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Soil Survey, the Profession I Embraced: a Few Pages from my Tour Diary

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Abstract: On 2022 World Soil Day (WSD), the author shares his experiences in soil surveys since his early days till date. Soil is the beginning of food, as mentioned in the year 2022 theme for WSD. Soil survey is the beginning of soil research regarding pedology, edaphology, and soil biology. The author delves into his experiences from different states, villages, and landscapes to identify varied soils. He argues about the grouping of soils and their utility in edaphology. Fieldwork, laboratory work, data generation, and dissemination are all critical; soil survey is the foundation of all such research activities. Fieldwork is strenuous, but in the long run, it's rewarding. The tour diary of the author describes the formation of spatially-associated Vertisols, Alfisols and Mollisols; besides, mention of Mollisols (brown forest soils) has been made along with the Histosols and their considerable capacity to be the hub of organic carbon which could be utilised as a model to combat climate change and global warming using artificial intelligence (AI). This soil database may serve as an essential engine for a negative emission strategy to combat global warming and assist land degradation neutrality (LDN). Starting his career in the Western Ghats, journeying through the tortuous paths of many terrains in the Satpura, Vindhyan, Himalayas, Northeastern regions and the southern Peninsula, the author returns to the same place at the end of his career, in the Western Ghats. He remained busy in research and has been continuing his quest for science.

Key words: *World Soil Day, soil surveys, tour diary, vertisols, alfisols, mollisols.*

Introduction

The International Union of Soil Sciences (IUSS) recommended an international day to celebrate Soil in 2002. Under the leadership of the Kingdom of Thailand and within the framework of the Global Soil Partnership, FAO supported the formal establishment of World Soil Day (WSD) as a global awareness-raising platform. The FAO Conference unanimously endorsed WSD in June 2013 and requested its official adoption at the 68th UN General Assembly. In December 2013, the UN General Assembly responded by designating 5th December 2014 as the first official World Soil Day. Congratulations to all of you to celebrate WSD with the theme for this year (2022) "Soils, where food begins".I am extremely grateful to the office-bearers of the Indian Society of Soil Survey & Land Use Planning (ISSLUP), Nagpur for this invitation to say a few words on this auspicious day. I am indebted to the Director, Indian Council of Agricultural Research-National Bureau of Soil Survey and Land Use Planning (ICAR- NBSSLUP), Nagpur, Maharashtra, Staff, ICAR-NBSSLUP, Nagpur and all others for your presence.

I shall talk on "Soil survey, the profession I embraced: a few pages from my tour diary". If soil is the

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beginning of food, as mentioned in this year's theme for WSD, then soil survey is the beginning of soil research regarding pedology, edaphology, and soil biology and for mapping such information for planners and administrators.

I never wanted to be a soil surveyor. I was trained at the Indian Agricultural Research Institute (IARI), New Delhi. I am one of those very few trained clay mineralogists in the country. And naturally, wanted to pursue my research in that field only. But as luck would have it, I landed in this Bureau (ICAR–NBSS & LUP) and was baptized as a soil surveyor.

The irony is that I didn't have formal soil survey training. My problem was I didn't have anyone to complain about it. There were reasons. In those days, S1 [designation of the Agricultural Research Service (ARS) scientists at the entry–level with a minimum Post graduate degree) received a raw deal with special reference to this institute. I was initially posted to take the unfinished job of the progressive reconnaissance (PR) soil survey (1:50000 scale) in the Pune district, Maharashtra. The rule was to stay in the field for 180 days in two equal splits, 90 days each in winter and summer. Thereafter the S1 scientists were at the mercy of our seniors, heads, and Director from July to October during the monsoon.

The survey party consisted of 4 persons—the party chief, field assistant, driver, and supporting staff. Since the All–India Soil and Land Use Survey (AISLUS) (now Soil and Land Use Survey Institute, SLUSI, attached directly to the Government of India, New Delhi) days, the party chief used to be a survey officer. Later, when AISLUS was bifurcated, and NBSSLUP was born, scientists used to lead the soil survey party as chief with the old mentality and work culture.

I must inform you at this stage about the entry of S1 scientists into the soil survey programmes. I may not be able to vouch for its authenticity, although! The story goes like this. Dr M.S. Swaminathan wanted ICAR to develop a soil map for India. Dr R. S. Murthy, the founder– Director of NBSSLUP, was given this responsibility. Dr Murthy gave a requisition for a 100– soil survey party headed by a similar number of S1 scientists. It was granted. That's how during the 1980s, the Agricultural Scientist Recruitment Board (ASRB), New Delhi advertised for 100 S1 scientists in the soil science discipline.

I am 1982 ARS batch; 91 soil science (pedology) posts were vacant that year. This means only nine positions were filled–in before I applied for the post. The low intake in NBSSLUP was because the candidates, even after their selection by the ASRB, India, avoided joining NBSSLUP for these 180 days compulsory surveys!

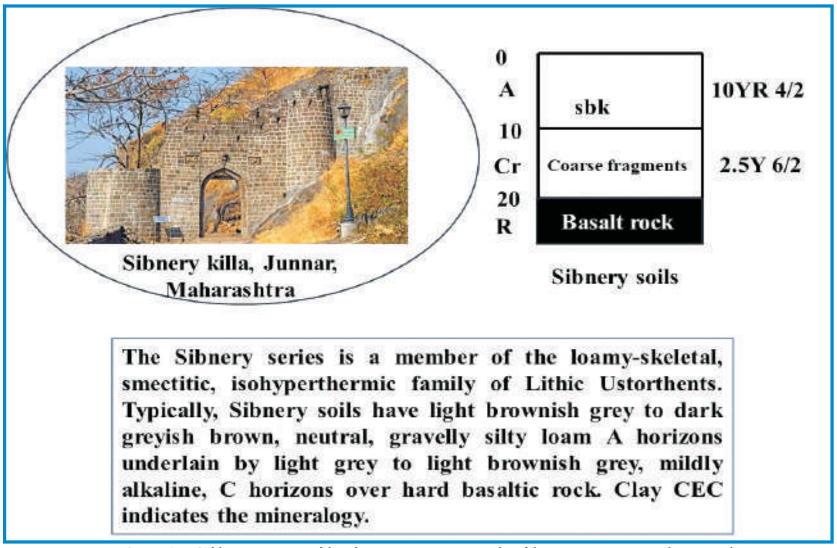
Soil Survey in Maharashtra

After receiving the order for the soil survey, my Principal Investigator (PI) asked me to contact the cartography department to collect the base maps and toposheets. I didn't know about either; the base maps and toposheets! It was October 1984. We lost our beloved prime minister when I was about to leave for this tour. There's turmoil throughout the country. So, we delayed our tour and set forth after one week of our scheduled departure. I reached Pune district's remotest village (*Pimpalvandi*, *Junnar* tehsil) in November 1984. My first camp was a one–room house which I'll not describe. All other facilities were available but outside the house. My first soil profile trainer was my assistant. Fine gentleman. The next time onwards, I took over, and he assisted sincerely and religiously.

