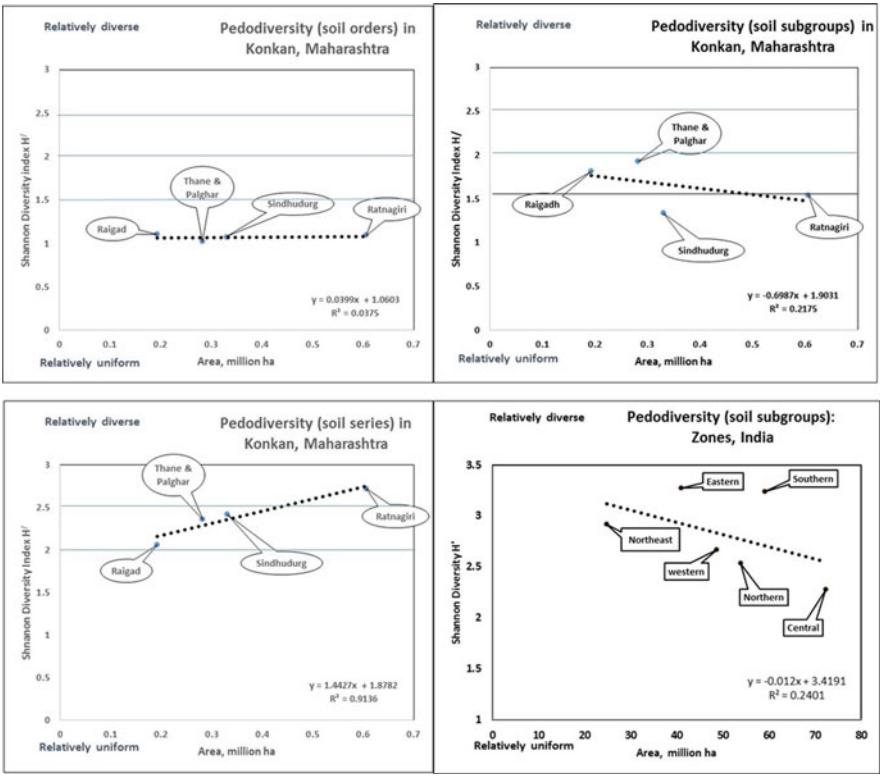

Fig. 15.8 Pedodiversity index (PDI) (H') and area relationship at soil order, subgroup, and series level in Konkan, Maharashtra, India. The last box shows the Diversity index of Indian soil subgroups as comparison. Konkan falls in the western part of India

to dry along the 700+ km south-north stretch of the region. These all together influences the diversity of habitats in this region.

Diversity of habitats in Konkan region may be comprehended by the land use land cover (LULC) classification. In addition, these data can be used to calculate the comparable diversity indices just as those worked out for various soil taxa. The data is summarized in Table 15.1. This LULC classification barely reveals the tremendous diversity of habitats enclosed by these very broad and vague terms, for example, the "Barren" which is around 20% of the total area includes the lateritic plateaus. These lateritic plateaus possess tremendous biodiversity and are of immense conservation importance which has been detailed elsewhere indicating their use for horticulture (Bhattacharyya 2021a, b). These areas Northern Western Ghats and Konkan region show high phylogenetic endemism in lateritic plateaus the predictors of which have been pointed down to poor soil conditions and seasonal ephemeral habitats (Bharti et al. 2020).

The forests of Konkan are a treasure trove of biodiversity. In addition to the evergreen, semi-evergreen, moist deciduous, dry deciduous, and scrub forests, there

Table 15.1 Area coverage ('00 ha) of different land use/land class categories in districts of Konkan region

Particulars	Konkan and districts					
	Sindhudurg	Ratnagiri	Raigad	Thane	Palghar	Konkan
Water bodies	45.56	121.35	121.15	82.92	81.79	452.77
Settlement	890.16	1640.18	863.33	916.54	612.81	5706.56
Agricultural	1173.69	1342.72	1295.94	677.97	1076.16	5556.48
Horticultural	1251.10	1243.34	937.54	932.31	914.83	5579.12
Barren	75.89	2325.5	1522.64	660.57	1164.41	6383.01
Forest	1050.46	2287.99	2217.69	955.28	1377.40	7012.83
Total	5168.88	8461.07	7010.23	4225.62	5225.39	30,094.78

Table 15.2 Extent of mangrove forest in the districts of Konkan region (source: FSI 2020)

District	Mangrove forest area (ha)
Palghar	2908
Thane	2063
Mumbai	277
Mumbai suburban	3723
Raigad	4193
Ratnagiri	1436
Sindhudurg	487
Konkan	15,088

are mangrove forests, beach forests, and coastal plantations (FAO 1998). These latter are transitional ecosystems from terrestrial to aquatic ecosystem. So, a very high level of edge effect is observed in these forests. This also results into a rich diversity of habitats, species, and genes.

