Journal of the Indian Society of Soil Science, Vol. 64 (Supplement) pp S41-S52 (2016)

The 27th Dr. S.P. Raychaudhury Memorial Lecture*

Soil Diversity in India

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Diversity is widely considered as synonymous to difference. Therefore, soil diversity should indicate the difference of soils. Various factors cause differences in soils. These could be natural and/or anthropogenic. To understand the diversity of soils, the knowledge on the potential of soil resources and its limitations, different kinds of methods used for management of these soils either for agriculture and non-agriculture purposes is vital.

India is known as a land of paradoxes because of the diversity of soils. The girdle of high mountains, snow falls, gracious and thick forests in the Himalayas, seas washing along the coasts in the peninsula including both western and eastern coasts, diversity in geological formations, diverse climate, topography and relief to give rise to the spectacular physiographic features. In India, the temperature varies from arctic cold to equatorial hot, rainfall from a few centimeters in the desert to humid climate experiencing several hundred centimeters per annum. These factors provide a landscape of high elevation plateau, hills, inter hill basins, uplands, world's most fertile plains, hydromorphic, swampy low lands and barren deserts. These variations of natural environment have resulted in soil diversity in India compared to any other country of similar size in the whole world. It was, due to these reasons, many soil scientists in our country were attracted to a systematic study on soils, their formation, classification and mapping to indicate their suitability for suggesting alternate land use and to develop planning for each parcel of land. Dr. S.P. Raychaudhuri was one of those pioneering soil scientists in our country, for whom I shall pay my tribute through some of my research accomplishments to open the topic of pedodiversity for soil diversity in our country. A humble effort will also be made to quantify both pedodiversity and soil diversity.

*Delivered on 20 August, 2016 at Mahatma Phule Krishi Vidyapeeth, Rahuri and organized by Rahuri Chapter of the Indian Society of Soil Science

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Database

The data generated earlier was used for the present study (Bhattacharyya *et al*. 2009, 2013). The database was generated using the soil information from the soil resource management programme. The database consists of seven zones *viz.*, northern, western, central, southern, eastern, north-eastern and islands. For each zones the database was arrayed statewise (Bhattacharyya *et al*. 2009, 2013).

Methodology

The soil diversity index (SDI) was assessed using the concept of occurrence of soil family (Soil Survey Staff 2014) per unit area (Bhattacharyya *et al*. 2013).To estimate the pedodiversity indices (PDI) various 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 states and Union Territories were extracted from the existing database. The PDI were calculated based on the area abundance of the taxa for India, for zones and for various states of India. Three types of indices were considered in this study: *richness* (S) (number of soil taxa), *evenness* (E) (area equitability of the soil taxa), and *diversity* (H') (considers both richness and evenness into account, or, in other words, the higher the richness and evenness, the higher the diversity) (Guo *et al*. 2003). The O'Neil's dominant index was estimated to assess the deviation of the estimated Shannon diversity index (H') from the maximum diversity (H_{max}) (O'Neil *et al*. 1988). Smith's E was calculated with the following relationship (Equation I) (Smith and Wilson 1996):

$$E = 1 - \frac{2}{\pi} arctan\{(\sum_i^S [ln(x_i) - \sum_j^S \ln(x_j)/S]^2) \div S\} \quad \text{... (Eq. I)}$$

where, S is taxa richness; x is the areal extent of i^{th}, j^{th} taxa. The taxa evenness E varies with a range of 0 – 1 where 0 and 1 indicates minimum and maximum evenness, respectively (Guo *et al*. 2003). These authors also recommended Shannon's diversity index (H′) (Shannon and Weaver 1949; Magurran 1988) to find out pedodiversity. It is calculated using the following equation (Eq. II):

$$H' = -\sum_{i}^{S} p_i \times \ln(p_i) \quad \text{...(Eq. II)}$$

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, suborders, (Soil Survey Staff 2014) great groups, subgroups and soil families. The O'Neil's dominant index (D) was calculated with the following equation (Eq. III) (O'Neill *et al*. 1988)

$$D = In(S) + \sum_{i}^{S} p_i \times ln(p_i) \quad \text{...(Eq. III)}$$

where, S and p_i as mentioned above.Besides, Simpson's index (Ds) was also estimated to assess the dominance using the following equation (Equation IV):

$$Ds = \sum\{pi(pi^{-1}) \div N(N-1) \quad \text{...(Eq. IV)}$$

where, pi and N are parameters as mentioned above.