I never liked this village life, especially with such a meagre facility. And my problem was to adjust myself since I have been staying in New Delhi, and working in one of the most sophisticated laboratories, namely the Nuclear Research Laboratory (NRL) in the Indian Agricultural Research Institute (IARI), New Delhi. But frankly speaking, this phase of my life and this quiet serenity amidst this nature helped me to understand landscape, physiography, and geomorphology vis–à–vis soils in these villages surrounded by the spectacular Western Ghats. The most important realization was that I had to map this vast landscape and soils in front of this enormous and endless landscape, about which I did not have any training; I was truly ignorant. This very feeling at that young age of mine used to make me humble. Everyday!

These subjects of physiography, geomorphology, soil survey and related aspects of mapping were not part of my course curriculum in B.Sc. (Agril. Hons.) and M.Sc. and PhD. Interestingly, soil taxonomy, the most crucial aspect of soil survey, was touched upon in only one course at IARI, New Delhi, which, instead of understanding the subject, created great fear and repulsion among students. The teacher confused me with the dreaded Latin names in the US soil taxonomy. He made soil taxonomy highly repulsive to me. Much later, I picked up the subject in the field. And now, in this remote part of Pune district, Maharashtra, I became my teacher of soil taxonomy in front of this vast unknown nature.

During my Post Graduate days, my guide advised me to procure a copy of the US soil taxonomy book (Soil Survey Staff, 1975) from the NBSSLUP, Delhi centre. I did it in 1978. That was my first visit to NBSSLUP. I never dreamt of working in this institute for the next 30 years! I used to carry this book on all my tours. Other favourite books, I used to carry, were written by Buckman & Brady, (Buckman and Brady 1984), and Bear's chemistry of soils (Bear 1969), and the USDA soil survey manual. My second camp was just in the foothills of the Sibnery killa (fort). This fort is the birthplace of the Maharaja Shivaji. A benchmark soil was established as the Sibnery series (Figure 1). I learnt about this soil during soil survey in this part of Maharashtra.



Fig, 1. Sibnery soils in Junnar Tehsil, Pune, Maharashtra.

(A: Surface horizon; Cr: parent material with rock fragments; R: rock; sbk: subangular blocky soil structure; 10YR 4/2: dark greyish brown; 2.5Y 6/2: light brownish grey.)

During the soil survey in the Deccan Plateau, I observed black soils more closely and could realize that these soils dominate the valleys and piedmont plains. Red soils overlooked the hills. I imagined the possibility of the black soils on the hills. I did not have any idea whether it was possible or not! I used to ask about the occurrence of black soils on the hills from the workers helping me dig the soil profile or sometimes from the villagers. The reply was always confusing. On many occasions, I used to climb the hills to search for black soils. In most of the cases, I was disappointed even after lot of physical and mental exercise. Fortune smiled upon me when I reached the Bhimashankar plateau in Maharashtra at 2500–3500 ft above mean sea level (msl) (Fig 2). This plateau houses one of the Jyotirlingas (temple of the Lord Shiva). I found black soils– deep black soils at this elevation with very high rainfall (Fig 3). It was a real discovery for me!

The question then arose about the formation and persistence of these black soils in such high rainfall areas (>3500 mm mean annual rainfall). The reason is the dominant clay mineral in these black soils, namely smectites, is ephemeral in humid climate negating the formation and persistence of such soils. The mystery was solved after a lot of coaxing, reading, and discussing with seniors; soil zeolite was discovered and reported for the first time in Indian soils. The Bhimashankar Plateau gave me my first international publication, followed by others (Bhattacharyya *et al.* 1993).

In those days XRD (X-ray diffraction) machine used to be hardware-driven and in spite of using voltage stabilizer electrical pulses betrayed on many occasions to confuse the users about the real peaks or the spikes! The red and black soil samples from the Bhimashankar Plateau were analysed for mineralogy using such XRD machines. Lot of unnecessary spikes were frequent in the diffractograms. For my samples, I remember, my senior(s) assessed such spikes and suggested me to ignore those for identifying minerals.

I used to get the diffractograms after screening of senior(s). I was amazed at the recurring occurrence of such spikes for all, almost all the samples in clay, silt and sand fractions. I thought if it is due to the voltage fluctuations, should recur always, every day and for each sample□Basic mineralogy books helped me to sort out this problem. After a lot of study. I could come to the conclusion that these spikes were the real peaks and should not be discarded. These peaks show the presence of minerals belonging to Si-poor heulandite (zeolite mineral) type. I had to convince seniors for their agreement, although. That is how the Ca-rich and Si-poor zeolites were discovered and reported in the Indian soils for the first time (Bhattacharyya et al. 1993). This paved the way to find similar minerals in other parts of the country and ultimately develop a map showing distribution of zeolite in Indian soils (Bhattacharyya *et al.* 2015a).