15.4.1.1 Mangrove Forests

In India, mangrove forests are found all along the coastline in varying extent. They occupy an area of 4045 square km (FSI 2009). The type of mangrove ecoregion found in Konkan is Indus delta-Arabian sea mangroves found along the western coast. They cover an area of 15,088 ha in Konkan region (Table 15.2).

Mangroves are plant species including trees, shrubs, palms, and ferns growing in saline intertidal coastal habitats such as estuaries and shorelines. There are more than 110 species of these plants throughout the tropics and subtropics. These species are physiologically adapted to overcome the problems of high salinity and frequent tidal inundation resulting in absence of oxygen. They form estuarine tracts of mixed mangrove forests (Rosati et al. 2008). Although mangrove forests are characterized by low floristic diversity at any given place compared with most inland forests in the tropics, they are definitely a rich and typical ecosystem. Mangrove forests are unique, highly productive and socioeconomically and biologically important. People on Konkan coast depend on mangrove forests for wood and a large variety of non-wood forest products like dyes, medicines, fodder, and honey. Mangroves host a wide variety of organisms, including a number of endangered species. They serve as a valuable nursery to many shrimps, crustaceans, and mollusks and act as a breeding and feeding ground for many commercially important fish species (Rosati et al. 2008). Few species of animals are restricted entirely to the mangrove forests. Besides, mangrove forests act as an ideal sanctuary for several migratory birds (FAO 1998). In addition, mangroves play an important role in protecting the coast, especially during surge storms, hurricanes, and tsunamis. These ecosystems are extremely fragile and hence require conservation and protection from permanent loss (Rosati et al. 2008).

15.4.1.2 Beach Forests

The beach forests or coastal forests found in Konkan region are classified as Malabar Coast moist forest ecoregion. This ecoregion represents the semi-evergreen forests along India's Malabar Coast, a narrow strip of land lying between the Indian Ocean to the west and extending up to the 250 m contour of the steep Western Ghats Mountains to the east (www.worldwildlife.org). The ample amount of rains brought by the southwestern monsoon largely influences the vegetation of this region. Although the forest is classified as semi-evergreen, the influence of rainfall and distance from equator has resulted into gradual trend from tropical wet evergreen in the south to drier and deciduous forests to the north. In addition, these forests have been largely replaced or interspersed with teak, giving the vegetation a semi-deciduous character; the teak is now considered indicative of a secondary successional stage or presence of plantations. A large variety of plant species in all the strata of forest ecosystem are found in these coastal forests. Several of these are endemic and near-endemics (www.worldwildlife.org).

15.4.1.3 Coastal Plantations

Plantation activity in India has taken up great strides in the last two decades. The rate of plantation has been more than 15,000 square km per year during this period (Puyravaud et al. 2010). Coastal plantations have often been established for both production and protection purposes. The production functions involve supply of fuelwood and other non-timber forest products (NTFPs). The basic protection purpose is stabilization of coastal sand dunes which keep shifting in inland direction. One of the recent approaches is to create shelterbelt plantations as a mitigation strategy for cyclones and tsunamis. The most popular and important species taken up for coastal plantations is *Casuarina equisetifolia* (whistling pine tree) along with some mangrove species. Others include *Acacias* and *Eucalyptus*. Apart from these forest plantations, Konkan region has extensive plantations of coconut and areca nut that can be included in coastal plantations.

15.4.1.4 Agro-Biodiversity

Konkan region has been proposed as a National Agricultural Biodiversity Heritage Site in India based on cultivation of enriched agro-biodiversity under diverse high-rainfall microclimatic conditions, development of unique tropical mixed cropping systems, generation and conservation of rich genetic diversity in crops (Singh 2014). The connecting link between wild and cultivated diversity, i.e., wild relatives are also very diverse in Konkan region as is evident by 58 species of wild vegetables in the region (Khan and Kakde 2014). The origin of this rich agro-biodiversity can be traced back to the richness of the natural floral diversity and in turn to the pedodiversity.

15.4.1.5 Floral and Faunal Biodiversity

It is important to note that diversity of algae and fungi is also rich in Konkan region. Even the foliicolous fungi are extremely diverse in Konkan. Approximately 191 species of such microfungi were recorded from the leaf samples throughout Konkan and interestingly; none of the species was found to be widespread as to be found in all four districts of this region (Dubey and Pandey 2019). Besides, nearly 29 species of mushrooms from Konkan region have been documented (Borkar et al. 2015). There are nearly 500 species of dicotyledonous angiosperms in Konkan (Singh and Karthikeyan 2000, 2001). The number of plant species in each district of the region is shown in Table 15.3.