Major Findings

Previous Studies on Soil Diversity

Voelckel initiated soil studies way back in 1893, which was later substantiated by Leather in 1898 (Bhattacharyya *et al*. 2013). Much before that, soils were classified into two groups, judging by their variations in terms of fertility into two classes *viz*. *Urvara* (fertile) and *Anurvara* or *Usara* (sterile). According to *arthashastra* (300 BC), soils were found to be diverse and, therefore, not suitable for all crops. On the basis of climate, soils/lands were found to vary as *Jangala* (dry places/plants, xerophytes), *Anupa* (marshy or swampy land) and *Sadharana* (region with ordinary plants, mesophytes) (Bhattacharyya and Pal 2016; Velayutham *et al.* 2016). During the 20^{th} to 21^{st} century, the scientific interest to understand the soil diversity in India began with the initiation of studies by Geological Survey of India during 1846 (Raychaudhuri 1979).

In 1898, four major types of soils were reported in the country. These are *Indo-Gangetic alluvial soils, black (regur) soils, red soils and laterite and lateritic soils.* Schokalskaya published a soil map of India showing 16 soil groups keeping in view the climate, vegetation, soil forming materials, salinity, alkalinity and pits during 1932. On the basis of ecological diversity, various types of soils were shown in a compiled soil map of India by Wadia and his assistants during 1935. The climatic variability was utilized for the first time to address the soil diversity when a soil map of India was published (Vishwanatha and Ukil 1943). Integration of climatic vegetation and physiographic variation was considered by Raychaudhuri in 1963 as evidenced by their comprehensive study on 27 diverse soil units in the country. Table 1 indicates the soil diversity in our country (Bhattacharyya *et al*. 2013; Soil Survey Staff 2014). Detailed chronology of events of soil mapping is shown in fig. 1.

Soil Diversity in India

Different types of soils in different parts of the country were reported, yet very little has been talked about soil diversity in India. The soil-forming factors, especially climate, vegetation and topography, act on a range of rock formations and parent materials leading to the development of different kinds of soils making soil a continuum (Jenny 1941) showing diverse properties vertically down the depth and laterally crossing all boundaries. Soil grouping is a general practice to suggest planning and management. The concept of soil taxonomy centers on the basic theme of differentiating soils on the basis of the properties of the soils being classified where the factors of soil formation helps describe soils indirectly (Smit 1986; Krasilnikov *et al*. 2009; Buol *et al*. 2011; Bockheim *et al*. 2014). It was conceived as a means of communicating soil information to other branches of science, in general and soil science (pedology), in particular. US soil taxonomy has been described as a classification that is mainly concerned with the relationships among soils (Bhattacharyya *et al*. 2015).

Soil diversity can be studied for a large country like India, only if the data collected at a larger scale to capture maximum diversity. Earlier, soil diversity reported at 1:7 million scale was incomplete (Fig. 1), since it could record only 103 various types of soils at the level of sub-orders in the soil taxonomy (Bhattacharyya *et al.* 2013; Soil Survey Staff 2014). Using image interpretation (remote sensing data), soil survey, laboratory data and GIS a larger database was generated at country level with its states as database unit(Bhattacharyya *et al*. 2009, 2013) (Table 1).