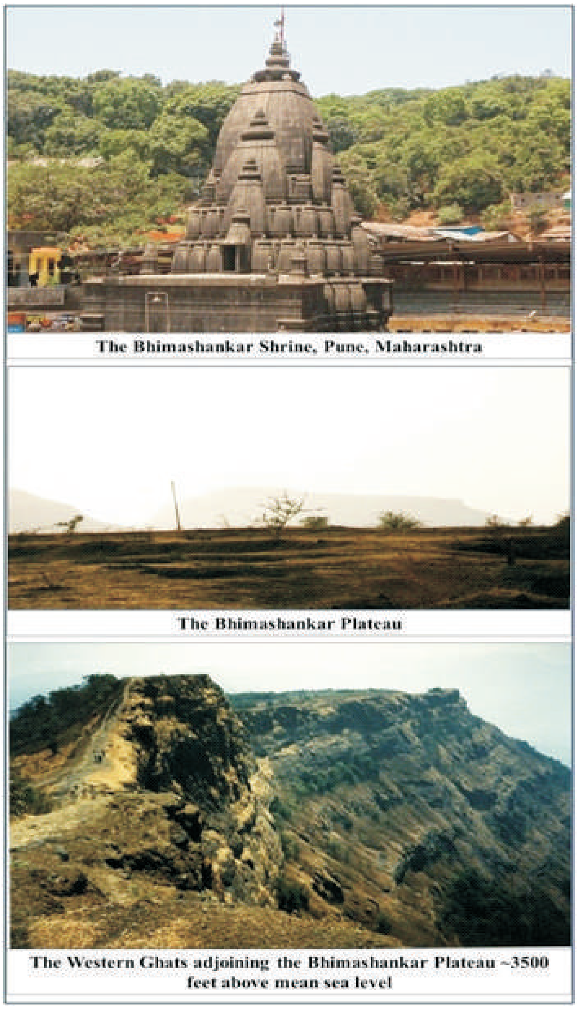


Fig. 2. The Bhimashankar shrine and plateau housing spatially-associated Vertisols, Alfisols and Mollisols with high rainfall in Pune. Maharashtra (Bhattacharyya *et al.* 1993, 1999, 2006).

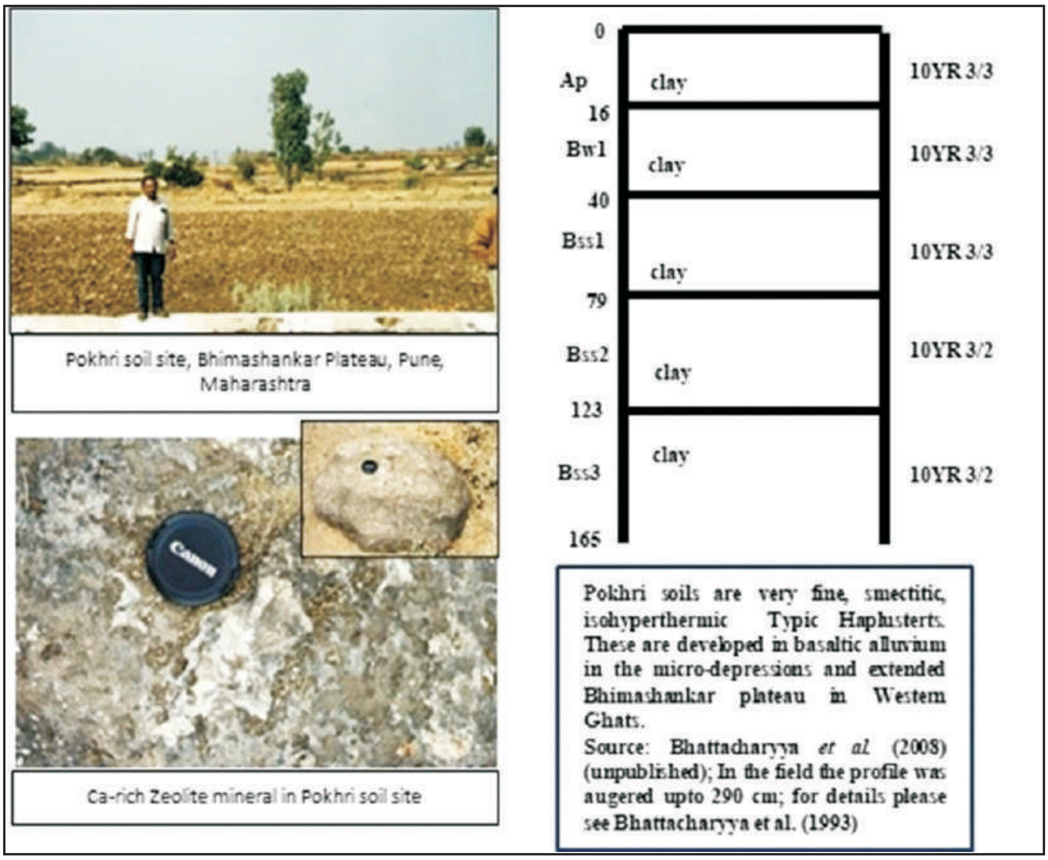


Fig. 3. Pokhri soils and the occurrence of Ca-rich zeolites in the Bhimashankar Plateau, Pune, Maharashtra.

My purpose in sharing my pages from my tour diary is to tell you that field can be your proper place for learning. You may not have the urban comfort there. You may not like the difficulties and the ambience, but it will be rewarding at the end of the day. And you shall realize it later in your career.

Soil Survey in Madhya Pradesh (MP) and Chhattisgarh

After Maharashtra, I worked in Soil Resource Mapping (SRM) Programme initiated by our illustrious Director, Dr J L. Sehgal (Bhattacharyya, 2022). As a member of this National Project, I was responsible for surveying in MP and Chhattisgarh (Mandla, Dindori, Shahdol, Jabalpur and Katni districts: parts).

My tours in Madhya Pradesh near Mandla brought me nearer to the tropical acidic Mollisols, the most valuable soils we should preserve. And I could report about these soils for the first time explaining the presence of calcium-rich zeolite minerals in amygdaloidal basalt both in the Satpura (MP) and the Western Ghats (Maharashtra) on similar elevations and landscapes but in different climates (Fig 4). One occurs in the tropical, and the other one in the subtropical climate. The causative factor for the formation and preservation of such soils, among others, is Ca-rich zeolites (Bhattacharyya *et al.* 2006). Such an exercise helped us to contribute to the world literature from India regarding zeolites and their role in the persistence of these soils in the tropics (Bhattacharyya *et al.* 1993, 1999, 2006). Besides the occurrence of Mollisols (brown forest soils) in the tropical India, we have recently reported Mollisols from the temperate India also to further enrich the world literature on this subject (Gangopadhyay and Bhattacharyya 2022) (Table 1). Friends, you may be aware that such soils were earlier reported from Pantnagar, Uttar Pradesh, now Uttarakhand. This aspect of soil science was subject to PhD research of one of our senior colleagues in Illinois, USA, during the late 1960s (Deshpande *et al*. 1971).

Fig. 4. The Satpura hills, a little north-east of Mandla city, M.P., India.

