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Characteristics of Konkan Soils and their Potential for Carbon Sequestration

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Abstract

Konkan, Maharashtra is different from other parts of Maharashtra and also from India in terms of variation in geology, climate, soils, and environment. Konkan covers an area of nearly 30 lakh hectares and represents a coast line of 720 km stretching south of Gujarat to north of Goa. This basaltic terrain receives a rainfall averaging 2500-4000 mm. The part of 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. Formation of these soils and their persistence has been detailed in this article. Information on different soil orders and other variations of soils are also discussed. As compared to the soils of the Indo-Gangetic plains and black soil region, Konkan soils show a decreasing trend of potassium reserve with increase in soil depth. Besides, the northern Konkan has more soil potassium as compared to the south Konkan suggesting the revision of recommended dose of K fertilizers to help the farmers in crop management.

Global warming and climate change often affect soil quality with special reference to soil carbon. Soil carbon stock both for organic (soil organic carbon, SOC) and inorganic (soil inorganic carbon, SIC) shows SOC to record 0.185 Pg (1 Pg = 10^{15} g) and SIC 0.048 Pg carbon stock in the first 30 cm depth of soil. The threshold limit of 0.064 Pg mha^{-1} of soil organic carbon in first 30 cm depth is assessed in Konkan, suggesting that Konkan eco-system is maintaining the soil quality and health. Besides, representative soils from Konkan show that SOC stock has increased while SIC stock has decreased over a period of 30 years. This has been explained by the submerged paddy cultivation to increase SOC. Submergence has also a retardant effect to form pedogenic carbonate in soils to reduce SIC. These soils with the major land use under forests, horticulture and agriculture sequester organic carbon to maintain the coastal ecosystem amidst climate change in this fragile ecosystem. Management interventions in terms of adding micronutrients such as zinc, boron and molybdenum are being made as these elements are deficient in Konkan soils. Konkan is blessed with a blend of quality Alphonso mango varieties. Due to conducive environmental conditions planting mango even on apparently hard lateritic outcrops has been a profitable venture. The present article also describes the reason behind the success story of this venture.

Key words: Konkan, climate change, carbon sequestration, soils, potassium, carbon, micro nutrients.

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Introduction

The term 'Konkan' is traditionally applied to the northern and central part of the western coastal lands of India as per the *Sahyadrikhanda* of *Skanda Purana*. Konkan has been a strategic landscape throughout the human history of the Indian subcontinent. Even today, it assumes a great importance because of having important centres of socio-political and economic activity like Mumbai, Thane, and Goa. Despite its larger traditional extents, the portion of Konkan region within the boundaries of Maharashtra state has been recognized as a distinct administrative unit of the state and throughout this article, we refer to Konkan to mean Konkan, Maharashtra only. The region has an area of 30,746 km^2 with a population of 28,739,397 (Anonymous 2011b); it has 7 districts viz. Mumbai, Mumbai suburban, Thane, Palghar, Raigad, Ratnagiri and Sindhudurg. Interestingly, five major districts of Konkan viz. Sindhudurg, Ratnagiri, Raigad, Thane and Palghar with 84% of total area support only 24% of total population of Konkan (Anonymous 2011b). This is essentially because highly urbanized metropolitan centres i.e. Mumbai, Mumbai suburb and Thane are located in this region. One of the key features of this region is high literacy.

Among the options to mitigate climate change, the sequestration of C in agricultural soils assumes added importance. There has been great interest in mitigating the climate change due to global warming by sequestering and storing carbon in soil and its influence on soil quality and agricultural productivity. The present article also makes an attempt to find out the potential of Konkan soils to sequester carbon with the present land use scenario.

Geography

Konkan is located between 15° 36' to 20° 15' N latitudes and 72° 40' to 73° 45' E longitudes. It is a narrow coastal strip situated between the Western Ghats and the sea on the western part of Sahyadris with longitudinal distance of 500 km and a width varying from 45 to 90 km. Part of Konkan falls in the Western Ghats also, which is commonly known as the Sahyadris. This chain of mountains extends from south of Tapi in Gujarat to the tip of Indian Peninsula and forms a physical and cultural barrier between plateau and coastal low-lands. The western edge of the plateau ends abruptly with an escarpment of about 600 m, descending to the coastal low-land of Konkan. This region has a crest zone of 15 to 25 km width with the dissected and slopy hill ranges and narrow interhill basins. The crest line decreases from north to south and has many plain hill-tops like the Bhimashankar (Bhattacharyya *et al.* 1993, 1999 and 2006), Mahabaleshwar and Lonawala plateau. It has also many peaks of varying heights ranging from 901 m of the Pondaghat peak (Goa) to 1646 m of the Kalsubai peak.

Owing to heavy rains, the Sahyadri hills form the source of all the principal rivers in the state and the whole Deccan area as well since it forms a water dividing line for east and west flowing rivers. This results dissections and head-ward erosion to develop plateaus, mesa, buttes, inselbergs and conical hills. From the Arabian sea to the Deccan area, the Western Ghats form a formidable barrier making the eastern part of the Ghats as the rain shadows, while the western part forming the Konkan, a very high rainfall zone (Subramanyan 1981).

The northern part of Konkan covering Thane, Palghar and Raigad is relatively flat with gently sloping residual hill tops of lateritic exposures; Kalyan and Karjat are in plains with some spurs of the Western Ghats such as Matheran hills (700 m above msl). To the south, part of Konkan is represented by the Panvel-Pen-Alibagh coastal plain with rugged topography that merges into the Arabian Sea. This gives rise to coastal plateau and creeks indicating a rocky and rugged coastal line that extends upto Sindhudurg district. Streams originating in the Western Ghats flow westward and meander their way forming very narrow inter-hill valleys and finally meet the Arabian Sea. From north to south, the coastline is broken by river valleys, small river mouth inlets, creeks, residual hills, cliffs, and different types of beaches. This region receives a rainfall of 2500-4000 mm, mostly through southwest monsoon during June-October. It has a marine humid to per humid climate (Bhattacharyya *et al.* 2007) with less diurnal variations. At different meteorological stations across the region, the rainfall varies and gradually decreases towards north Konkan (Figure 1; Table 1).

Geology

The rock formation in Konkan region is basalt along with granite, gneisses and laterites. The relief features of the region are essentially the product of its geological past carrying the signatures of climate change from humid to semi-arid (Bhattacharyya *et al.* 1993, 1999) and the agents of denudation working on the geological mantle. The relief of the region is charactrised by its highly uneven nature and the very narrow riverine plains with fringe coast lines. Nearly 85% of the land surface is hilly. The coastline is irregularly marked by alternating bluff and curving bays, but it is shallow and hence has a limited use for navigation. The landscape of the region is basically uneven by the Deccan lavas which cover most of the area except the southern and south eastern part which is underlain by metamorphic rocks. The typical lava landscape developed under tropical humid condition persists almost everywhere. This region can have five broader types of physiography viz. (i) the coast lines, (ii) the narrow mesa, buttes and alluvial plains and inter-hill basins, (iii) plateaus and residual hillocks, (iv) partly detached and partly connected to the main hill range and (v) scarp-faces of the Sahyadri proper. The scarp-face has sufficiently heavy erosion, so that several portions have been detached from the main range and they appear as isolated small plateaus or in extreme cases as pillars or conical hills standing down permanently to create a scenic beauty. Although these are detached and isolated, their genetic (basalt) relationship with the main range is clearly visible from the arrangement of the horizontal lava bands.

Table 1. Agro-climatic stations in Konkan region and range of data available at each station.

Sr.No.	Agro-climatic stations	Database Years
1	Vengurle	1991-2013
2	Mulde	1991-2015
3	Nileli	2012-2015
4	Phondaghat	2012-2015
5	Shirgaon	2003-2015
6	Wakawali	1991-2015
7	Dapoli	1991-2015
8	Repoli	2008-2015
9	Karjat	1991-2015
10	Panvel	2011-2015
11	Palghar	2009-2015
12	Mumbai	2010-2014

Data Source: Anonymous 2016a.

The Western Ghats rise precipitously across to an average height of 1200 m results in an orographic rainfall being heavy all along the West Coast. The lee-side towards the east receives less than 1000 mm of rainfall and is typically rain-shadowed (Bhattacharyya *et al.* 1993, Rajaguru and Korisettar 1987). Occurrence of numerous ferruginous soils capping the detached plateaus at an average elevation of about 1100 m above msl with an annual rainfall of more than 5000 mm along the Western Ghats suggests that an extensive peneplaned surface with gentle southerly slopes and moderate relief existed earlier in this part (Sahasrabudhe and Deshmukh 1981). In the dominantly erosional landscape of the Deccan Plateau (Kale and Rajaguru 1987) the existence of mesas, buttes

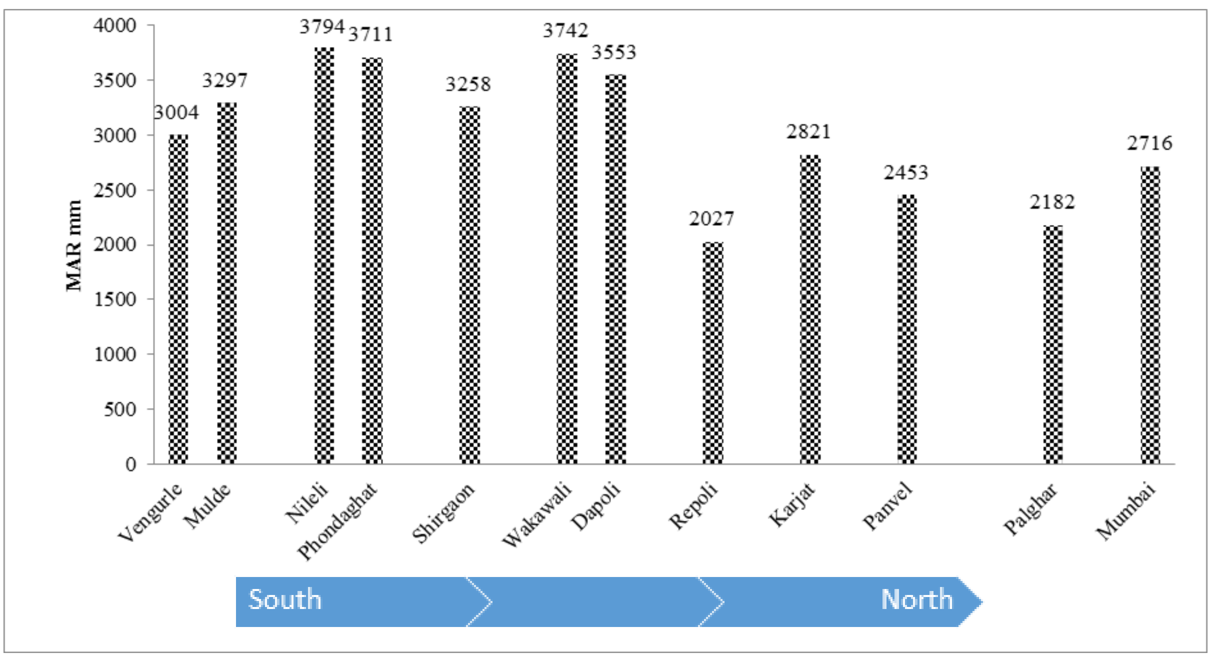


Fig. 1. Variation of rainfall in different parts of Konkan (Source: Anonymous 2016a).

and inselbergs are described as the results of different erosional cycle (Subramanyan 1981). The similarity in the relative elevation of different geomorphic features and its surroundings perhaps indicate that these features were not independent as they exist in the present day situations (Bhattacharyya *et al.* 1993, 1999).