There are, however, criticism on the soil information generated including the maps. There were questions raised about the usefulness of such information showing soils in Latin names. Soil taxonomic names are used for grouping soils in the chronological sequence such as order, suborder, great group,

Table 1. Soil diversity in India

Serial No.	Soil orders*	Major soils**	States	Extent	
				'000 ha	Percentage
1	Inceptisols, Entisols, Alfisols, Aridisols	Alluvial	J&K, HP, Punjab, Haryana, Delhi, UP, Gujarat, Goa, MP, MS, AP, Karnataka, TN, Kerala, Puducherry, Bihar, Odisha, WB, ArP, Assam, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, A&N	100,006	30.4
2	Aridisols, Inceptisols, Entisols	Coastal alluvial	AP, Karnataka, TN, Kerala, WB, Gujarat, Odisha, Puducherry, Lakshadweep, A&N	10,049	3.1
3	Alfisols, Ultisols, Entisols, Inceptisols, Mollisols, Aridisols	Red	AP, Karnataka, Kerala, TN, Puducherry, Rajasthan, MP, MS, Gujarat, Goa, ArP, Assam, Manipur, Meghalaya, Nagaland, Mizoram, Tripura, Delhi, UP, HP, A&N	87,989	26.8
4	Alfisols, Ultisols, Inceptisols	Laterites	AP, Karnataka, Kerala, TN, Puducherry, MS, Odisha, WB	18,094	5.5
5	Mollisols, Inceptisols	Brown forest	Karnataka, Maharashtra	540	0.2
6	Inceptisols, Entisols	Hill	Manipur, Odisha, WB, Tripura, Nagaland	2,262	0.7
7	Mollisols, Entisols	Terai	UP, Sikkim	326	0.1
8	Mollisols	Mountain meadow	J&K	60	-
9	Alfisols	Sub-montane	J&K	104	-
10	Vertisols, Mollisols, Inceptisols, Entisols, Aridisols	Black	MP, MS, Rajasthan, Puducherry, TN, UP, Bihar, Odisha, AP, Gujarat	54,682	16.6
11	Aridisols, Inceptisols, Entisols	Desert	Rajasthan, Gujarat, Haryana, Punjab	26,283	8.0
	Others***			28,305	8.6
	Total			328,700	100

*Soil Survey Staff (2014); **Bhattacharyya *et al*. (2007, 2013)
***Includes glaciers (0.4%), sand dunes (0.01%), mangrove swamps (0.04%), salt waste 0.01%), water bodies (0.1%), rock land (0.25%) and rock outcrops (7.8%). MP, Madhya Pradesh; MS, Maharashtra; UP, Uttar Pradesh; J&K, Jammu and Kashmir; TN, Tamil Nadu; AP, Andhra Pradesh; ArP, Arunachal Pradesh; WB, West Bengal; HP, Himachal Pradesh; A&N, Andaman and Nicobar Islands.