Two micro-centers of plant endemism are identified in the Konkan region (Nayar 1996). These are *Mahabaleshwar-Khandala* and *Konkan-Raigad*. According to one recent analysis, out of forty-nine Indian endemic plant genera, three (and five species contained within them) are endemic to these two centers (Irwin and Narasimhan 2011). Nearly 181 endemic taxa, belonging to 84 genera and 36 families are reported in the Northern Western Ghats-Konkan region (Shigwan et al. 2020). Konkan region has been specially highlighted as a center of rapid diversification of genera like *Ceropegia*, *Glyphochloa*, *Dipcadi*, and *Eriocaulon*. The diversity of fauna is equally impressive in the Konkan region. A comparative statement of number of species found in Konkan, Western Ghats, Maharashtra, and India is provided in Table 15.4.

Table 15.3 Floral diversity in districts of Konkan region

Sl. no.	Districts	No. of plant species
1	Thane	417
2	Raigad	392
3	Ratnagiri	454
4	Sindhudurg	484

Table 15.4 Number of animal species in various groups recorded from Konkan region as compared with larger regions

Taxon	Konkan	Western Ghats	Maharashtra	India	World
Mammals	84	137	96	417	6399
Birds	399	500+	535	1287	10,426
Reptiles	62	227	97	518	5817
Amphibians	24	219	43	384	7825

Note: number of species compiled from various sources from a wide temporal range
Sources: Burgin et al. (2018), Dinesh et al. (2015), eBird (2017), Frost D R (2018); Anonymous (1974), Gunawardene et al. (2007), MOEF (2008), Padhye and Ghate (2002), Srinivsaulu et al. (2014)

15.5 Linking Pedodiversity and Biodiversity: A Mobius' Strip

Mobius strip is a curious and intriguing object that can be created with a strip having two surfaces, but once created, it will give an illusion of having only one continuous surface (Alagappan 2021). The Mobius strip was discovered independently by A. F. Mobius and J. B. Listing in 1858. The Mobius strip has been used in the recycling symbol. The relationship between two interrelated aspects of natural diversity namely pedodiversity and biodiversity may be viewed in the image of a Mobius strip. They are distinctly different, yet when we understand the link between them; it is difficult to consider them as two distinct surfaces. We can infer richness of either of these from the richness of the other. Thus, a region rich in biodiversity can be safely assumed to have a high pedodiversity.

The concept of diversity has been widely used in ecological studies, although mainly for the biotic component (biodiversity) (Magurran 1988; Sugihara 1981). Impacts and importance of abiotic influences (stress) of soils on the biota so far as biodiversity are concerned resemble a Mobius strip. The strip is otherwise linked but not perhaps converging in its exactness (Fig. 15.9). However recent observations indicate lot of similarity between these two diversities.

Pedodiversity is conceptually defined as the inventory of the variety of discrete pedological entities, i.e., pedotaxa and pedogenetic horizons, as well as the analysis of their spatial and temporal patterns (Fig. 15.10) (Ibáñez et al. 1990, 1994). There are essentially two components of diversity: the variety of categories (or taxa) and the way in which the individuals are distributed among those taxa (evenness or

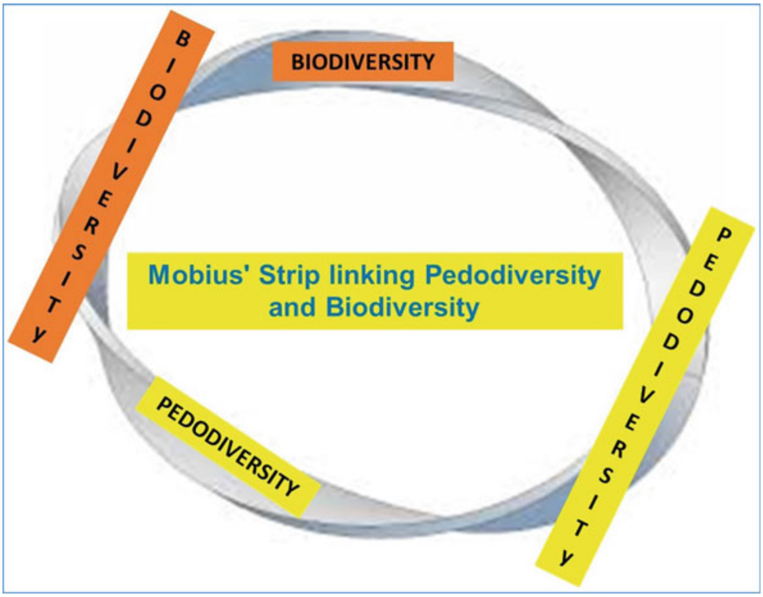

Fig. 15.9 Mobius' strip linking pedodiversity and biodiversity: schematic diagram