Land Use

Among agricultural crops, paddy is the major crop grown in the valleys due to the variations in landscape, high rainfall, soil types and social reason. Mainly two different types of physiographic units such as valley and/or inter-hill basins are frequented. Hills are common in Konkan, which make the south and north Konkan distinctly different in agricultural land use (Figure 2). North Konkan has less net sown area and its cropping intensity is marginally higher than south Konkan (Anonymous 2011a). Cultivable area, cultivable waste land, barren land and other fallows are more in south Konkan than in north. Forest cover is more in north Konkan than in south (Anonymous 2015, Anonymous 2016b) (Figure 3).

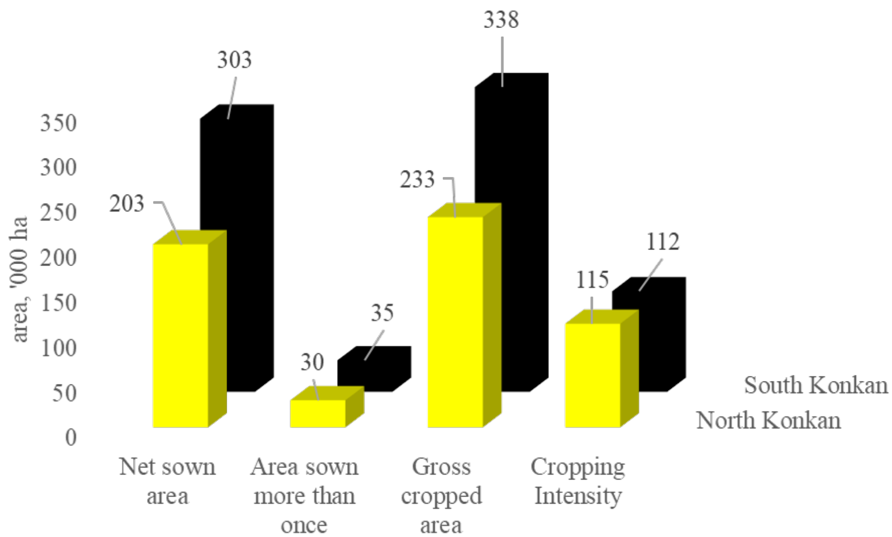


Fig. 2. Agricultural land use in north and south Konkan, Maharashtra (Source: Anonymous 2011a).

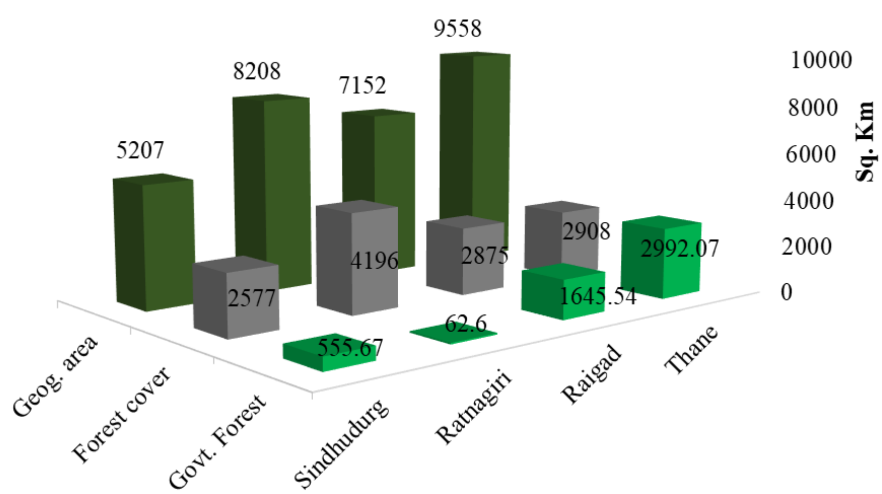


Fig. 3. Area under forests in Konkan districts. Note that the extent of government forest in Ratnagiri and Sindhudurg districts is very little compared to the forest cover (Source: Anonymous 2015; Anonymous 2016b).

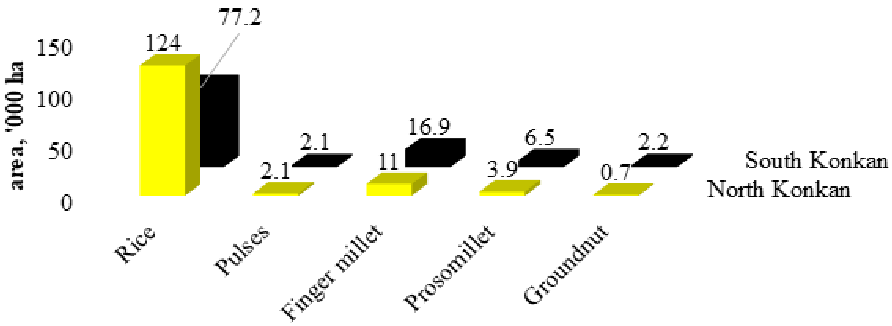


Fig. 4. Major Field crops under rainfed kharif in Konkan, Maharashtra (Source: Anonymous 2011a).

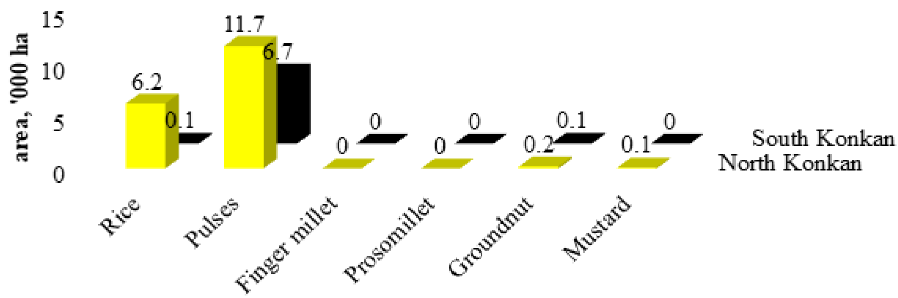


Fig. 5. Major Field crops under irrigated rabi in Konkan, Maharashtra (Source: Anonymous 2011a).

Details of major field crops in south and north Konkan in kharif and rabi are shown in Figures 4 and 5. Other crops such as spices, finger millets, proso millets and groundnut are more extensive in south than in the north Konkan. During rabi, pulses and rice occupy more areas in north and south Konkan (Figure 5). Total area under irrigation in Konkan is 4384 km^2. North Konkan has been reported to exploit ground water (46%) more than south (25%) (Figure 6). This justifies more ground water utilization in north Konkan for irrigation (Figure 6).

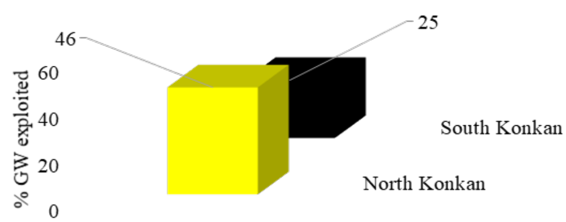


Fig. 6. Ground water (GW) utilization in north and south Konkan (Source: Anonymous 2011a).

Soil Formation

The soils in Konkan are mainly red and black. Part of the landscape has laterite caps showing rock outcrops. Konkan soils show varying crop productivity depending on various soil properties including carbon, clay content, cation exchange capacity (CEC), clay cation exchange capacity (clay CEC) and a host of physical, chemical and microbiological properties including the mineralogical parameters (Bhattacharyya *et al.* 2013, Pal and Deshpande 1987, Patil 2016). Detailed micro-nutrient studies of the Konkan soils have been recently revised by Patil (2016). The present article also takes a stock of soil micro-nutrients in Konkan.

The levels of soil carbon, both organic and inorganic, form an important factor influencing soil quality and health. Of these two types, organic form of carbon has been described as a boon for the farmers since it helps supplying nutrition to plants and soil microbes in right proportion. The inorganic carbon formation of soil in the form of calcium carbonate has been describd as a signature of climate change. This pedogenically-formed $CaCO_3$ has been described as a bane for farmers since it causes chemical depredation of soil making them unsuitable for cultivation without appropriate amelioration techniques (Pal *et al.* 2000, Bhattacharyya *et al.* 2016). Since native soil nitrogen is controlled by organic matter, total organic carbon in soil can indirectly indicate the amount of native nitrogen available to plants. Besides nitrogen, a mention is also made about the available potassium stock in soils in this paper. The crop removal of potassium has been equal or in excess of the uptake of nitrogen from soils due to intensive cropping with high yielding varieties. With the pressure increasing for land use to get more crop production, the gap between removal of K and its application to crop is widening. It is in view of this; the use of K fertilizers should be judicious and be based on database on K reserve in soils and their spatial distribution indicating the optimum amount in various soil size fractions (Bhattacharyya *et al*. 2007).

Soils in Konkan have been preserved under high rainfall and in better vegetative cover which suggests that organic carbon in these soils has been preserved for a long time which is in sharp contrast to those in the semiarid tropical part of India (Bhattacharyya *et al.* 2008). However, due to huge difference in topography, the loss of surface soil due to erosion is also very high causing loss of soil organic carbon (Tiwary *et al.* 2015). Other than carbon, potassium which is normally expected to be high in basaltic terrain needs to be continuously monitored in Konkan. In the context of the overall agricultural scenario of the Konkan region, the present effort takes a review of the existing pedological research carried out and also to find out the status of soil quality and health of Konkan soils with special reference to carbon sequestration vis-à-vis climate change using some primary soil datasets.

Methods

The necessary information about the soils covering Konkan region was collected from the primary data sets of NBSS and LUP, Nagpur (Challa *et al.* 1999) and a few other soil data was generated at different laboratories in India. Fresh soil samples were collected from south Konkan to generate a few soil parameters. The soils were air-dried and analysed for different soil parameters following standard methods (Jackson 1973). Selected few were analysed for mineralogical analyses (Jackson 1979). The bulk density values were collected from the available data sets. The carbon stock (Pg; 1 Pg is 10^{15} g) in soils was calculated using the following formula (Bhattacharyya *et al.* 2008)

$$\text{SOC stock in soil (Pg)} = \frac{\text{Carbon content } (\text{g g}^{-1}) \times \text{BD } (\text{mg m}^{-3}) \times \text{Area } (10^6\text{ha}) \times \text{soil depth (m)}}{10}$$

where SOC is soil organic carbon. For soil inorganic carbon (SIC), the same steps were followed using 12 parts of C present in $CaCO_3$ values. The sum of SOC and SIC stock gave the total carbon (TC) stock in the soils

The size of soil potassium stock (Tg; 1 Tg is 10^{12} g) is determined using extractable potassium by neutral normal ammonium acetate. The details of this estimation as soil K and K_2O is shown below (Bhattacharyya *et al.* 2007).

$$NH_4OAc\text{ extractable K stock in soil (Tg)} = \frac{\text{Extractable K } (\text{g g}^{-1}) \times \text{BD } (\text{Mg m}^{-3}) \times \text{Area } (10^3\text{ha}) \times \text{soil depth (m)}}{10}$$

$$\text{K}(\text{Kg ha}^{-1}) = \frac{NH_4OAc\text{ extractable K stock in soil (Tg)} \times 1000}{\text{Area } (10^6\text{ha})}$$

$$K_2O\ (\text{Kg ha}^{-1}) = \frac{\text{K}(\text{Kg ha}^{-1})}{0.8}$$

The soil diversity index (SDI) was assessed using the concept of occurrence of soil order/subgroup/series (Soil Survey Staff 2014) and extent (Bhattacharyya *et al.* 2013). To estimate the pedo-diversity indices (PDI), various measurements 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 districts were extracted from the existing database. PDI were calculated based on the area abundance of the taxa for Konkan region and for each district separately. Three types of indices were considered in this study: richness (S) (number of soil taxa), and diversity (H') (considers both richness and evenness i.e. area equitability of taxa into account, or, in other words, the higher the richness and evenness, the higher the diversity) (Shannon and Weaver 1949, Magurran 1988, Guo *et al.* 2003). The Simpson's index of dominance (Magurran 1988). Both these formulae are shown below-

$$H' = \sum p_i \times \ln p_i$$

$$D_s = \sum \{p_i(p_i - 1) \div N(N-1)\}$$

where S is taxa richness; p_i is the proportion of i^{th} taxa; p_i is estimated by n_i/N, where n_i is the area covered by i^{th} 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, subgroups and soil series (Soil Survey Staff 2014).