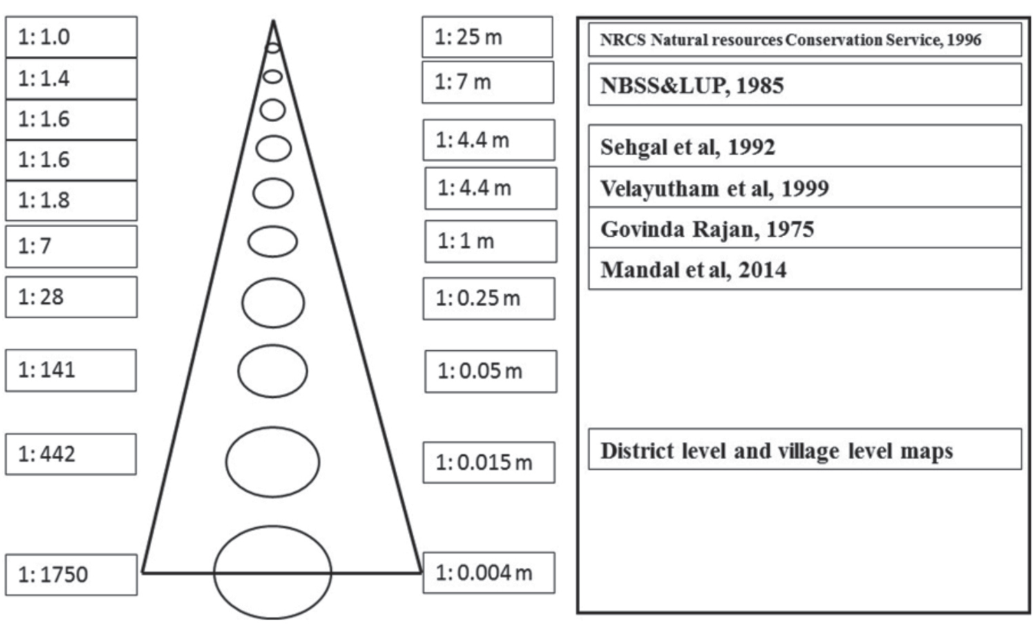

Fig. 1. Chronology of soil studies in India

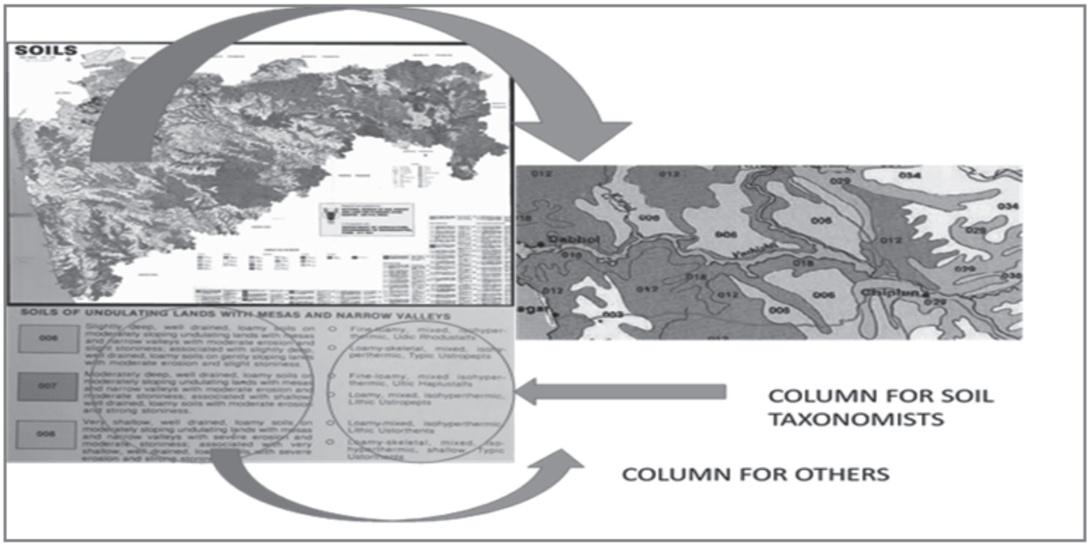

Fig. 2. Use of soil map for the soil taxonomists and others

subgroup, family and ultimately to the soil series keeping in view the information on geology, landscape, and climate which directly or indirectly carry the signature of soil information. The soil characteristics and their signatures are hidden within these Latin names and, therefore, appear un-understandable for a few. It is clarified that taxonomic names of soils are meant for a group of soil scientists who have been trained as pedologists and can decipher these Latin names to understand the close relation of soil forming factors, soil properties and the soil diversity. For others, the description of soils depicts the detailed soil properties (Fig. 2). There were efforts to use other common soil names to link with these soil taxonomic groups *e.g.* family, but it becomes difficult since with the help of 27 and/or 103 soil groups of Raychaudhuri *et al*. (1963), it becomes difficult to describe nearly 1247 diversified soils in India (Bhattacharyya *et al*. 2013) (Fig. 2). Similar Latin names are in vogue in biological sciences and are widely used, referred and cited.