Table 1. The variations in the characteristics of Mollisols from different parts of the world

Soil Characteristics	Asia					Europe	North America	South America			Russia	Ukraine
	India			Iran	China	Turkey		Argentina	Brazil	Uruguay		
	The Satpura Range	The Western Ghats	Sikkim									
	The variations in the characteristics of Mollisols from different parts of the world											
Area, million ha					34.8 (54.5)		200 (21%)	88.7 (32)	4.2 (0.%)	13 (75)	900 (52.6%)	34 (62%)
MAR, mm	1422	3287	2000 −3000		300–600		500–1500	500–1500	500–1500	500–1500	350–700	490–650
MAT, ^{0}C	24.4	27	12 (maxim um) and 6 (minim um)		−2.5 to 5.6		5—20	14–19	14–19	14–19	−4 to 8	7–7.7
pH (water)	5.8	5.7	4.4–5.1	8.2	slightly acid to alkaline	8					alkaline to acid	6.7–8.6
Clay (%)	34	52	23–58	28		36				25–46		
Smectite (%)	79	26	12.5−37.3	NA	yes	NA				yes (dominant)		10–46 (mixed with smectites)
Kaolinite (%)	12	60	6.8–18.6	NA	yes	NA				yes	25–60	3—29
Mica (%)	9	14	36–91	NA		NA				yes		
Vermiculite/hydromicas												60–85
Chlorite					yes (dominant)							2—20
$CaCO_3$	Nil	Nil		30	.	12						
Organic matter (%)	3.5	2		1.8	2.8–5.4	1.8				1.1–2.7		3—12

Sources: (Bhattacharyya *et al*. 2006; Gangopadhyay and Bhattacharyya 2022; Liu *et al*. 2012).
The datasets are incomplete; hope some of you will complete.

Temperate soils in India did not receive the attention they deserved. I hope some of you may lay your hands on it. This is important judging by the fact that Mollisols store an appreciable amount of organic carbon in the cooler climate and may serve as an essential engine to be part of a negative emission strategy to combat global warming and to assist land degradation neutrality (LDN) (Bhattacharyya 2022 a). Such soils along with the Histosols (Organic Soils) (Please see Fig 13 explained later) may be a model to focus our research on future strategies to combat climate change and global warming; this information may also pave the way to use artificial intelligence (AI).

In Madhya Pradesh (MP), I saw the landscape and soils from all sides of Pachmarhi, the famous hill station this state the Junnardeo village (south), adjoining Chhindwara, the terrain was uneven and stony, making cultivation difficult. The reason was slope and associated erosional problem. Interestingly the other side of the Pachmarhi, towards Pipariya village, witnessed deep to very deep black soils (Vertisols) in the Narmada valley with well–developed slickensides rarely seen in Vertisols from other parts of the country. This was due to the nearness of the depositional alluvial belt of the Narmada River. Farmers used to grow soybean profitably in those days, which developed many soybean–related agro–industries in and around these areas.

On top of the Pachmarhi hills, the soils are red and belong to Alfisols. Some road cuts showed very deep soils indicating an advanced weathering front. Although these soils were not studied in the laboratory by me from this part of the MP, yet similarity in landscape, climate and geology with the Satpura suggests that these soils are dominated by smectite–kaolin interstratified minerals (Bhattacharyya *et al.* 1993, 1999, 2006, 2015 b). The identification of smectite interstratified with 0.7 nm minerals in these soils demonstrate its influence in SOC accumulation of Mollisols–Alfisols–Vertisols catenary sequences of tropical soils in the Satpura and the Western Ghats (Bhattacharyya *et al.* 2005; Bhattacharyya 2021 a) (Figure 5).

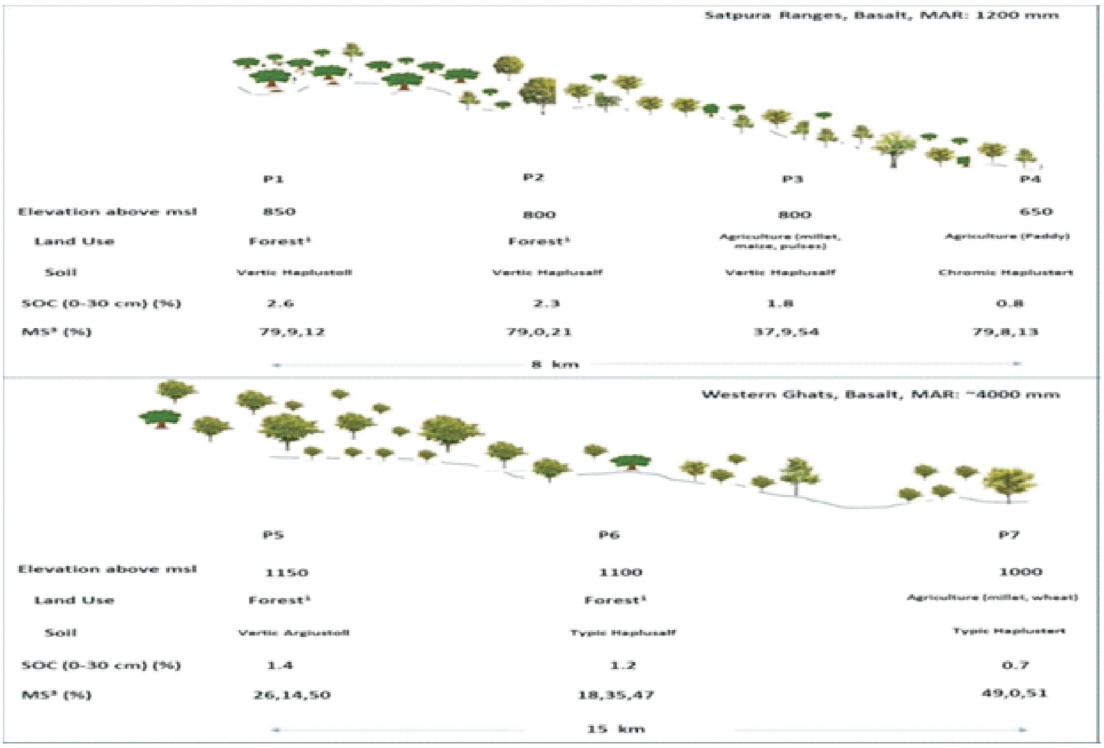


Fig. 5. A schematic diagram of the Mollisols–Alfisols–Vertisols catenary sequence in (a) the Satpura Ranges, Madhya Pradesh and (b) the Western Ghats, Maharashtra, India [1]*Tectona grandis, Madhuca indica* in Satpura and *Tectona grandis* in the Western Ghats. [2] MS (%) Mineral Suite: Smectite, Mica, Kaolinite minerals (in 0–30 cm depth of < 0.2 micro metre) (Source: Redrawn Bhattacharyya 2021a).