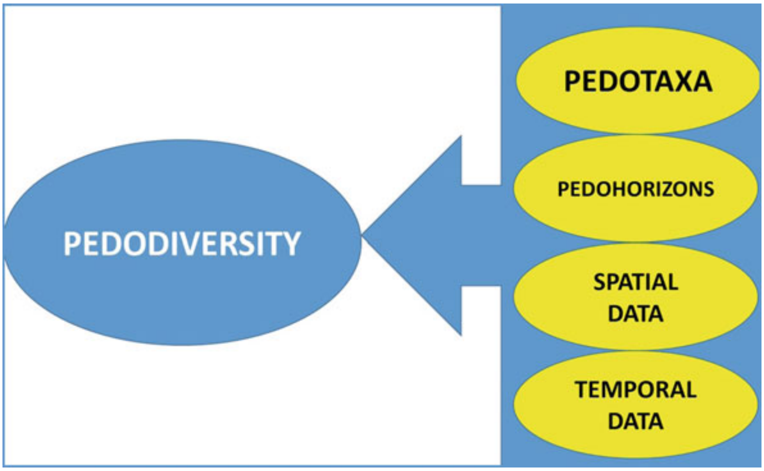

Fig. 15.10 Concept of pedodiversity to link temporal soil information and its spatial domain

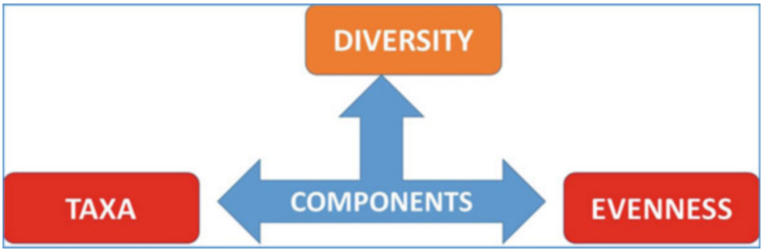

Fig. 15.11 Components of soil/pedodiversity

equitability). Indices of diversity either incorporate both components of diversity into a single value, or less frequently, tend to neglect one of these components. Species diversity measures are divided into three main categories: species richness indices, indices based on the proportional abundances of species (e.g., the Shannon index) and species abundance models (Fig. 15.11) (Magurran 1988). Interestingly soil types are included in the list of possible elements to calculate diversity indices (Huston 1994). For any resource at a given taxonomic level, therefore, it is possible to study its taxonomic diversity.

Diversity analyses utilize mathematical tools which have been applied by ecologists for decades to analyze the intrinsic regularity of ecological entities. Remarkably, the spatial patterns of pedo-geographic units detected by pedologists are rather similar to those reported by biologists for a plethora of ecosystems (Petersen et al. 2010). In summary, biological and pedological systems follow similar mathematical patterns of (i) diversity; (ii) richness and diversity-area relationships; (iii) richness and diversity-time relationships (islands and terrace chronosequence); (iv) abundance distribution models; (v) taxa-range size

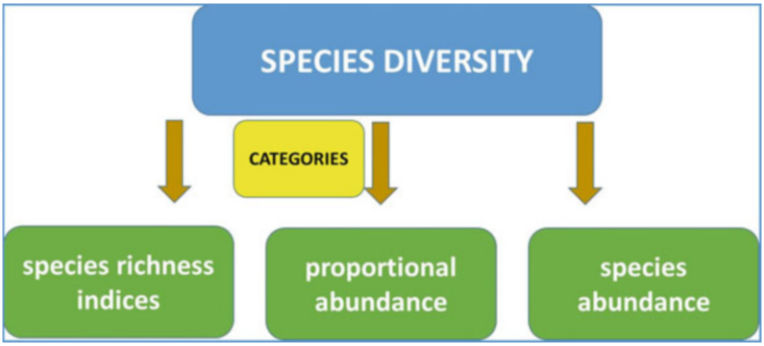

Fig. 15.12 Categories of species diversity: pedological systems

distribution; (vi) nested subset analysis; (vii) fractal and multi-fractal analysis; (viii) complementarity algorithms for selecting areas to design networks of natural reserves; and (ix) mathematical structures of classifications (Fig. 15.12) (Ibáñez 2006). Furthermore, predictions of the theory of Island Biogeography have been used to explain the pedorichness and soil assemblage analyses in archipelagos (Ibáñez and Effland 2011). These are intriguing facts that must be analyzed in depth given that pedodiversity-area relationships cannot be explained using the biological assumptions (MacArthur and Wilson 1967).