Results and Discussion

Formation of soils in the hilly areas of Konkan

Konkan comprises of two different types of landscape, one is popularly called Konkan coast and other is a part of the Western Ghats. The latter part is commonly known as Sahyadri which forms a western edge of the Deccan plateau with several basaltic lava flows. Coast in the Western Ghats is a narrow strip which is nearly 820 km long and 15-20 km wide.

Spatially-associated red and black soils are common in the Konkan coast. The formation of red soils was possible in the prevailing humid tropical climate due to the process of laterization, which is a prolonged process of chemical weathering to produce the wide variety of Fe and Al-rich soils with typical red colour. Long exposure of the red soils formed in Konkan has hardened these soils to form a hard laterite rock in many areas which are devoid of vegetation. Unlike the soils in the north- eastern part of India (Bhattacharyya *et al.* 1997) and the lateritic soils in Kerala (Chandran *et al.* 2004). These red soils in Konkan and the Western Ghats are rich in bases qualifying them to be classified as Alfisols and not Ultisols (Soil Survey Staff 2014). Earlier studies on red soils of the Western Ghats showed the presence of calcium- rich zeolites even in the present humid climate. This suggested that the loss of bases during leaching of soils is regularly replenished by bases from this calcium-rich zeolites (Bhattacharyya *et al.* 1993, 1999, 2006).

Presence of black soils (Vertisols and their intergardes) in the humid tropical climate was reported in the Western Ghats (Bhattacharyya *et al.* 1993). These soils are common in the northern zone of Konkan. These are rich in shrink-swell minerals (smectites) and are still preserved in the present day humid tropical climate in Konkan. Clay CEC values of these Vertisols indicate

Table 2. Characteristics of selected soils in Konkan, Maharashtra

Soil Type	Soil Series	Depth (cm)	Clay (%)	EC dSm^{-1}	pH	Organic Carbon (%)	$CaCO_3$ (%)	CEC [cmol (+)kg^{-1}]	Clay CEC [cmol (+)kg^{-1}]	Mineralogy class*	Soil Classification**
Black	Pural	0-4	30.5	-	5.3	5.03	0	13.6	45	Smectitic	Lithic Ustorthents
Red	Vengurla	0-16	48.4	0.2	5.8	1.32	0	17.9	37	Mixed	Ultic Haplustalfs
		16-44	54.6	0.18	6	0.75	0	18	33		
		44-84	61.7	0.34	6	0.52	0	22.5	36		
		84-107	63.2	0.22	6.3	0.52	0	24.2	38		
		107-140	64.6	0.26	6.1	0.58	0	24.4	38		
Red	Nandgaon	0-18	51.4	<0.2	5.7	2.77	0	25.5	50	Smectitic	Typic Haplustepts
		18-33	54.7	<0.2	5.9	nd	0	24.8	45		
		33-56	57.3	<0.2	6.1	nd	0	28.8	50		
Red	Amboli	0-14	35.8	<0.2	5.5	3.51	0	19.2	54	Smectitic	Typic Haplustepts
		14-30	38.2	<0.2	5.5	2.61	0	19.7	52		
		30-45	30.6	<0.2	5.5	2.46	0	19.3	63		
Red	Rajapur	0-16	34.5	<0.2	5.9	2.66	0	11.2	33	Mixed	Lithic Ustorthents
Red	Sangameshwar	0-8	35	<0.2	5.5	2.01	0	19	54	Smectitic	Lithic Ustorthents
		8--40	38.5	<0.2	5.8	1.66	0	25.2	65		
Black	Palghar	0-15	55.4	6.5	6.9	1.02	3.9	46.3	84	Smectitic	Vertic Halaquaepts
		15-35	58.5	5.3	7.6	0.95	2.9	47.5	81		
		35-53	61.7	8.5	7.8	0.72	4.0	54.7	89		
Black	Virthan	0-17	51.9	0.38	7.9	2.44	3.8	38.9	75	Smectitic	Entic Haplusterts
		17-43	55.1	0.35	8.1	1.01	3.8	37.6	68		
		43-61	56.4	0.2	8.4	1.01	3.6	40.8	72		
		61-85	56.6	0.2	8.4	0.92	3.5	41.8	74		
		85+	56.6	0.2	8.4	0.77	4.1	36.3	64		
Black	Jawahar	0-16	48.5	<0.2	5.9	1.77	0	22.8	47	Smectitic	Typic Ustorthents

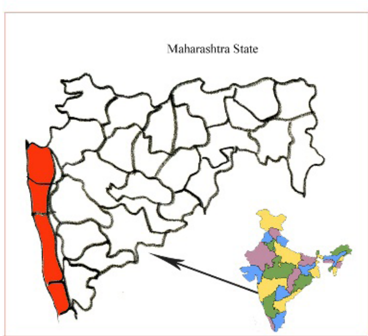
*Bhattacharyya *et al.* (1999),**Soil Survey Staff (2014); Revised organic carbon following Bhattacharyya *et al.* (2015)

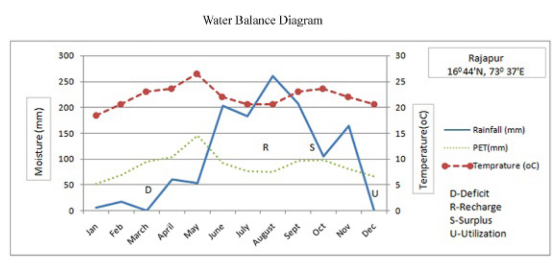
that these clays are rich in smectites (Bhattacharyya *et al.* 1997) (Table 2). Smectite minerals are the first weathering product of the Deccan basalt (Pal and Deshpande 1987). Persistence of smectitic black soils were explained by the presence of calcium-rich zeolites which not only retarded the transformation of smectite minerals to the stage of kaolinite, but also resulted in a poor drainage condition in the low lying basins of the Konkan coast, which makes cultivation of sub-merged paddy possible in these parts of Maharashtra. Schematic diagram of the soil physiographic relation is shown in Figures 7, 8 and 9.

Soils

Konkan soils are developed in the weathered basalts; black soils are formed in the lower elevation and red soils in the hills and foothills following a progressive landscape reduction process (Bhattacharyya *et al.* 1993) during humid climate. Due to presence of smectite minerals, the black soils shrink due to major stress in dry season (summer) and swell in presence of water (monsoon and/or irrigation). Black soils (Vertisols and their intergrades) are more prevalent in the northern part of Konkan as compared to the southern. Spatially-associated red soils are generally shallow and common in higher elevations and foot hills, which belong to Entisols, Inceptisols and Alfisols and are also spatially-associated with the black soils (Vertisols and their intergrades) (Soil Survey Staff, 2014) like in other humid parts of the Western Ghats (Bhattacharyya *et al.* 1993, 1999, Pal and Deshpande 1987, Bhattacharyya *et al.* 2000, Pal *et al.* 1989).

On many places in Konkan regions the Konkan landscape is often characterized by laterites which appear almost as hard surface formed due to irreversible hardening of free iron oxides. The hardening occurs due to ignorance of most of the farmers who open the soft soils and allow it to expose in open air, which may vary from one foot to several feet. Laterites are often thought to be infamous for not allowing any crops to grow (Magurran 1988). Interestingly, Konkan laterites support luxuriant vegetation. This suggests that the term laterite is a misnomer. The soil data base developed for





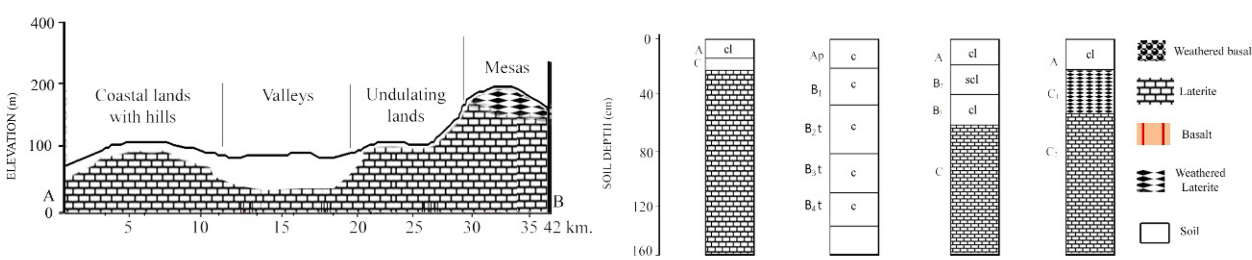


Fig. 7. Soil-landscape relation representing association of shallow soil in the hills and mesas (Entisols), medium soil in the undulating lands (Inceptisols) and deep soil in the valleys (Alfisols) in South Konkan, Maharashtra experiencing ~ 2500 mm rainfall.

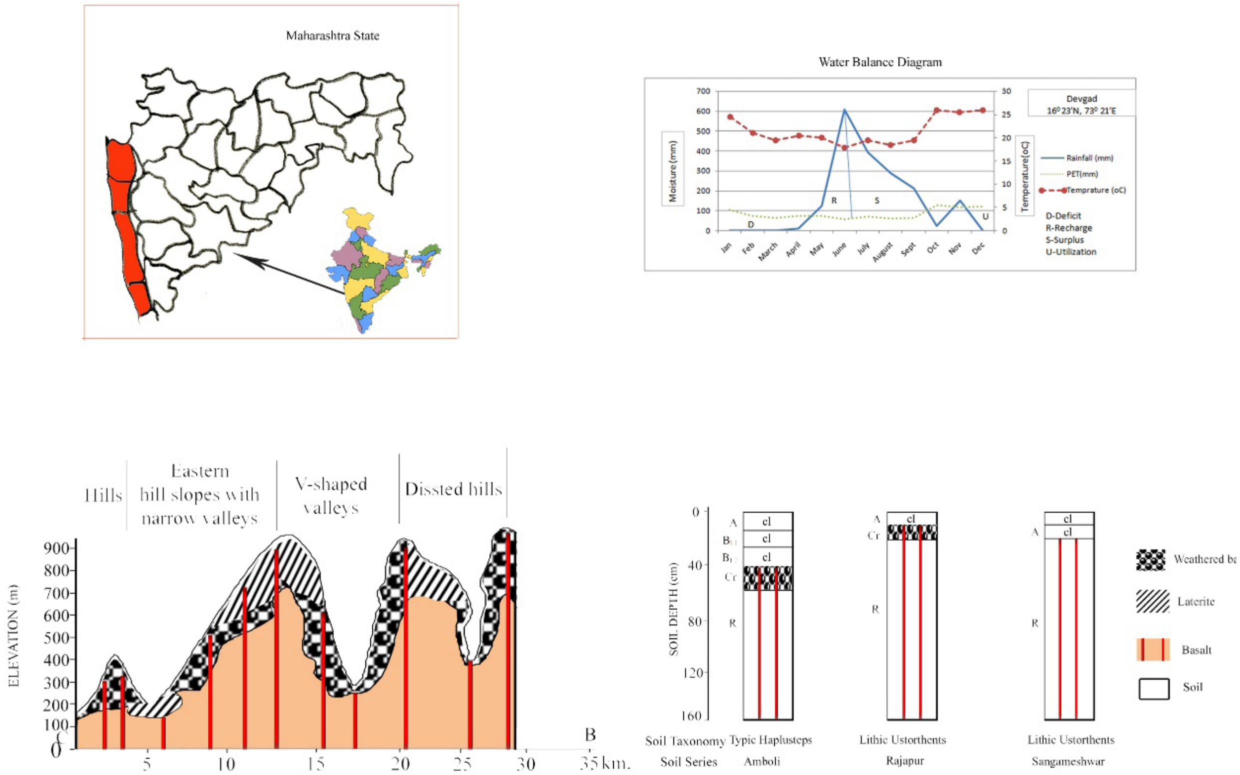


Fig. 8. Soil-landscape relation representing association of shallow soil in the hills (Entisols) and medium soil in the narrow valleys (Inceptisols) in South Konkan, Maharashtra experiencing ~3000 mm rainfall.