The highest peak of the Pachmarhi Hills houses the religious shrine of Lord Shiva at Dhupgarh (Mahadeo Hills: The Satpura Range). The soils are medium in depth, red in colour and belong to Alfisols. This place is a tourist attraction; besides, many devotees throng here to visit the Shiva temple on the *Shivaratri Day* from different parts of the country. A schematic diagram of Alfisols–Inceptisols –Vertisols topo–sequence is shown from this area. (Figure 6) which indicate replication of soil types in similar landscape with similar geology and climate. This, in other words, validate the soil formation model in tropical India.

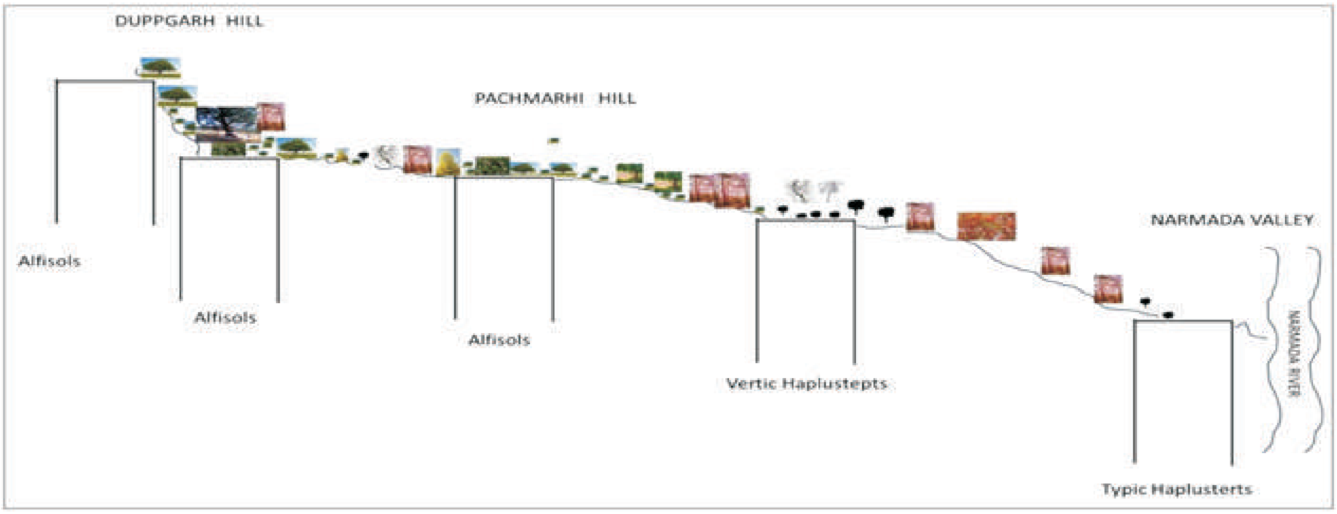


Fig. 6. Pachmarhi hills and soils in topo–sequence, Madhya Pradesh.

During my stay in Umaria Village, Madhya Pradesh, I studied typical Alfisols with the soil textures of loamy sand, sandy loam, sandy clay loam, sandy clay and clay transition down the depth . These Alfisols are a real feast of training for students to explain clay iiluviation. This was near Shahdol district, growing bamboos and other forest species. I saw trucks with loads of bamboo going to the nearby paper mills.

Later my senior colleague visited the site and confirmed the clay cutans and taught me to make clay balls and to observe the clay cutans using a 10X lens. He learnt it from Mr. J.C. Bhattacharjee, the renowned soil expert. It was an important lesson for me. Much later, I visited this place in connection with some other projects and could see these soils again (Fig. 7). This area was an extension of Bandhavgarh Reserve Forest, Madhya Pradesh.

On the other side of Shahdol towards Katani on the Jabalpur–Katani Road, the landscape completely changes from forest to scanty agricultural fields. These areas experience severe cold during November–February (as low as 0°C in January), high rainfall during

Fig. 7. Landscape, land use and soils in forest system, M.P.

monsoon (June–August) and typical tropical summer during April–June. The road towards Katani, way to Allahabad, houses cement factories due to the proximity of limestone quarries on the east–southeast of the Vindhyan. Similar cement factories I saw in Gujarat during my stay in Jasdan, near Porbandar. While surveying the part of Adilabad, Telangana, I found limestones and limestone dominant landscapes where farmers were carrying out poor agriculture due to very shallow soils and other limitations (Fig. 8)

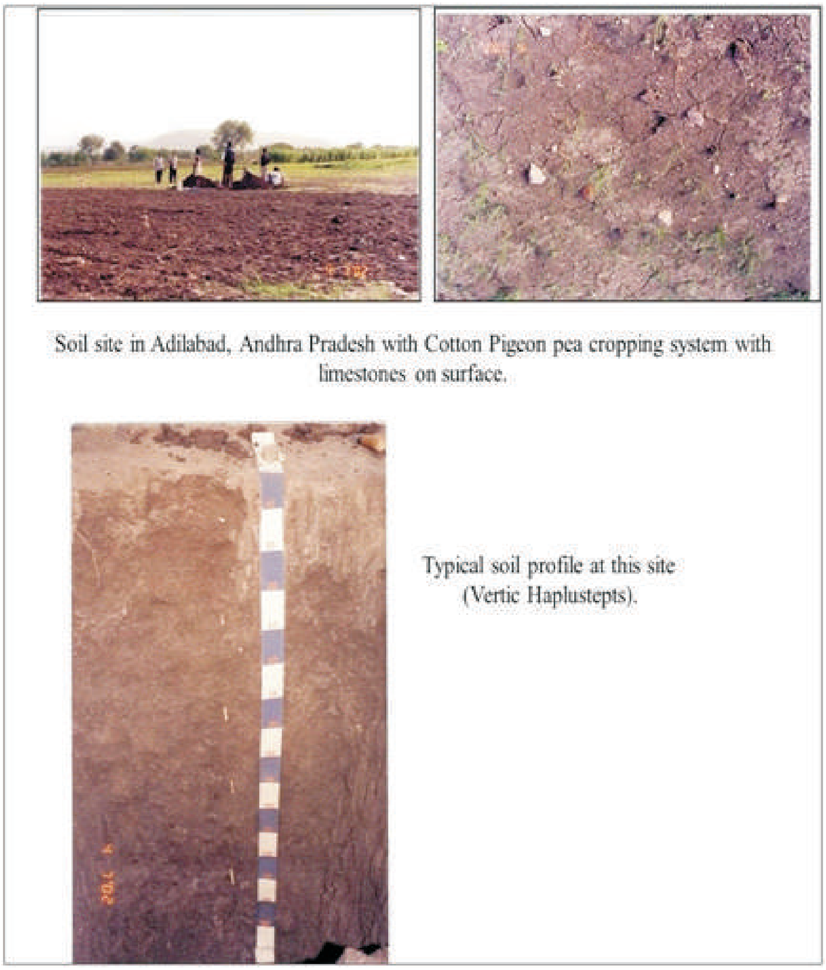


Fig. 8. Landscape, and dominant soils in Adilabad, Telangana.