15.5.1 Soil Diversity and Pedodiversity

The concept of diversity has been widely used in ecological studies in connection with biodiversity (Sugihara 1981; Magurran 1988). However, discussion to include the abiotic stresses from soils on the ecosystems has found very little attention. Inorganic carbon sequestration and soil/land degradation causing poor crop performance especially in the drier climates due to abiotic stresses in Indian context have been discussed elsewhere (Bhattacharyya 2021a, b, c). This brings a paradigm shift to catch the imagination of other experts in other parts of the globe to use Indian case studies as a model to study pedodiversity (Ibáñez et al. 1995). Soil and pedodiversity is linked so are their contribution to the key aspects of heritage such as biological and cultural (preservation of biodiversity, ancient, and traditional sustainable practices), soil monitoring (benchmark soils in monitoring programs), prehistoric and paleontological (archive of artefacts and remnants of extinct species), bio-geosphere (archive of past environments), and geological (pedodiversity is a part of the concept of geo-diversity) (Ibáñez et al. 2012). Figure 15.13 shows the relation between soil and pedodiversity and their heritage vis-à-vis ecosystem services (Bhattacharyya 2021b). The relationships between pedodiversity and the diversities of other natural bodies are shown in Fig. 15.14.

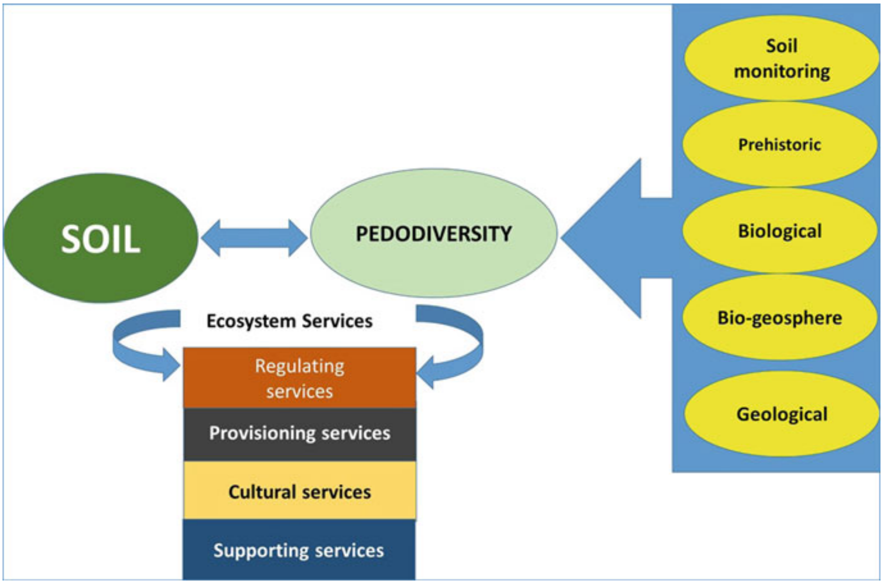

Fig. 15.13 Role of soil and pedodiversity in providing ecosystem services (also see: Bhattacharyya 2021b)

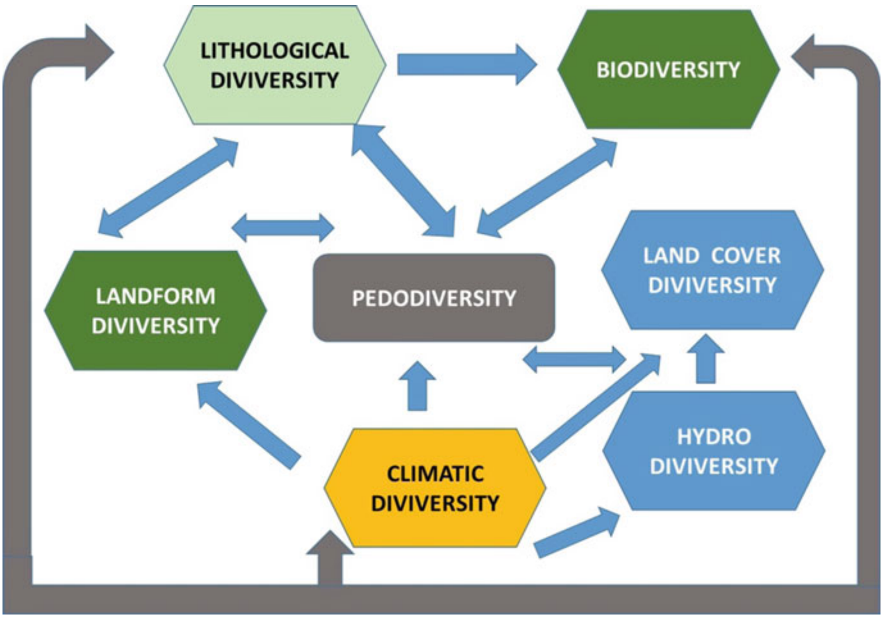

Fig. 15.14 Relationships between pedodiversity and biodiversity with other forms of diversity in nature (adapted from Ibáñez et al. 2012)