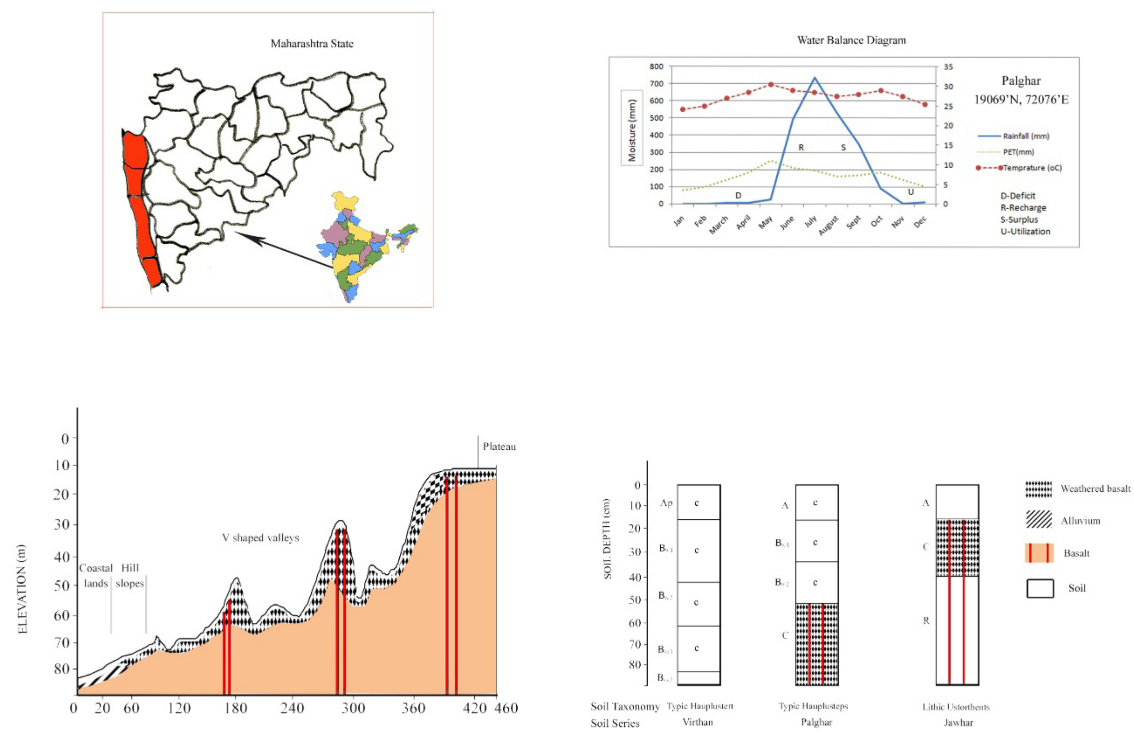


Fig. 9. Soil-landscape relation representing association of shallow soil in the hills (Entisols) and medium soil in the narrow valleys (Inceptisols) and deep black soil in the broad valleys (Vertisols) in North Konkan, Maharashtra experiencing ~2500 mm rainfall.

the Konkan, Maharashtra is described below for different districts in Konkan.

Soils of Sindhudurg district

Soils of Sindhudurg belong to three soil orders viz. Inceptisols, Alfisols and Entisols. Inceptisols are the dominant type (Figure 10). The soils in this district have five subgroups and seventeen soil series.

Soils of Ratnagiri district

There are three soil orders viz. Entisols, Alfisols and Inceptisols, with shallow Entisols occupying nearly 50% area of the district indicating huge loss of surface soils due to water erosion (Figure 11). Total nine sub groups and twenty three soil series are reported in this district.

Soils of Raigad district

This district has four soil orders viz. Entisols, Inceptisols, Vertisols and Alfisols. Most of the soils which are moderately deep to deep fall in categories of Vertisols and Alfisols (Figure 12). This district has total ten sub groups, and fifteen series.

Soils of Thane district

Inceptisols, Entisols and Vertisols are identified in this district. Interestingly, Alfisols have not been reported from this district (Figure 13). This district has eight sub groups, and fifteen soil series.

Soil Parameters

Cation exchange capacity of clay (Clay CEC): Clay CEC indirectly shows dominant clay minerals in soils. Nearly 77 % soils in Konkan are smectitic indicating that these soils i) have more water-holding capacity to grow short-duration rabi crops and thus can help in increasing the cropping intensity in the region, ii) can store more nutrition, and iii) can sequester more organic carbon (Figure 14).

Soil Reaction (pH): Nearly 90 % soils in Konkan are slightly to moderately acidic; the black soils are alkaline. Interestingly, black soils constitute ~25 % in Konkan.

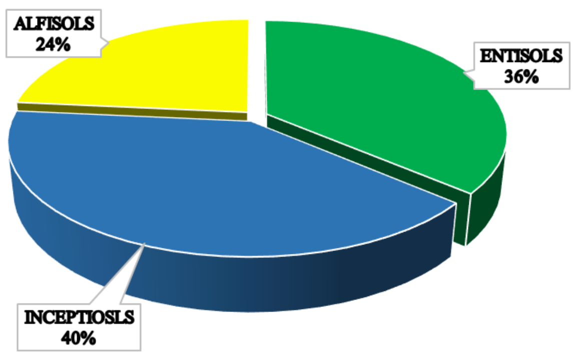


Fig. 10. Soils of Sindhudurg district and their distribution.

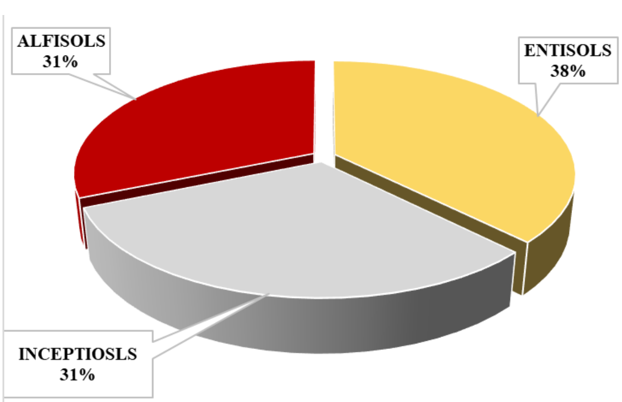


Fig. 11. Soils of Ratnagiri district and their distribution.

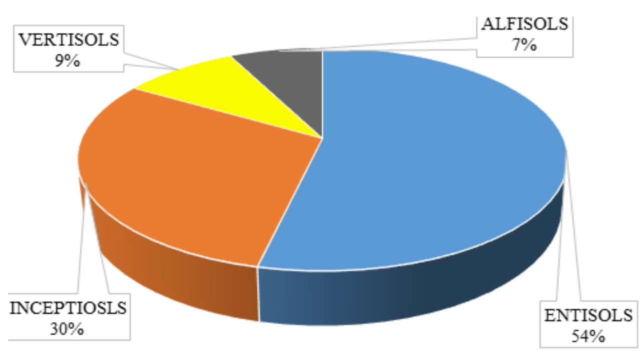


Fig. 12. Soils of Raigad district and their distribution.

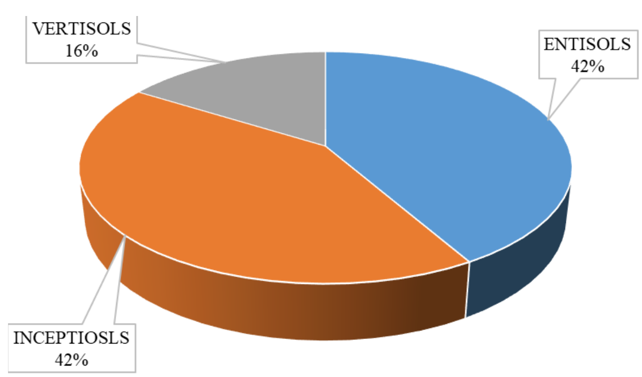


Fig. 13. Soils of Thane and Palghar districts and their distribution.

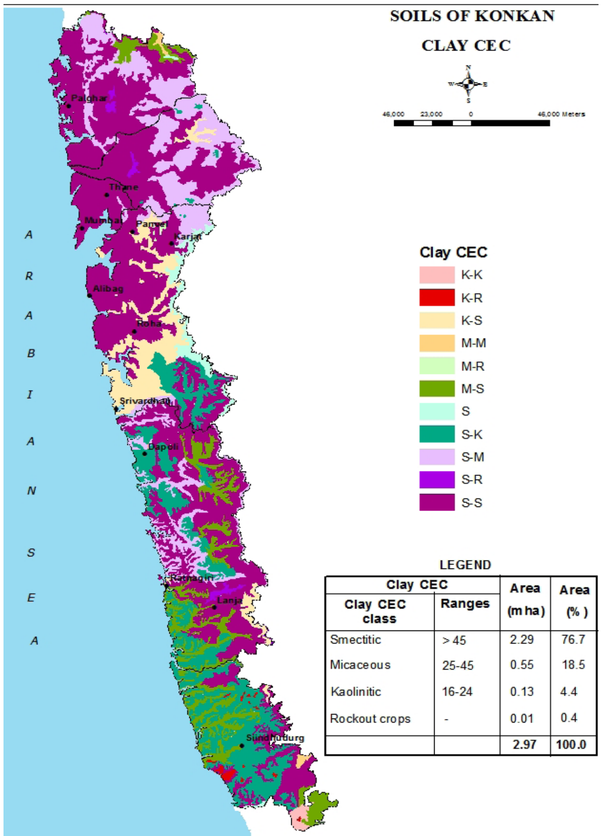


Fig. 14. Soils of Konkan: cation exchange capacity of clay (cmol+kg^{-1})