Soil Survey in Gujarat

Besides Madhya Pradesh and Maharashtra, I spent quite some time in Gujarat carrying out the Soil Resource Mapping of India (Subproject: Gujarat) in the Kathiawar Peninsula. I worked in the Ranns. We were lost in the mirage in the Rann, I remember. I worked in the sea creeks dominated by mud flats with very deep soils almost devoid of vegetation. The subsurface horizons were greenish and showed the presence of gypsum. Black alkali soils are part of this landscape. A pinch of such soil on the tongue used to confirm high salinity of these soils. The only vegetations found were the tiny herbs almost touching the ground making them invisible. The villagers used to pluck these shrubs to feed the cattle. I learnt from them that since these shrubs are salty to taste, the cattle love to eat these plants.

I saw alkali soils which were amazingly black and used to challenge the range of the Munsell Colour Chart. By that time, I had already gained some knowledge about the typical black soils (Vertisols) in Pune, Maharashtra, and I could realize that these soils in Gujarat mud flats are black, but differently black! These soils have all the features of Vertisols, but the structures are prismatic and blocky, as expected in the Na-dominated soils. I remembered my soil science classes of Late Dr. L N. Mandal about the black alkali soils in Kalyani, West Bengal. Fortunately, I was carrying the Bear's Chemistry book (Bear 1969) and could realize that I was sitting in a black alkali soil profile. It was a terrific feeling to see these soils in field in 1986-87 about which I read in 1977 in my classrooms. Due to high sodicity, these black soils attain a pH of more than 8.2 or so. High pH dissolves the organic matter, which smear the soil matrix to give these soils (Sodic Haplusterts / Calciusterts) blacker than the typical black soils (Typic Haplusterts) (Fig. 9) (Bhattacharyya *et al*. 1994). My textbook reading and its practical demonstration in the field made me extremely grateful to my teachers.

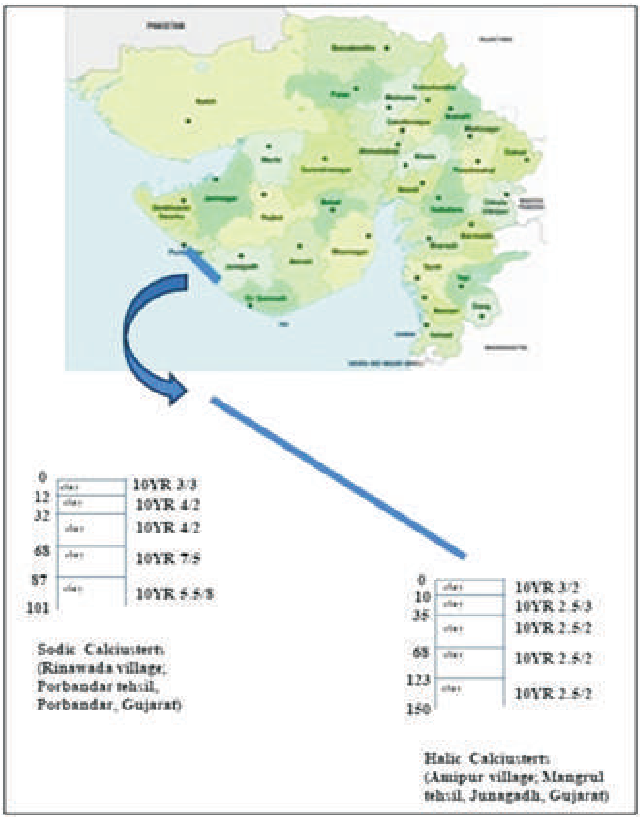


Fig. 9. Black soils in the mudflats in coastal Gujarat (Source: Bhattacharyya et al. 1994)

Aridisols alongwith Psamments (sandy Entisols) are common in the Gujarat coasts. Low rainfall (<550 mm MAR rainfall) added with the problem of high salinity causes severe soil moisture stress for plants. Many of these areas do not support crops. And the misery of farmers increases due to highly saline groundwater unsuitable for irrigation. High soil salinity and the pedo-environment make these soils physiologically dry. At places, the overhead climate (read rainfall) may not help classifying those areas as aridic. Yet, soil taxonomy (Soil Survey Staff, 2014) has an inbuilt system to address crop requirements and their performance if comprehended from that perspective justifying grouping those soils as Aridisols. Please realize it and apply wherever appropriate.

I worked in Gujarat when the state was reeling under severe drought (1986-87). I found many black soils with exceedingly wide and deep cracks, and the soil depth up to 25-30 cm on surface was dehydrated. While digging a profile of this type of soil, two labourers more than 3-4 hours, and sometimes more; these are dry sodic/calcic Vertisols and may be on the border line of Aridisols.

Farmers used to narrate me that these soils require *davai* (medicine) in the form of gypsum to mellow the surface (10–15) cm soils. The predicament of the farmers was that this chemical (gypsum) was only sparingly soluble in water. The well water which the farmers used as irrigation were saline and sometimes bitter to taste (due to high soluble magnesium salts) making these soils bad to worse. They needed rainwater which was scarce. The addition of poor–quality of irrigation water from wells renders more sodic. A similar situation has been reported from the Purna Valley soils (Vertisols) (Padekar *et al*. 2016). I hope things must have changed by this time in Gujarat with lot of improvement.

There is a possibility to prepare transects showing typical black soils in the central Kathiawar Peninsula (Rajkot, Junagadh) and one to the south, southwest towards Porbandar and another towards the south, southeast leading to Bhavnagar. Gradual increase in both atmospheric and pedological aridity and the nearness to the seashore change the soils towards more sodicity and aridity (Sharma *et al.* 2006).

The pedological aridity (soil moisture stress) leading to physiological aridity reminds me of a few Aquepts reported from the Sundarbans. These soils also occur in a physiologically dry ecosystem. There is a reduced moisture regime, but should this dryness demand a revisit in grouping these soils? I requested many colleagues from our country's eastern part to research on this aspect. I hope they are working now. Can you include such research issues in your agenda? Please consider. This will help you understand the link between crop/tree physiology and US soil taxonomy. Trees understand this problem and, accordingly, acclimatize them with the ecosystem. The pedologist should comprehend it and put in practice.