15.5.2 Soil Diversity and Biodiversity

Soil diversity and biodiversity may be discussed in relation to (i) rare soils and rare plants and (ii) endangered soils and plants (Ganguli et al. 2019). This will enable planners to think seriously about soil/pedodiversity and biodiversity for preservation of nature and future planning (Amundson et al. 2003). Wild mangoes as an incredible wealth of posterity in India have its own natural biodiversity. Species, *Mangifera indica* is commercially cultivated. Among the other species, the occurrence of *Mangifera sylvatica* in the northeastern parts of India or *Mangifera andamanica* in the Andaman group of islands is worth-mentioning. Variability of this dimension of mango results from the chance seedlings and seed propagation either by natural elements (seed dispersion) or anthropologically over a long period. This demands preservation of these wild mango species and their biodiversity for posterity (Fig. 15.15). There is a great interest and necessity to preserve the wild mango biodiversity which can be maintained globally through efforts of collection, documentation, and plantation to preserve the mother orchards (Ganguli et al. 2019). These are store house of gene pools for evolving future mango varieties with their unique qualities. These wild and edible mangoes are in danger of extinction and most certainly represent the important resources for the future of mangoes (Table 15.5).

In Konkan plant species in terms of taxa richness representing biodiversity in the region showed a type of relation which seems interesting. Pedodiversity, measured by Shannon diversity index (H'), indicated low H' in higher taxa richness (biodiversity). This is more pronounced at the level soil subgroup pedodiversity (Fig. 15.16). This might hint that concept of pedodiversity and biodiversity may merge at some

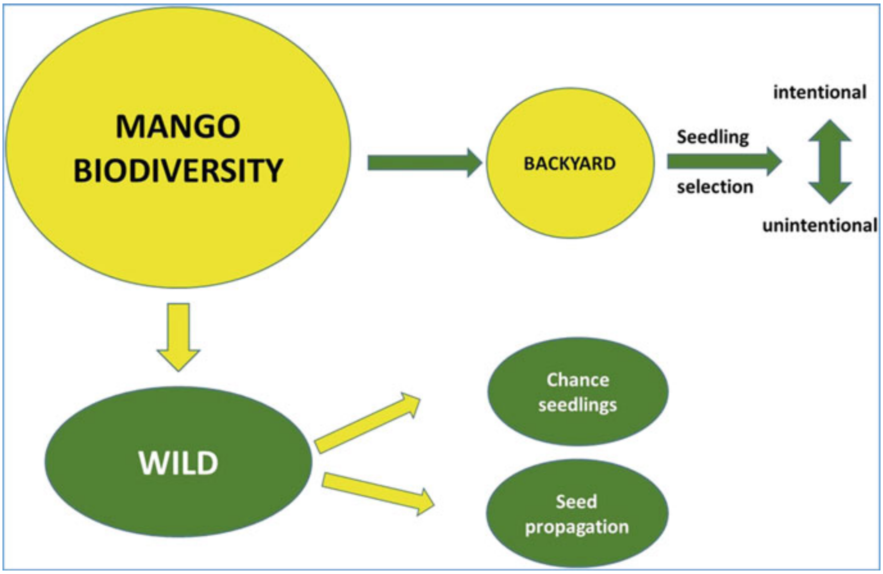

Fig. 15.15 Mango and its biodiversity (Dinesh et al. 2011; Ganguli et al. 2019)

Table 15.5 Mango species under different categories of threats

Threat category	Mango spp.
Rare	*Mangifera andamanica*, *Mangifera camptosperma*, *Mangifera gedebe*
Endangered	*Mangifera cochinchinensis*, *Mangifera flava*, *Mangifera lagenifera*, *Mangifera pentandra*, *Mangifera reba*, *Mangifera superba*
Vulnerable	*Mangifera duperreana*, *Mangifera inocarpoides*, *Mangifera monandra*, *Mangifera timorensis*, *Mangifera zeylanica*

Dinesh et al. (2011), Ganguli et al. (2019), Mukherjee (1985)