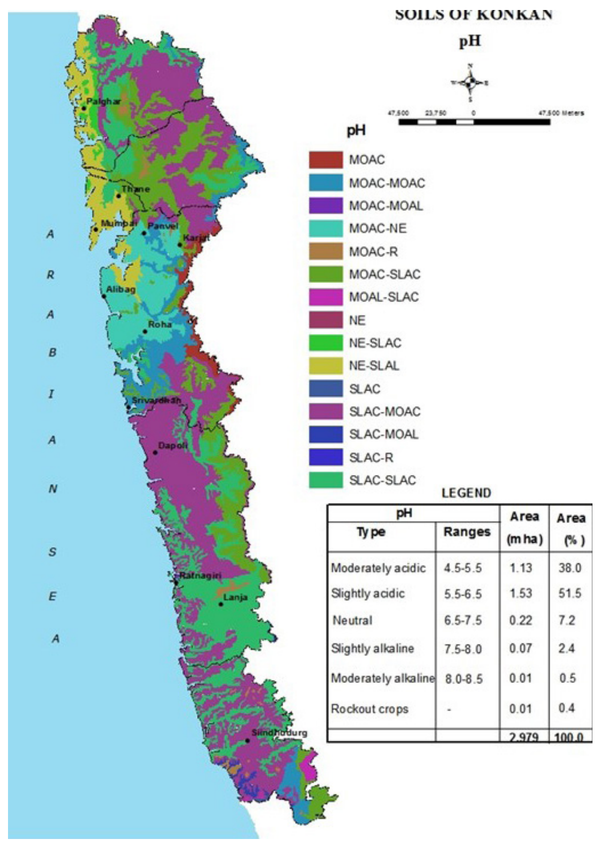


Fig. 15. Soils of Konkan: soil reaction (pH)

Therefore remaining 15% black soils are acidic. These black soils are also dominant in typical shrink-swell minerals which can survive only in alkaline environment. Persistence of these soils even in acidic environment suggest the presence of Ca-rich zeolites in these soils (Bhattacharyya *et al.* 1993, 1999, 2006) (Figure 15).

Soil organic carbon (SOC)

SOC status signifies the soil quality and health. Nearly 71 % Konkan soils are rich in OC (Figure 16) (Bhattacharyya *et al.* 2008, 2009). SOC stock often helps to prioritize areas for SOC sequestration. In Konkan, most of the soils are maintaining enough SOC stock in surface (Figure 17) suggesting that the present land uses are maintaining soil quality and health (Figure 18) (Bhattacharyya *et al.* 2008, 2009). This will be discussed later.

Soil Texture: Four soil textural classes are identified in Konkan. Nearly 70 % soils belong to sandy clay to sandy clay loam suggesting good drainage of these soils making fruit trees ideal for this region (Figure 19). Interestingly, the soils with heavy texture (due to more clay content) are black soils and are mostly used for paddy cultivation.

Soil Diversity in Konkan

Diversity within any varied system can be computed using any of the several diversity indices developed for the purpose. Computing soil diversity index is an emerging tool to understand and compare soils of different regions. An attempt is made to find out the quantitative index of soil diversity in the coastal ecosystem of Konkan, Maharashtra.

Taxon richness

The total number of soil orders in Konkan region are four i.e. Entisols, Inceptisols, Alfisols and Vertisols. Vertisols are reported only in Raigad and Thane districts. Alfisols do not occur in the northern part of Konkan in Thane district. 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

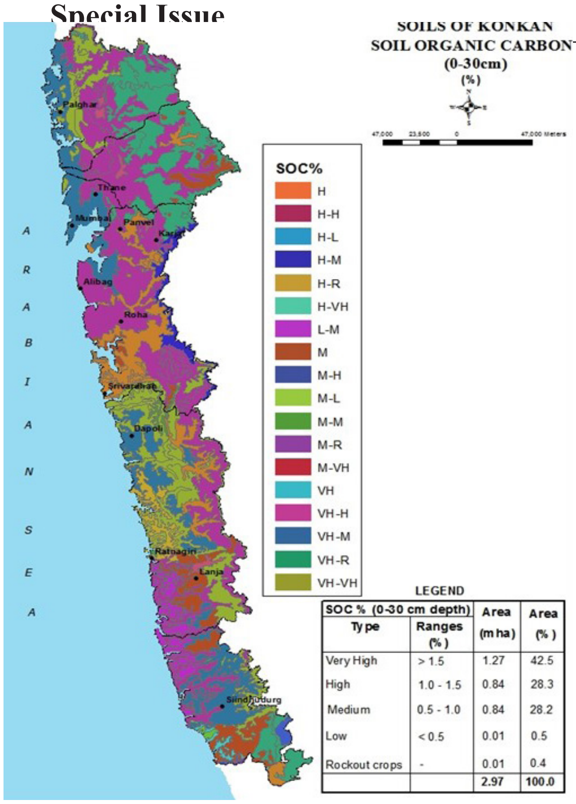


Fig. 16. Soils of Konkan: organic carbon

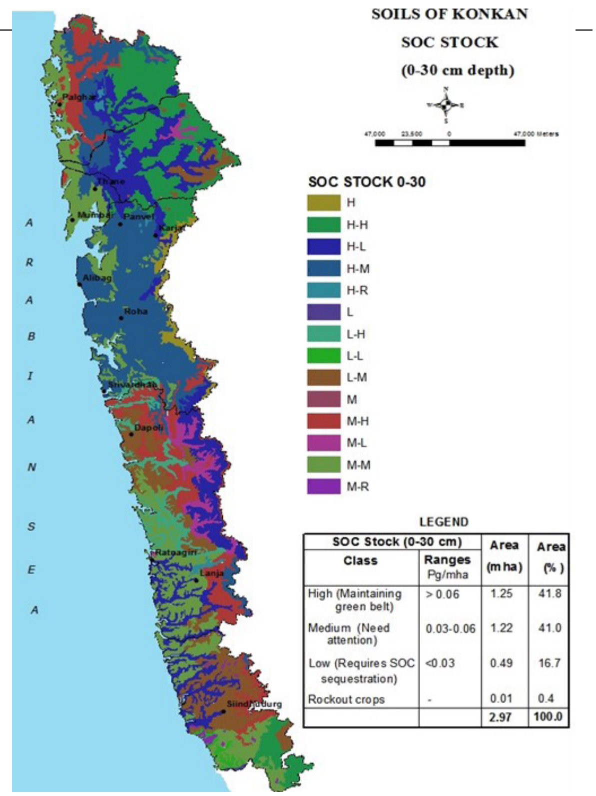


Fig. 17. SOC stock per unit area in Konkan (0-30 cm depth)

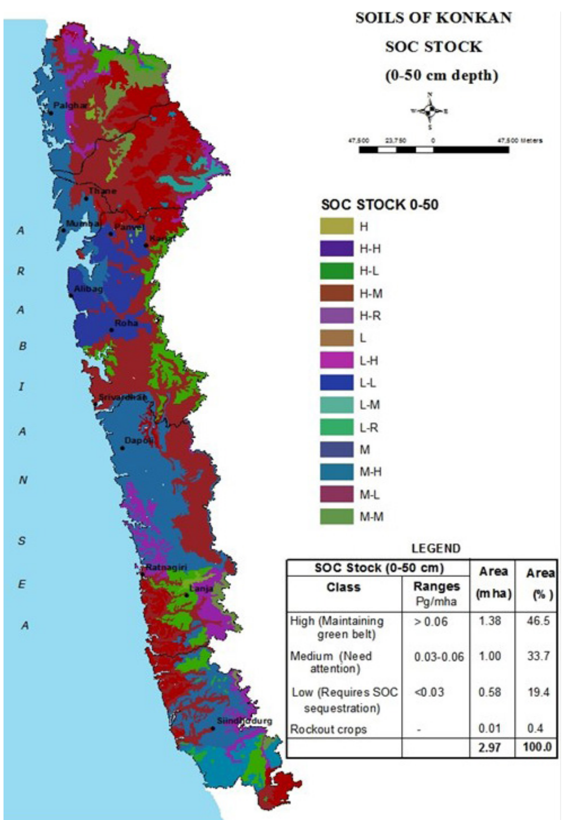


Fig. 18. SOC stock per unit area in Konkan (0-50 cm depth)

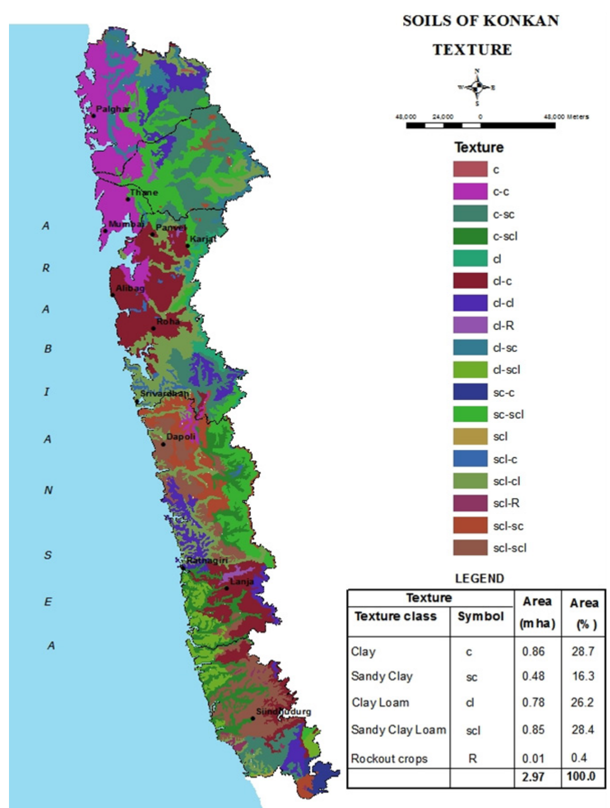


Fig. 19. Soils of Konkan: soil texture (particle size distribution)

taxon richness followed by Sindhudurg (17) and Raigad and Thane (15 each).

Shannon Diversity

At the taxonomic level of soil series, the diversity was maximum in Ratnagiri district followed by Sindhudurg, Thane, and Raigad (Figure 20). Whereas at the level of soil suborder, the diversity was maximum in Thane district followed by Raigad, Ratnagiri and Sindhudurg (Figure 21). As expected, exactly opposite trends were found in terms of taxa dominance for both taxonomic levels (Figures 22 and 23).

The soil diversity obviously increases at the lower levels in soil taxonomy (Soil Survey Staff 2014). This is in tune with an earlier study at the national level (Bhattacharyya 2016) even though that study did not attempt diversity assessment at series level. Interestingly, the diversity 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 series level Ratnagiri soils show more diversity. 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.

Potassium stock in Konkan soils

Potassium has been identified as a deficient element after nitrogen and phosphorus in soils. Of the prime K-bearing minerals, only micas are more important than K-feldspars so far as K- supplying capacity of minerals to plants are concerned. As the Deccan basalt does not

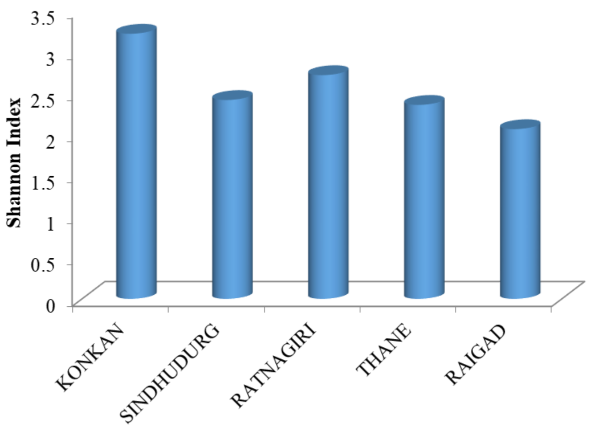


Fig. 20. Shannon Diversity index in different districts of Konkan region and for the region at the taxonomic level of soil series.