Soil Diversity at Different Scales of Mapping

Distribution of soil orders, suborders, great groups, subgroups and families shows a wide diversity of soils in India (Bhattacharyya *et al*. 2013). There are seven soil orders, 22 suborders, 78 great groups, 220 subgroups, and 1247 families in all the states of India including the Union Territories (Bhattacharyya *et al*. 2009) (Table 2). There are soils (orders) which were reported later but not included in these datasets (Bhattacharyya *et al*. 2013). At the order level, seven different types of soils are found. These are Inceptisols, Entisols, Alfisols, Vertisols, Aridisols and

Table 2. Soil diversity in India*

Country/ States	Number		Number per million hectare Soil Families
	Orders	Soil Families	
India	7	1197	
Northern Zone	6	381	38
Jammu and Kashmir	4	93	4
Himachal Pradesh	4	56	10
Punjab	4	46	9
Haryana	4	41	9
Uttar Pradesh (including Uttarakhand)	5	145	5
Western Zone	5	222	9
Rajasthan	5	96	3
Gujarat	5	126	6
Central Zone	5	270	4
Madhya Pradesh (including Chhattisgarh)	5	175	4
Maharashtra	5	95	3
Southern Zone	7	342	25
Andhra Pradesh (including Telangana)	6	134	5
Karnataka	7	98	5
Tamil Nadu	6	75	6
Kerala	5	35	9
Eastern Zone	4	233	17
Bihar (including Jharkhand)	4	79	5
Odisha	4	98	6
West Bengal	3	56	6
North-Eastern Zone	4	246	66
Arunachal Pradesh	4	58	7
Assam	4	82	10
Manipur	4	32	14
Mizoram	4	41	19
Meghalaya	4	33	15

*Data of a few states were not included due to different scale of survey; the values increase when all the states and UTs are considered

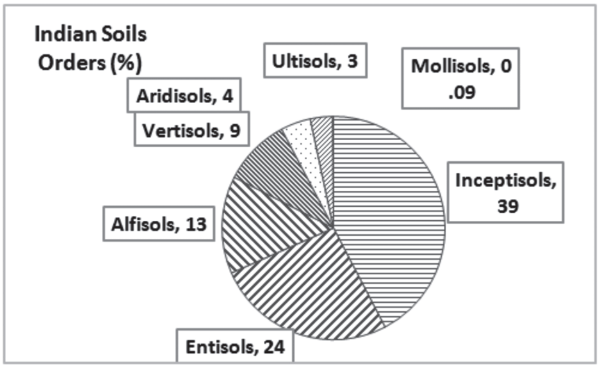

Fig. 3. Soils identified at order level of US Taxonomy in India

Ultisols (Fig. 3). At the sub-order level, 22 different types of soils are found within these 7 soil orders. At a larger scale, 78 soils are identified at the great group level while at the subgroup and family levels, 220 and 1197 diversified soils have been reported, respectively (Fig. 4).

Soil Diversity in Different Zones of India

Soil diversity, due to combined influence of different soil forming factors is preserved within the soil since it can memorize various episodes of changes of soil properties in course of soil formation (Bhattacharyya *et al*. 2013; Bhattacharyya 2014). Since India has a diversity of bio-climate, geology, agro-climate, agro-ecological regions (AERs) and agro-ecological sub regions (AESRs), soil diversity is observed in different parts in India. Since soil family is the highest category for which datasets are available now, this has been considered as the ideal representative of soil diversity.

Soil diversity in northern zone of India

This zone covers 20 per cent area of the country. Total 393 number of soil diversity is reported in the northern part of India at family level of U.S. Taxonomy (Soil Survey Staff 2014). This zone consists of the states like Uttar Pradesh, Uttarakhand, Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana and Delhi. Among these states, a typical shrink-swell soils (Vertisols) are observed only in Uttar Pradesh. Later studies showed that there are soils which have vertic properties in the river bed in Jammu & Kashmir (Bhattacharyya *et al.* 2007). Brown forest soils (Mollisols) are observed in Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh (Fig. 5a).