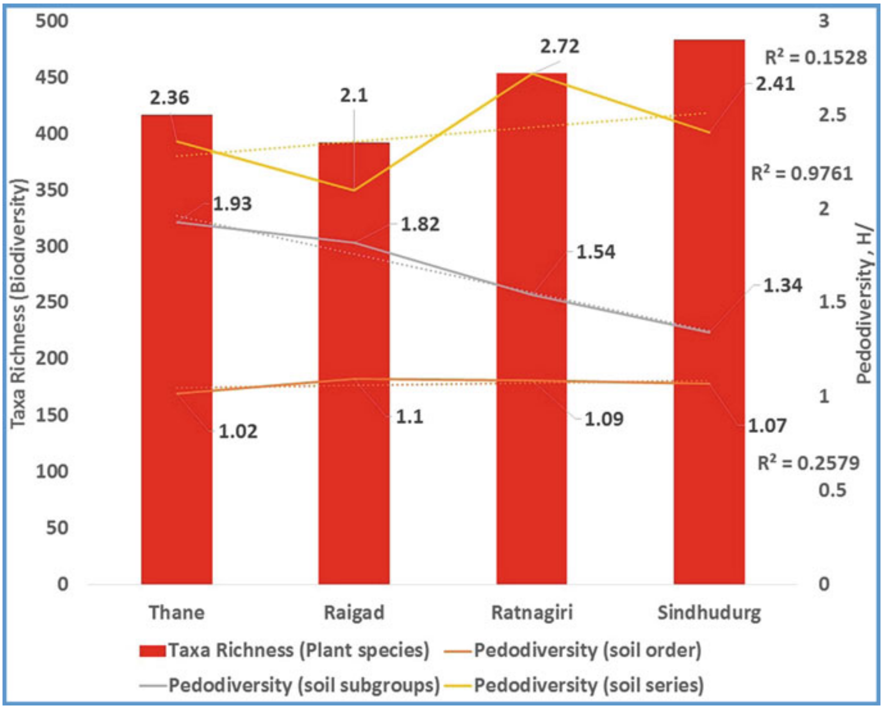

Fig. 15.16 Pedodiversity and biodiversity in terms of plant species richness in different districts of Konkan, Maharashtra

scale of data collection. Usually subgroup level of soil classification may be suggested at a scale of 1:250,000 or above. Biodiversity database may accordingly be collected at that kind of scale depending on other local factors.

There is an example of the relationship of rare soils to plants, in the form of the annual grasslands of eastern Merced County, California region, that is an integral part of the California Floristic Province, one of the top 25 biodiversity hotspots on Earth (Cincotta and others 2000; Myers et al. 2000). A sizable number of endemic species form in these pools (Vollmar 2002). There is a systematic change in pool frequency and soil chemistry (Brenner et al. 2001) with time that creates an edaphic gradient that is a major factor in influencing the plant species composition on a regional scale (Holland and Dains 1990). Similar typical areas exist in India also so far as plants/tress specificity is concerned like Darjeeling tea in Darjeeling and specific areas in North Bengal; Litchi in Mujjafarpore, Bihar; and Alphonso in Konkan, Maharashtra. Such edaphic and crop relations led to soil-site specific characteristic to evolve agroecosystem-based land use planning (Bhattacharyya et al. 2015). Because of the plant/trees preferences for specific soils near a particular agro-ecosystem, there is a need to establish a preservation design to include the soils in those ecosystems. Otherwise, both plants and soils become endangered as a result of land use. There is also a need to prepare a list of type of soils which are endangered due to natural as well as anthropogenic activities to preserve biodiversity (Amundson et al. 2003).

"Concluding no bad effect of poor land use when it really happens" is the precautionary principle which brings conservationists and /developers in the same platform to reduce the possibility of committing a "Type II" error (Shrader-Frechette and McCoy 1993; Noss et al. 1997). This error is specifically relevant to medicine, environmental engineering, and conservation biology resulting in irreversible damage to the patient, ecosystem, or soil (Noss et al. 1997). The conservation of diverse soil scapes should proceed simultaneously with scientific research that fully explores their qualities, values, and functioning and shall help us not to commit irreversible mistakes to destroy nature. The concept of LDN vis-à-vis pedodiversity and biodiversity may address these problems with remedial measures.

15.6 LDN and Maintenance of Biodiversity and Pedodiversity

One of the major soil-forming factors is climate. Therefore, climate change and LDN vis-à-vis pedodiversity and biodiversity require soil as the focal point for discussion. Land area is dwindling due to many reasons. The main reason is its degradation, both natural and anthropogenic. It seems, therefore, logical to save our motherland and focus on LDN whereby the amount and quality of land resources, necessary to support the ecosystem functions and services and enhance food security, remain stable or increase within specified temporal and spatial scales and ecosystems. Appropriate LDN measures will lead to saving soils/land from degradation to restore biodiversity. Business as usual approach will lead to extensive damage to soils/land resulting in loss in our bio-heritage (Fig. 15.17).