The struggle for existence is the characteristic of all living beings. Vivipary is one such process to ensure propagation of tree species in adverse situations. Vivipary permits embryo growth while still attached to the mother tree. This is typical of mangroves grown on a highly saline and flood–infested unstable surface and subsurface conditions (Majumder *et al.* 2010).

The *Sundari* (*Heritiera littoralis*) and the mangrove (*Rhizophora mangle*) trees grow on brackish soils (Figure 10). These soils look saturated with water. However, high salt concentrations might create an aridic pedo–environment, as shown in Figure 10 from Sagar Island, West Bengal. Soil grouping should, therefore, relate to edaphology. It will be exciting, and you will find more enthusiasm to research in this particular area.

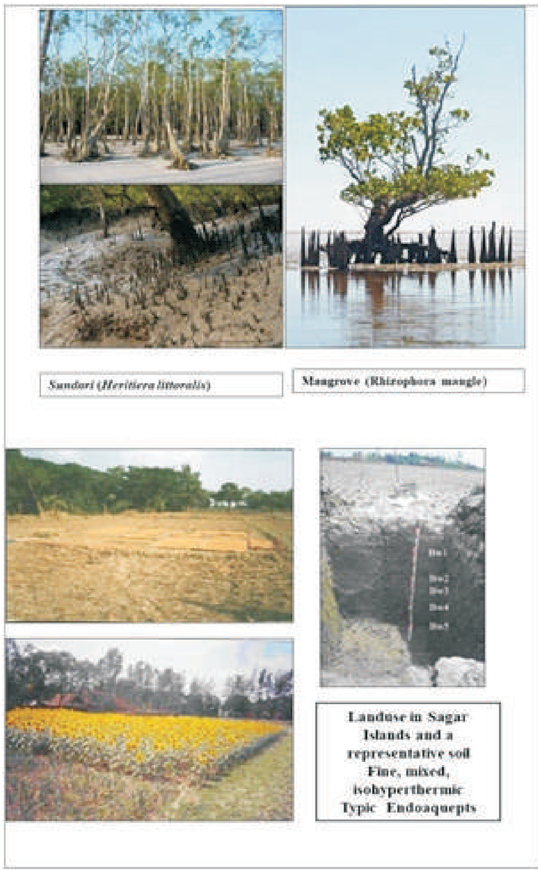


Fig. 10. Mangrove and other vegetations in the Sundarbans showing a representative soil in the cultivable areas of Sagar Island (Ray *et al.* 2005).

Soil Survey in North-Eastern Region (NER)

My tour diary of our country's North–eastern region (NER) indicates my experiences about humid and per–humid climates. It was a completely different landscape, different climate, varied crops, the Himalayan geology; and strikingly different than what I saw and studied in the basaltic landscape. The NER taught me more about hydromorphic soils in the Assam Plains. I beheld nature very closely. The hydromorphic soils (mostly, Aquepts: Soil Survey Staff, 2014) in the NER show distinct gleying and it is educative and rewarding for both the teachers and the taught. The formation of Aquepts, Vertic Inceptisols and the course of the Brahmaputra River indicate an interesting observation to link geography, geomorphology and soil science (Figure 11) (Bhattacharyya *et al*. 1998). The soil colours of these Aquepts might challenge the range of the Munsell colour chart; in the same way, you might face problems capturing the colour of the *black alkali soils* (Sodic Haplusterts/Calciusterts) in the mud flats of the north of Porbandar, Gujarat. Should you revisit the Munsell colour chart to create a new page? Please consider.

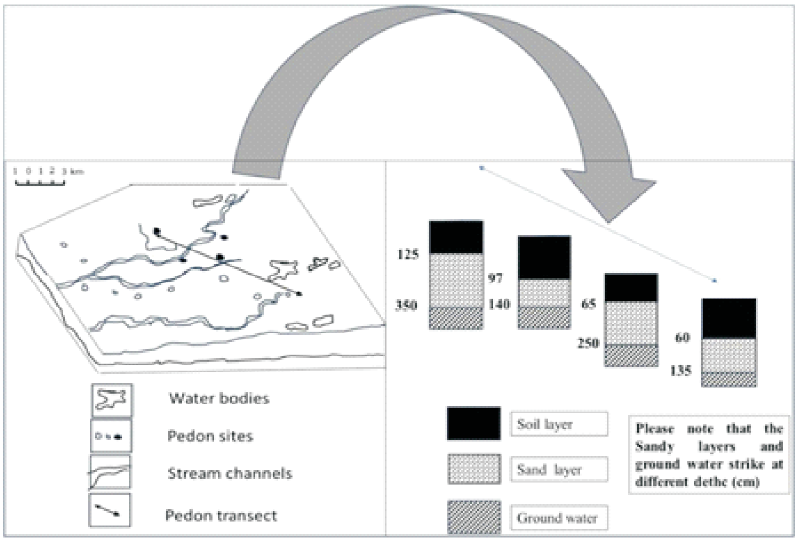


Fig. 11. Aquepts and vertic aquepts in the Brahmaputra valley, Assam showing different levels of ground water depths. Many such water-logged paddy soils require revisit for their classification. These soils can store relatively high organic matter due to the characteristic hydromorphic conditions (source: Bhattacharyya *et al.* 1997).

For quite some time, I worked on a Rubber project in Tripura. It was the first consultancy project of NBSSLUP, Nagpur, initiated by the NER centre, Jorhat, Assam, with the dynamic leadership of Dr. J. L Sehgal, the then Director of the institute. This project's success helped us bag the next Rubber Consultancy Project in Tamil Nadu and Kerala in a typically tropical climate best-suited for rubber. That was the highest consultancy project in ICAR in terms of total external funding in1996. The northeastern region taught me to be more formidable both off and on the field. It helped me when I returned to Nagpur with renewed vigour and experience .

Other than fieldwork, laboratory observations also carry a lot of meaning in the routine research work of a soil surveyor. Very few people appreciate it. Most of them think that the soil survey is complete after the fieldwork. It is, in fact, the beginning of the research. Laboratories and the staff's comments shouldn't be overlooked. It would be best to have regular dialogue with the technical officers and other supporting staff. You never know. Some of their observations might open a new area of research.