Soil diversity in western zone

This zone covering 16.5% area of the country showed total 249 soils. The western zone consists of 3 states *viz.* Rajasthan, Gujarat and Goa. Aridisols are dominant in Rajasthan. There are reports of Salorthids (Aridisols) also in Gujarat. Ultisols and Alfisols are common in all these states (Fig. 5b). Earlier studies of Alfisols and Ultisols indicate that the present climate may not be favourable for their formation suggesting a change of climate from wetter to dry regime in these parts of the country. Soil diversity can, therefore, indicate various signatures of climate change stored in soils (Bhattacharyya 2014).

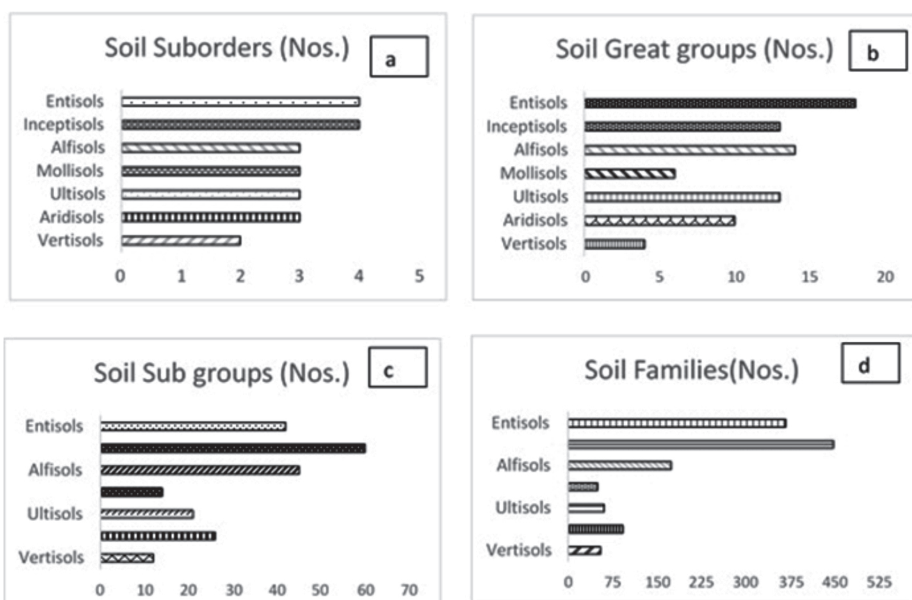

Fig. 4. Occurrence of total sub-orders (***a***), great groups (***b***), subgroups (***c***) and families (***d***) in various soil orders identified in India