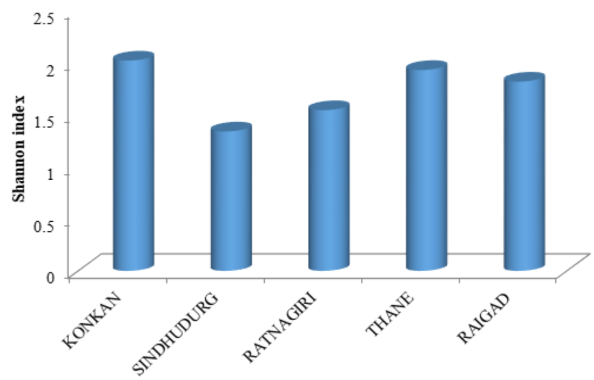


Fig. 21. Shannon Diversity index in different districts of Konkan region and for the region at the taxonomic level of soil subgroup.

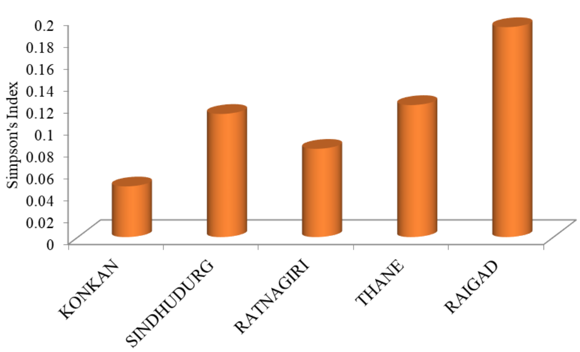


Fig. 22. Simpson's index of dominance in different districts of Konkan region and for the region at the taxonomic level of soil series.

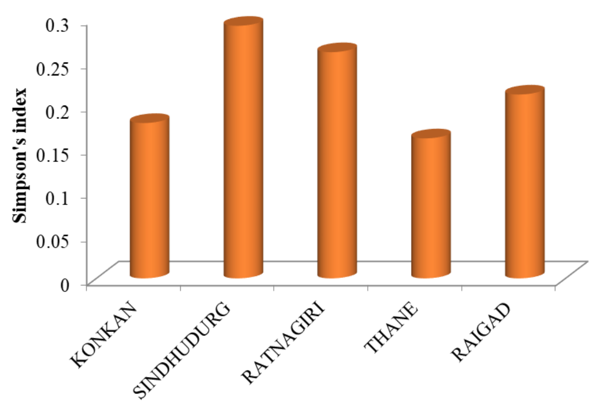


Fig. 23. Simpson's index of dominance in different districts of Konkan region and for the region at the taxonomic level of soil subgroup.

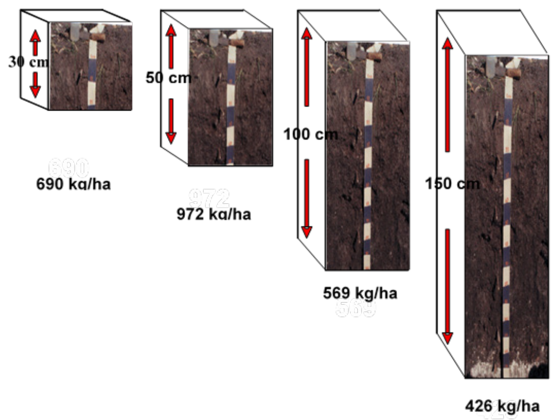


Fig. 24. Potassium stock in different depths of soils in Konkan, Maharashtra.

contain micas, the red and black soils derived from its alluvium are not expected to be micaceous like the soils of the Indo-Gangetic Plains (IGP). The small amount of mica in red and black soil association which are common in Konkan are concentrated mainly in silt and coarse clay fractions. Their parental legacy is due to erosional and depositional episodes in these soils developed in the weathered Deccan basalt.

Geo-referencing soil potassium datasets is an important step to estimate potassium stock in Konkan soils (Bhattacharyya *et al.* 2007). Potassium stock in soils of Konkan is detailed in four different depths (0-30, 0-50, 0-100 and 0-150 cm) (Figure 24).

Ideally, soil potassium stock increases with depth of soil as is observed in soils of the Indo-Gangetic Plains and the black soil region (Bhattacharyya *et al.* 2007). Interestingly, in Konkan soils, the potassium stock showed a decreasing trend with the increase in soil depth. The major reason is that the soils of Konkan region are shallow due to soil erosion and are mostly limited to 40-50 cm depth; below this hard rock or weathered parent material (basalt) is observed. This makes insufficient data of K on soils beyond 50 cm depth. However for deep to very deep soils formed in the few inter hill basins, K data are generated and are used to estimate potassium (K) stock. A comparative account of K stock of three zones of IGP, BSR and Konkan in four different depths (Table 3) suggests that potassium in Konkan region is more than that in the IGP in first 30 cm depth of soils. However, beyond 30 cm depth, potassium stock is low in Konkan soils when compared to other two regions. This suggests that potassium application in Konkan soils both for annual and perennial crops is necessary to maintain the level of native soil potassium as well as to enhance crop performance.

Table 3. Soil Potassium Stock in three different regions in India: a comparison

Soil Depth (cm)	Soil Potassium Stock (kg ha^{-1})		
	Indo-Gangetic Plains	Black Soil Region	Konkan
0-30	667	992	690
0-50	1200	1583	972
0-100	2542	3063	569
0-150	3664	4554	426

Table 4. Potassium stock in different districts in Konkan, Maharashtra (kg ha^{-1})

Districts	Soil depth (cm)		
	0-30	0-50	0-100
Ratnagiri	446	497	447
Sindhudurg	511	895	747
Raigad	665	345	604
Thane	727	1195	801
Palghar	2489	4260	4260

Table 4 indicates the soil potassium stock in five districts of Konkan, Maharashtra. A closer look indicates that Ratnagiri and Sindhudurg soils have relatively low potassium stock as compared to Raigad and Thane soils. Interestingly Palghar soils contain nearly 2500 kg ha^{-1} potassium in first 30 cm depth. When we compared datasets in southern and northern Konkan, we find that northern Konkan has more soil potassium in first 50 cm depth as compared to south Konkan (Figure 25). This might suggest that there is a scope for revising recommended doses of K fertilizers for crops in northern Konkan which will help the farmers to revise the dose of K fertilizers.

Climatic variation in Konkan and Potential for Carbon sequestration in Konkan soils

Soils are under pressure to grow more food due to increasing demand of the growing population. It has been estimated that the earth's soils need to provide separating, regulating and provisioning of an estimated 9.6 billion people (Bhattacharyya *et al.* 1997). It has also been opined that SOC is critical to the majority of the surveys, which might also include the role of inorganic carbon for tropical soils with special reference to the resilience of soil health (Bhattacharyya 2016). The

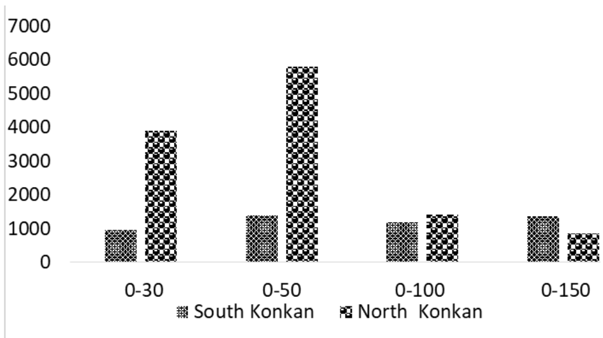


Fig. 25. Potassium stock in soils of north and south Konkan, Maharashtra (kg ha^{-1}): a comparison.

Fig. 26. Soil organic carbon stocks (Pg) in Konkan, Maharashtra.

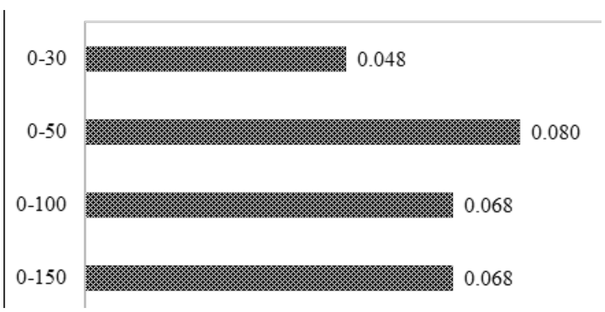


Fig. 27. Soil inorganic carbon stocks (Pg) in Konkan, Maharashtra.

role of soil carbon for multiple benefit has been dealt elsewhere in details. (Milne *et al.* 2015, Banwart *et al.* 2013).

Relevance of organic and inorganic forms of soil carbon has been dealt by others. The importance of inorganic form of carbon (SIC) has been registered in national and international journals for quite sometimes (Bhattacharyya *et al.* 2008). In India a few parts of the country contain soils with high amount of SOC and less amount of SIC, and the other parts show a reverse trend. Soils, as a matter of fact, act as a major sink and source of atmospheric carbon dioxide. The sequestration of organic and inorganic carbon in soils and its monitoring requires basic information of both organic and inorganic carbon data in soils (Bhattacharyya *et al.* 2008). This has been continuously addressed for the last sixteen years for Indian soils, for the soils of the Indo-Gangetic plains (IGP), for the black cotton soils and for those of the north eastern region (Bhattacharyya *et al.* 2016, 2008, 2016, 2015, 2000, 2000, 2004). In view of the fragile eco-system in the coastal areas of Maharashtra viz. Konkan, the soil health always remains an important issue. Since there is a dearth of information on carbon stocks of Konkan soils the present attempt aims to bring the primary data sets on soil carbon in the following.

Figure 26 shows that SOC stock in first 30 cm depth as 0.185 Pg (1 Pg = 10^{15} gram). In general, soil carbon stock increases with soil depth (Bhattacharyya *et al.* 2008). However, for the Konkan soils, the SOC stock decreases to 0.05, 0.07 and 0.039 Pg in 0-50, 0-100, 0-150 cm depth, respectively (Figure 26). This happens because majority of Konkan soils are shallow and do not go beyond 50 cm depth and are mostly limited to < 50 cm depth.

Konkan represents the coastal eco system with an average rainfall of 3000-4500 mm. We understand that soil formation under high rainfall regime, calcium carbonate (SIC), should be rare and almost non-existent. Interestingly, SIC is reported in soils in some parts of Konkan. Therefore, we could estimate the SIC stocks for 0-30, 0-50, 0-100 and 0-150 cm and the values are 0.048, 0,080, 0.068 and 0.068 Pg (1 Pg= 10^{15} g), respectively (Figure 27).