Land use and its changes bring major changes in diversity. This could be changes in soil/pedodiversity leading to disturbed biodiversity. Naturally occurring land degradation (chemical soil degradation) requires steps for land degradation neutrality (LDN). This includes, among many other interventions (Bhattacharyya 2020), appropriate land use policy. This needs involvement of multidisciplinary experts (Fig. 15.18) (Bhattacharyya 2020).

The contribution of various experts is paramount not only from biodiversity point of view but also in bringing some areas under agriculture and other allied activities. Both vertical and horizontal expansion of areas under agriculture, animal husbandry,

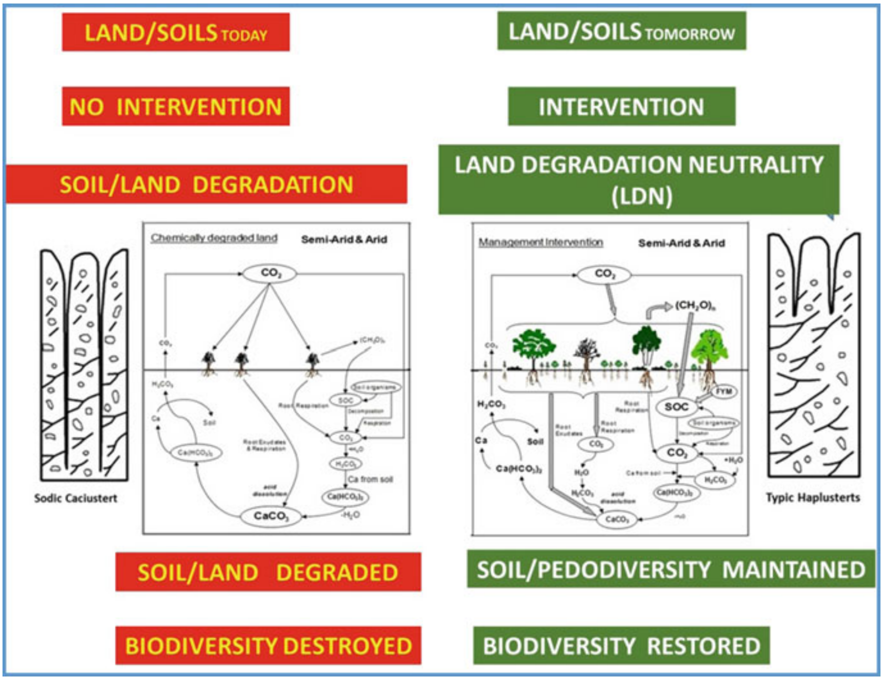

Fig. 15.17 Land degradation neutrality (LDN) shall restore soil/pedodiversity and biodiversity (Bhattacharyya 2020, a, b)

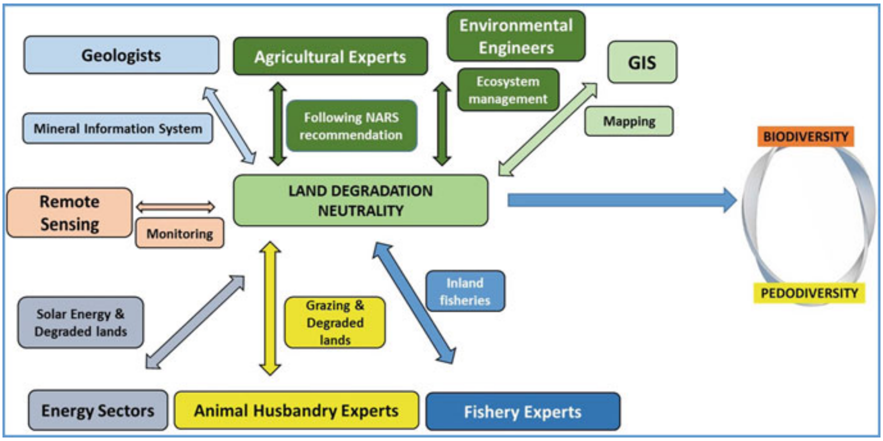

Fig. 15.18 Suggested policy to achieve LDN to help maintaining soil/pedodiversity and biodiversity

fisheries, and other nonagricultural sectors such as forestry will help maintaining biodiversity. Bringing waste land to harness nonconventional source of energy can be useful to help in using alternate source of energy to reduce carbon footprints, and also to enable farmers non-dependable on conventional sources of energy. Land degradation neutrality (LDN) can thus nullify the ill effects of global warming or climate change. Future research should focus to fulfil the target of LDN with an acceptable policy to converge the Mobius strip of biodiversity and pedodiversity.

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