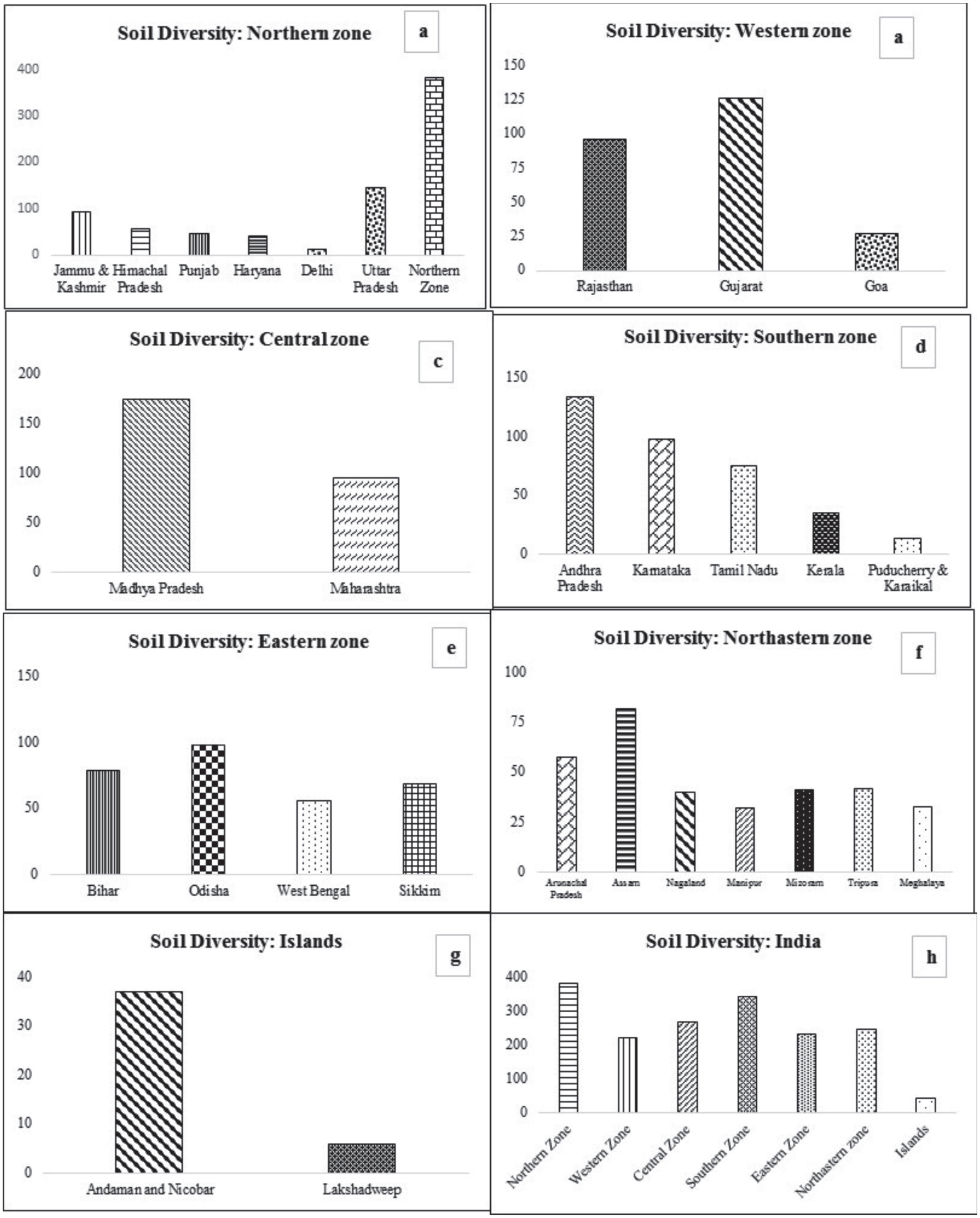

Fig. 5. Soil diversity in different zones in (a) northern (b) western, (c) central; (d) southern; (e) eastern; (f) northeastern; (g) islands; and (h) India

Soil diversity in central zone

This zone consists of 3 states and occupies 23% area of the country. Number of soil diversity in Madhya Pradesh (undivided) is more than in Maharashtra as evidenced by the occurrence of 270 soil families (Fig. 5c). Besides, Madhya Pradesh has double the area under typical black soils as compared to Maharashtra. Brown forest soils (Mollisols) are reported in the Sapura and Western Ghats of Madhya Pradesh and Maharashtra, respectively.

Soil diversity in southern zone

This zone consists of 5 states such as Andhra Pradesh (undivided), Karnataka, Tamil Nadu, Kerala, Puducherry and Karaikal and covers 19.3% area of the country. Out of five, four states showed the occurrence of fertile brown forest soils (Mollisols) and support the hypothesis that Mollisols can occur in tropical climate also with some conditions (Bhattacharyya *et al.* 2006). Total 356 number of soil diversity is found in this zone (Fig.5d). Typical black soils (Vertisols) are common in all these states. Occurrence of Vertisols in Kerala reported later (Nair *et al.* 2006; Bhattacharyya *et al*. 2013) and therefore, is not part of soil datasets presented here. However, while revising the soil map of the black soil region, Vertisols of Kerala and other parts of India were considered (Mandal *et al.* 2014).

Soil diversity in eastern zone

This zone consists of the states of Bihar, Jharkhand, Odisha, West Bengal and Sikkim and occupies 13% area of the country. A number of soil diversity in this zone shows more variation in Odisha followed by Bihar, Sikkim and West Bengal. Total 302 diversified soils are reported from this zone (Fig. 5e).