Figure 28 shows the changes in carbon stock of the selected BM spots in Konkan, over two different time periods, namely 1987 and 2017. An increase in SOC stock of more than 100 % and a decrease of SIC stock to the tune of 59 % over last 30 years suggest the reduction in pedogenic carbonate formation or dissolution of carbonates due to more vegetation. The areas are under paddy cultivation. While studying long-term lowland rice and arable cropping effects on carbon of tropical soils Sahrawat *et al.* (2005) indicated an increase in SOC content. The results of Palghar soils in Konkan support that soils under lowland rice system preferentially accumulate organic matter and are important for sequestering atmospheric C. Soil submergence, as practised in lowland rice systems, also seems to prevent formation of $CaCO_3$ and thus prevents or slows down degradation of calcareous soils such as Vertisols to sodic soils. Besides, the ameliorative effects of flooding on

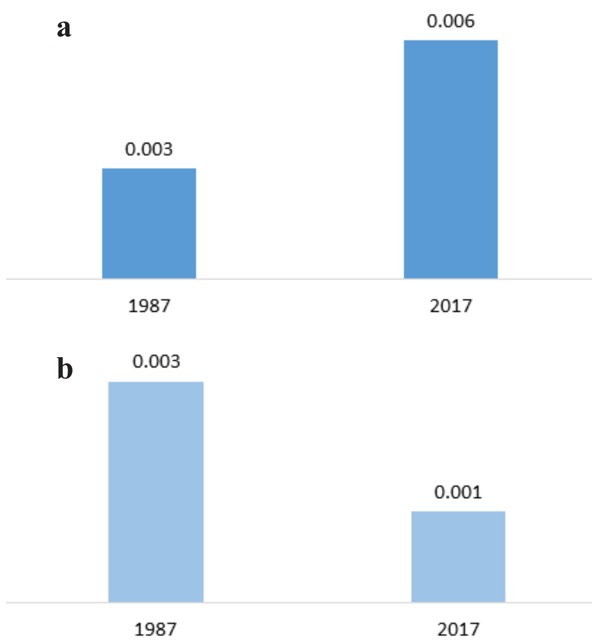


Fig. 28. Changes in (a) soil organic carbon (SOC) and (b) soil inorganic carbon (SIC) stock over 30 years (1987–2017) in Palghar soils in Konkan under paddy cultivation.

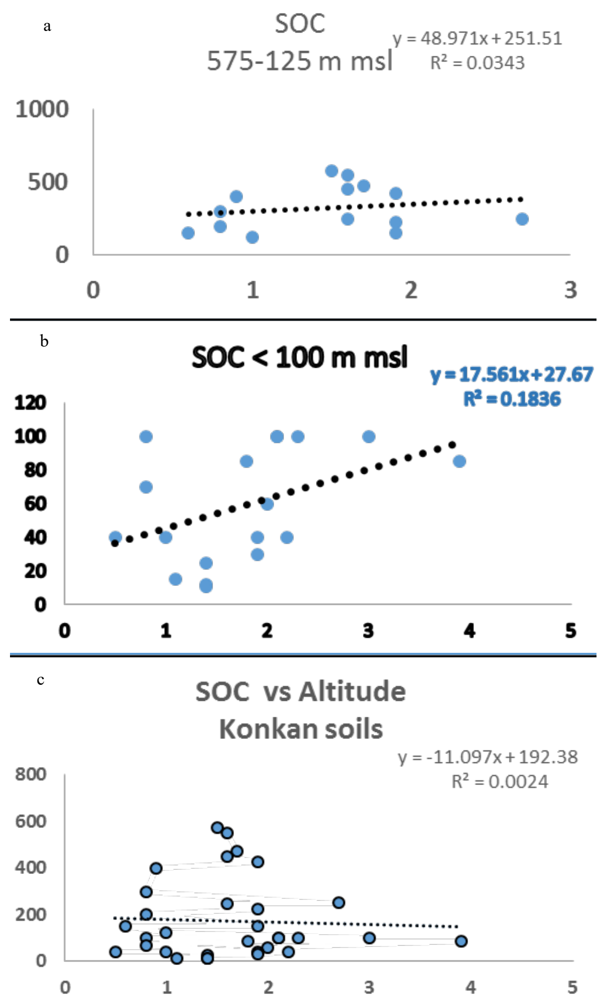


Fig. 29. Organic Carbon distribution with altitude in the soils of Konkan, Maharashtra, a) within 575-125 m above mean sea level (MSL) b) within < 100 m above mean sea level; and c) within >575m above mean sea level to the coast .

pedoenvironment and fertility are influenced by chemical and electrochemical properties of soils (Bhattacharyya *et al.* 2007).

Konkan represents a part of the Western Ghats (Challa *et al.* 1999) and thus shows variation in topography, which indicates a probable relation with soil carbon and altitude. Altitude affects tropical temperature and alpine environment and with the change in altitude, climatic conditions change and so do the flora. Precipitation and temperature are the major components of climate which changes with altitude. The vegetation and litter coverage increase with elevation. Soil organic matter increases with altitude effecting the formation of Mollisols which are dominant in Sikkim (Gangopadhyay *et al.* 2018). Unlike Sikkim soils, Konkan soils show a different kind of trend with SOC in relation with altitude (Figure 29). From the maximum elevation (575 m above MSL) to the coast, a decreasing trend with SOC and altitude is observed (Figure 29 c). When the data were segregated into three different altitudinal ranges viz 5-75, 100-25 m and less than 100 m, the relation between SOC and altitude appears interesting. There is a strong SOC -altitude relationship within for soils formed below 100 m above MSL (Figure 29 b). However, the soils situated at the higher altitude (575-125 m) the relation is not promising (Figure 29 a). This is in sharp contrast to the positive correlation found in the soils of Sikkim (Gangopadhyay *et al.* 2018). The soil data sets of Maharashtra generated earlier (Tiwary *et al.* 2015) might have ignored the presence of brown forest soils (Mollisols in US soil Taxonomy (Soil Survey Staff 2014) containing high organic carbon (3-4 % soil organic carbon) in the adjoining Western Ghats that are spatially-associated with red (Alfisols) and black (Vertisols and their intergrades) soils in the Western Ghats (Bhattacharyya *et al.* 1999, 2006, Gangopadhyay *et al.* 2018).

The soil carbon data of Konkan, Maharashtra helps to find out the state of soil health in terms of organic matter content in soils vis-à-vis soil physical and microbial growth. Earlier experience in Tripura representing the north east region (NER) showed relatively high SOC contents in the hills, *tilla* lands (small hillocks) and also in the valleys. The NER in India represents the green belt. Earlier SOC level of 1% was shown as a threshold limit of soils with good health (Bhattacharyya 2016). Following the soil information system using fourteen (ACZ) of the Planning Commission (Bhattacharyya *et. al.* 2008), Tripura was reported to maintain the threshold limit of 0.046 Pg million ha^{-1} SOC stock as compared to all India average of 0.029 Pg million ha^{-1}. The agro-climatic zone number two (ACZ 2) representing the entire NER, stores organic carbon to the tune of 0.064 Pg ha^{-1} (Bhattacharyya *et al.* 2001; 2008) (Figure 30). The present datasets indicates that Konkan soils maintain the SOC stock of 0.062 Pg million ha^{-1}. Therefore, the storage rate of OC in Konkan soils qualifies them to be in to green belt of the existing Konkan ecosystem.

Presence of Ca-zeolites in soils of the Western Ghats (Bhattacharyya *et al.* 1993, 1999) and also in Maharashtra (Figure 31) favoured more organic carbon sequestration in soils (Bhattacharyya *et al.* 2006) as evidenced by the formation and persistence of Mollisols in the basaltic terrain (Bhattacharyya *et al.* 2006). The first approximation of quantitative estimates of zeolitic soils in India indicates nearly 2.8 million ha under zeolitised soils with maximum area in Maharashtra (Bhattacharyya *et al.* 2015). It was reported that in absence of detailed mineralogical analysis of clay and silt fractions of soils the dominant minerals can be ascertained using the clay CEC data of soils (Shannon and Weaver 1949). The revised datasets of dominant soil in Konkan show that the mineralogy is smectitic (Table 1). In most of the cases smectite dominant red and black soils are reported to be zeolitised in the Western Ghats (Lal 2000).

Micronutrients status in Konkan soils

The status of micronutrients in Konkan soils is detailed by Patil 2001. (Figures, 32, 33, 34, 35, 36). Available iron (Fe) is plenty in Konkan soils and the mean values in North Konkan, South Konkan, and coastal saline soils are much above the critical level (Tandon 2009) (Figure 32); although its deficiency has been reported in calcareous black soils (Vertisols and their intergrades) (Yadav 1988). Same is the scenario for available manganese (Mn) (Figure 33). Patil (2001) reported minimum content of Mn in black soils. Mean available copper (Cu) content is reported to be above the critical level of 0.1 mg kg^{-1} (Figure 34). Cu deficiency was not observed in paddy soils of Konkan (Lal 2000). Mean zinc (Zn) level is relatively high in black soils in North Konkan (Figure 35); in general, Zn deficiency is low in Konkan soils although 8 percent paddy soils have been reported to be deficient in Zn (Patil 2001). Revised estimate showed nearly 28 percent soils in Konkan are deficient in Zn (Figure 35). Boron content in Konkan soils is low and shows deficiency symptoms (Figure 36). Figure 35 shows an overall deficiency of Zn, B and Mo in Konkan soils and suggest appropriate management interventions.

Planting of Mango in lateritic rock outcrops in Konkan

Areas with soil depth of 80-100 cm were considered as ideally suitable for mango cultivation. This excluded

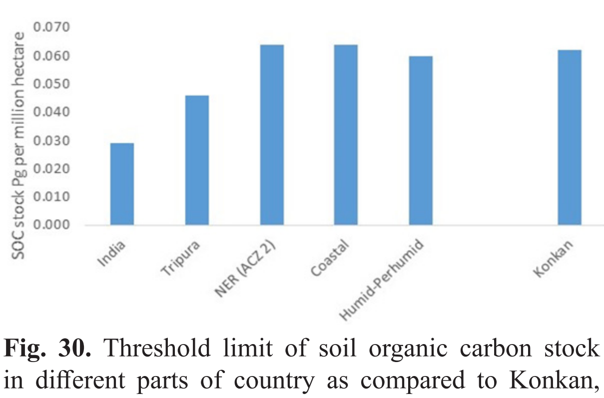


Fig. 30. Threshold limit of soil organic carbon stock in different parts of country as compared to Konkan, Maharashtra.

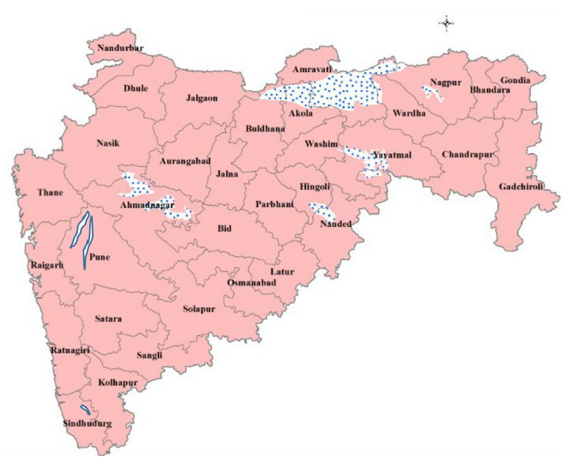


Fig. 31. Distribution of zeolitic soils in Maharashtra.

large tracts of rocky areas particularly in south Konkan because they were considered as uncultivable wastelands because of laterite rock outcrops. With the horticultural revolution in Konkan region post-1990, all the suitable land for mango with specified depth was occupied immediately. This prompted some farmers to explore the possibility of planting mango on apparently hard-rock areas occupied by lateritic outcrops. Their age-old observations of early flowering and production of good quality mangoes of Alphonso trees planted in the natural cracks on rocky areas were the major reason behind adopting this new strategy. Advanced mechanization of drilling, blasting and excavation of pits in hard rocks played an important role in the spread of this approach. Rough estimation indicated that nearly 3 lakh hectares of such hard rock area is fallow in Konkan, Maharashtra.