You made considerable efforts to survey distant places to collect soil and water samples. And now, you have to see if the soils are correctly stored and analysed. Are the data generated reproducible, authentic, religiously drawn, and analysed by sincere laboratory assistants? Do you find the information tabled contradicts the general belief and findings reported so far? Are you accepting it or overlooking it? In NER, I had an experience which may be interesting for you. The technical officers reported values of 1*N* KCl pH of soils higher than the water pH. This was contrary to the general observations since 1 *N* HCl pH is always lower than water pH. After several repeats, the results appeared the same. It was overlooked. I learnt about this much later when I reached the NER centre in Jorhat, Assam. The samples were analysed again for pH. I found the observations of the technical officers were correct after I made a detailed analysis of these soils to generate detailed chemical and mineralogical parameters. We identified gibbsite minerals in clay fractions, which helped us to develop a model understanding of the formation of gibbsite in tropical Meghalaya, India (Bhattacharyya *et al.* 2000 a, b).

Later, we used this model for Kerala soils (Chandran *et al.* 2004) which validated the model of gibbsite formation in tropical soils (Bhattacharyya et al. 2000a, b). A few such soils were under rubber cultivation, I recall. Since then, I have been toying with the idea of the performance of rubber trees in gibbsitic and non-gibbsite soils in the traditional rubber-growing states of south India. I had requested my colleagues to work on it. Maybe some of you will take it up in future.

Dear colleagues, the fact is that the journey of the researcher never ends. So, may I request you to remember this for all your efforts to carry out your research? Don't think your job ends when you return to the Headquarters after the strenuous soil survey tour. Please be ready for the next challenges: data gathering, data analysis, preparing inventory, data presentation, and writing and disseminating information. Soil survey is only the beginning of your future research agendas.

Soil Survey in other parts of India (BSR, black soil region and IGP, Indo Gangetic Plains)

Black soil region BSR

My tour diary of many other parts of the country suggests that I mention the occurrence of black soils in non-traditional areas (Bhattacharyya *et al*. 1993, 2021). Such an incident is truly revealing. You may also keep your eyes open to search for traditionally-occurring soils in the non-conventional areas. You have an advantage now-a-days since you are working on larger scales of soil mapping and with the global positioning system (GPS). And I am sure you won't miss the soils occurring in patches, we could not recognize due to scale limitations.

People often feel comfortable with black soil and red soil terminologies. Latin words used in soil taxonomy are difficult to comprehend. So instead of Vertisols, black soils are more popularly accepted due to easy understanding. But people forget that there are black soils which are red! These soils are common in Gujarat and Maharashtra. I studied such soils first in the north of Porbandar, Gujarat and then in the Hingoli district in Maharashtra. Yavatmal district also has a sizeable extent of these soils. Please be vigilant about similar soils when you are working in the field. These red Vertisols are endowed with fibrous minerals called palygorskite. These minerals are negative soil modifiers, unlike the positive ones like Ca-rich zeolites (Bhattacharyya 2021 a, b), as I mentioned earlier. These red Vertisols require careful management intervention, my dear natural resource managers (Bhattacharyya *et al.* 2018).

It was good to see the gypsic Vertisols in Kovilpatti, Tamil Nadu—a beautiful place with good people showing cordial behaviour and lovely hospitality on and off the field. The soils we studied are naturally-occurring gypsiferrous soils, which create natural amendments in the soil ecosystem to hinder soil sodicity (Fig. 12).

Fig. 12. Kovilpatti soil profile (Gypsum containing Vertisols) in Tamil Nadu, India.

It's the beauty and bounty of nature in the southern tip of the country. We did some work on these soils. More can be done. Please consider. Kerala houses acid sulphate soils. I wish I should do something about these soils. I could not yet. I hope you will take up these jobs in future. My colleagues Dr. K. M. Nair and Dr. Anil Kumar K.S share a few information on acid sulphate soils from Kerala (Fig 13), which may generate interest for some of you on these soils.

Fig. 13. Trissur Kole acid sulphate soil, landscape and soil profile (Histosols: Terric Sulfihemists).

Friends, I have been busy developing a database on soil diversity for the whole country using the soil information system developed earlier (Bhattacharyya and Pal 2014; Bhattacharyya *et al*. 2014 a, b, c; 2016, 2010 a; Bhattacharyya 2022 b). This paper is a blend of review and research on Indian soils with numerous datasets which might lead you to find new research areas in soil science with particular reference to pedodiversity, biodiversity and soil endemism (Bhattacharyya 2022 b).

Epilogue

My tour diary pages are gaining dust over time. I tried to gather a few researchable issues for you all after undusting the nearly-torn pages of my diary. People crowd my mind during this journey: scientists, juniors, seniors, students, research fellows, research associates, villagers, farmers, village office bearers, *sarpanch* and others; this makes my thoughts drifted to many other issues on which I could not lay my hands on! This makes me emotional and thus stops my pen to write more about the people and the places I visited during the soil survey programme.

The expectations and curiosity of the villagers always helped me consider their welfare during the fieldwork. I sit back leisurely and start thinking, did I do anything for them I don't find an answer. Friends, I guess I must have failed on many counts. When you visit these villages, please try to complete the unfinished jobs of your seniors.

We have been working on different models for predicting crop performance, soil quality and health (Bhattacharyya *et al*. 2010 b, 2011, 2013, 2007 a, b; Telpande *et al.* 2013; Ray *et al.* 2014; Chatterjee *et al.* 2014); also trying to visualize the future soils in the event of climate change and global warming (Bhattacharyya 2022 c, Bhattacharyya *et al.* 2012, 2008; 2016) and lnking soils with our ancient literatures (Bhattacharyya 2023). Dear friends, all such efforts should culminate in developing a model understanding of using artificial intelligence (AI) in agriculture, natural resource management, and ecosystem functions to benefit human civilization for the next generations.

The journey started in the Western Ghats ended in the other side of the Ghats towards the Arabian Sea. I observed coastal Maharashtra closely and could gather enormous experience about the soils, flora and fauna to utilize soil information system for horticultural crop planning (Bhattacharyya *et al.* 2019, 2021).

I keep on thinking about such new areas of research. I try to use and modify my ways of analysing my data in light of modern concepts. This way, I create my own story, destroy it and rebuild it. Without a suitable research companion at this period of my life, I am creating and recreating my story as if ploughing my lone furrow. It is in this context I find this quotation interesting.

"To exist is to change, to change is to mature, and to mature is to go on creating oneself endlessly (*Henry Bergesonn)"*.

I am doing that and shall continue to create and recreate it. God bless you all!

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