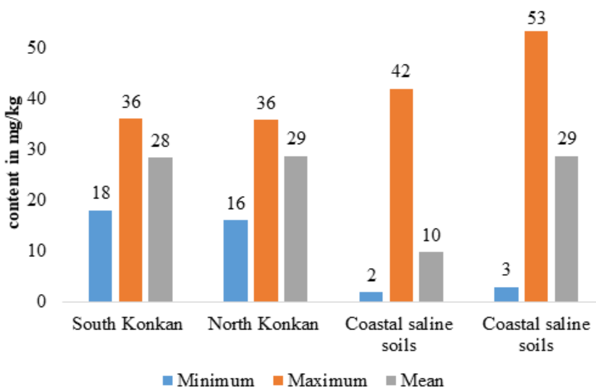


Fig. 32. Status of Iron (Fe) in Konkan soils.

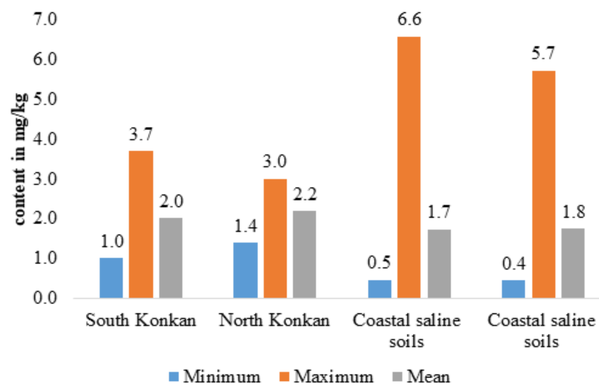


Fig. 35. Status of Zinc (Zn) in Konkan soils.

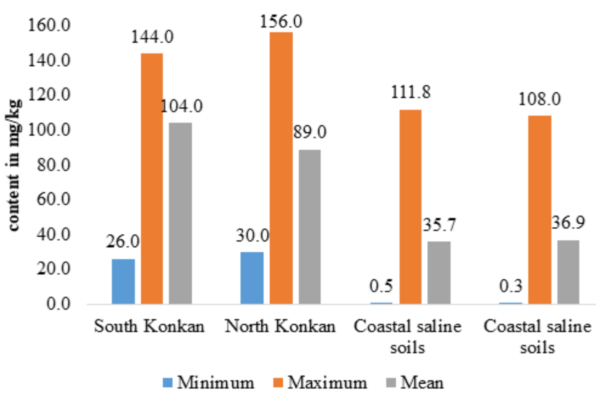


Fig. 33. Status of Manganese (Mn) in Konkan soils.

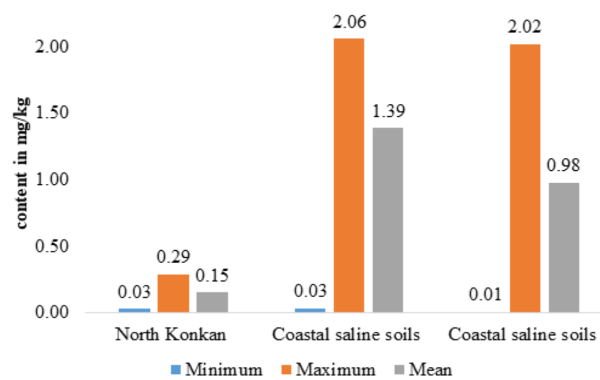


Fig. 36. Status of Boron (B) in Konkan soils.

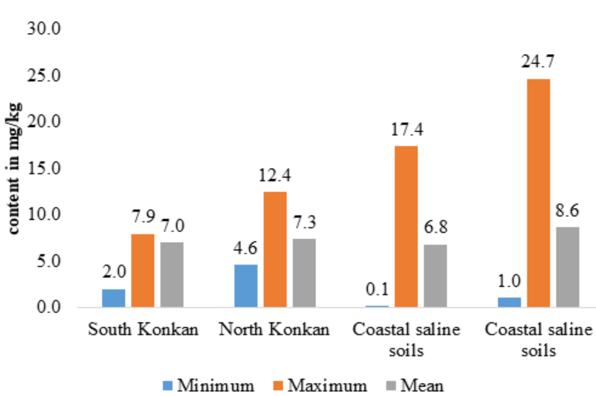


Fig. 34. Status of Copper (Cu) in Konkan soils.

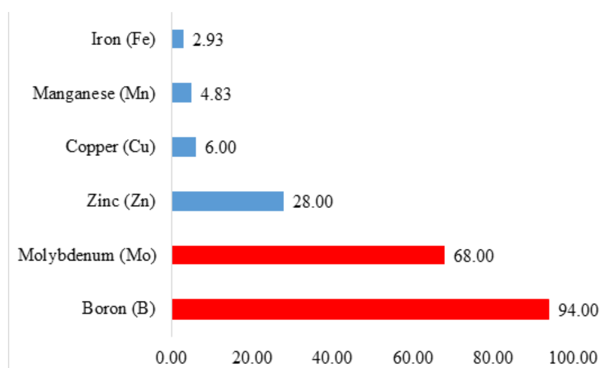


Fig. 37. Deficiency of micronutrients in Kokan soils (values in per cent).

Some success stories indicate that Alphonso grown on such type of so called wastelands bear fruits early which are sold at a premium price in metros and abroad due to its characteristic taste and colour. These areas are Sindhudurg district (about 30% of total area in Vengurle, Malvan and Deogad tahsils) and Ratnagiri district (10-15% of total area in Rajapur, Lanja, Ratnagiri, Guhagar, Dapoli and Mandangad tahsils).

There are mixed experiences of the farmers in terms of failure and success of hard rock mango cultivation (Salvi *et al.* 2009). The success of this technology mainly depends on (1) type of rock (continuous hard, semi-hard or soft rock determining root penetration and water drainage), (2) generation of cracks in the side-walls and bottom of the pit facilitating root spread, (3) dimensions of the pit to occupy at least 75-100 cubic feet of soil, (4) quantum and quality of soil used for refilling the pits, (5) time and intensity of prunning as per the planting density adopted. Primary laterite is a rock of sub-aerial formation of fine-grained and monogenous texture with the exception of iron content. It has been reported to form mainly in the Deccan plateau especially on the higher elevation of the Western Ghats with variable thickness of 50-90 ft in the southern Maharashtra including Mahabaleshwar (Pascoe 1964). Most of the laterites found in the low lying coastal region on the east and west side of the peninsula is termed as secondary laterite. Between Mumbai and Ratnagiri, the appearance of secondary laterite is well pronounced and it extends down south to Goa separating the Western Ghats from the sea. Between Ratnagiri and Goa, the secondary laterite forms a kind of plateau with a general elevation of 200-300 ft. above MSL from the coast to the inland towards the Western Ghats. This laterite is also found on a higher elevation and it shows it's conglomerati (Pascoe 1964). It is found at 35 ft in Ratnagiri which is less than the average. In the south of Malvan, the underlined rock is reported (as in other parts of the Deccan trap) of gneissic and metamorphic origin. The bulk of the laterite of India is reported near the Western Ghats and in the southern part of Maharashtra. Laterite is highly porous and when freshly queried it may be very soft and can be cut by a pick or a knife. It hardens when exposed to air due to desiccation of the argillaceous components resulting in redistribution of ferric oxides.

The fresh pits prepared for planting Alphonso in Phondaghat (Sindhudurg district) are situated exactly near the sea coast (Figure 38). The samples collected from different depths from these pits were analyzed and the data are shown in Table 5. General observations made in these laterite areas suggest presence of cracks, relatively loose debris and mixture of red and black soils. These soils appear to nourish the mango trees naturally. This is notwithstanding with the fact that normal practice after excavation is to fill with soils (brought from other areas), cow dung and super phosphate. Appropriate productive mechanism is also suggested to avoid termites in the form of mixing the soil with 100 gm. of Folidol (methyl parathion) (Salvi *et al.* 2009).

It seems probable that after the initial drudgery of establishment in the hard rock aided by loose soil, manures and phosphorus, these trees receive consistent supply of nutrition from these zeolitized basalt. It has earlier been reported that these calcium-rich zeolites are present in the sand fractions to the tune of 2 - 3 % (Bhattacharyya *et al.* 1999, 2006, Srivastava 2002). It is quite probable that the hard basalts and its weathered counterparts (*murram*) should contain more zeolites to help in providing nutrition to the young mango plants. Earlier studies on mineralogical makeup of weathering rinds of basaltic indicated presence of smectite minerals even in relatively hard basalt rock (Bhattacharyya *et al.* 2018) (Figure 39). It, therefore, seems prudent to justify that the young Alphonso plants receiving nutrition from calcium- rich zeolites and smectite- rich weathered basalt to establish them into full grown trees bear excellent quality fruits. Proximity to sea to cause necessary stress may add to the overall success of this practice.

Table 5. Selected properties of the soils in Devgad, Sindhudurg district, Konkan

Sample No.	Depth	pH (Water)	pH KCl	Del pH	EC	Sand (%)	Silt (%)	Clay (%)	Fine clay (%)	Extractable Na (cmol(+) kg-^{1})	Extr. K (cmol(+) kg-^{1})	Extr. Ca (cmol(+) kg-^{1})	Extr. Mg (cmol(+) kg-^{1})	CEC (cmol(+) kg-^{1})	Base Saturation %
Ia*	75	5.62	3.92	-1.7	0.042	28	52	21	27	0.95	0.49	9.21	4.07	20	73
Ib	75	5.27	4.17	-1.1	0.092	15	37	48	23	1.38	1.13	4.65	2.32	18	54
IIa	75	5.27	4.14	-1.13	0.069	17	48	36	22	0.89	0.63	2.82	1.43	18	33
IIb	75	5.5	4.05	-1.45	0.046	28	51	22	21	1.05	0.53	0.44	3.89	19	31

*Sample I and II from the plots of 18 Mango Research Sub-centre, Rameshwar, Devgad, district Sindhudurg, Maharashtra.

Fig. 38. Mango plantation on hard rock planting (a) and (b) site of plantation while blasting and digging soils at Phondaghat, south Konkan, Maharashtra; (c) developed mango orchard on hard rock in south Konkan, Maharashtra.

Fig. 39. Basalt weathering (a) as in field; (b) onion peel weathering, and (c) cut surface showing rinds which contain smectite minerals.

Conclusions

Tropical soil formation model in the Western Ghats and Maharashtra is unique in soil science parlance because of the presence of soil modifiers like Ca-zeolites and thus does not match with soil physical and chemical properties in NER and in middle and lower Himalayas in India. Although Konkan has been characterized by hard lateritic out crop areas but the luxuriant vegetations are prevalent both in the upper niches as well as at the lower elevation. Since laterite has been defined as an infamous landscape not to support vegetation, the luxuriant vegetation in Konkani on laterites suggests that these are represented by soils with clays which are capable of holding more nutrition and moisture to support trees and crops. High organic carbon reserve in this soils support such connotation. Konkan soils occupy a vast area and therefore detailed basic and fundamental research are warranted to unravel the mystery of their excellent support to encourage the enterprises of forestry, horticulture and agriculture (Pascoe 1964, Ganguli *et al.* 2018, Bhattacharyya *et al.* 2018). This part of Maharashtra may reveal more information to enrich the available soil information system and the eco-system managers may fined these coastal areas as challenging sopts for future research to develop a viable coastal policy which can to act as a model for the entire.

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