Soil diversity in northeastern zone

This zone is comprised of Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya to cover an area of 7% of the country. Soil diversity is more in Assam followed by Arunachal Pradesh, Tripura and Mizoram. Low activity clay soils are common in this zone (Bhattacharyya *et al*. 1994). Total 328 diversified soils are observed in this zone (Fig. 5f).

Soil diversity in islands

The islands consist of 2 Union Territories which cover 0.2% area of the country. The Andaman and Nicobar islands have a considerable area under brown forest soils (Mollisols). Total 43 types of soils are reported in this zone (Fig.5g).

Soil Diversity Quantified

Soil diversity characterized by the variation at the state level (Fig. 6) shows that in each zone, diversity varies from 43 to 393 (Fig. 5h). The number of soil families in a few states (Uttar Pradesh, Rajasthan, Madhya Pradesh and Andhra Pradesh) is higher than in other states, suggesting that the number of soil families per million hectare (SF Mha^{-1}) may be assumed as soil diversity index (SDI) since it will depict a better indicator of soil variation.

Most of the states in the northeastern region (NER) showed higher SDI than the other states, because NER and other hilly states like Himachal Pradesh show more soil variation due to different physiographic, geological and other soil-forming factors that have given rise to different soil mapping units. Because of the limitations of 1 : 250,000 scale of mapping, a SDI threshold value of 4–5 and 10–20 was worked out for alluvial Indo-Gangetic Plains & black soil regions (BSR) and hilly areas of India, respectively (Bhattacharyya *et al.* 2013). India has a value of SDI as 5 which indicate that at least 5 different soils are present in each million hectare in our country. The SDI was maximum in the northeastern zone and minimum in the central zone (Fig. 6).

The SDI in different states within northern, western, central, southern, eastern and north eastern zones was measured. As reported earlier (Bhattacharyya *et al*. 2013), a few states were surveyed at 1: 50,000 scale. To maintain the uniformity of data structure, information of those states was not considered while computing SDI (Table 2). In the northern states, Himachal Pradesh showed the highest SDI followed by Punjab, Haryana and Uttar Pradesh. In the western zone, Gujarat indicated more SDI than Rajasthan. Similarly, in the central zone, Madhya Pradesh showed more SDI than Maharashtra. Kerala indicated the maximum SDI in southern zone, while West Ben-

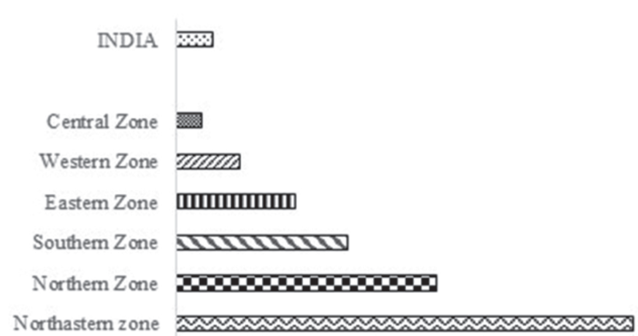

Fig. 6. Zone-wise soil diversity index (SDI) in India

gal and Odisha showed more SDI than Bihar in the eastern zone. In the northeastern zone, Mizoram indicated the maximum SDI followed by Meghalaya, Manipur, Assam and Arunachal Pradesh (Table 2).

Soil Diversity and Pedodiversity

Soil diversity is the variation of soils due to various factors which include pedodiversity. Pedodiversity refers to the diversity within the pedo-environment. Pedo-environment varies due to pedogenesis which is again controlled by factors such as parent material, climate, topography and biotic factors. Therefore, pedodiversity is a measure of soil variation and can be considered as a function of soil diversity since the latter shall include edaphology; pedodiversity centres mainly on pedology (Bhattacharyya 2014). In India, both soil and pedodiversity and their quantitative approaches are

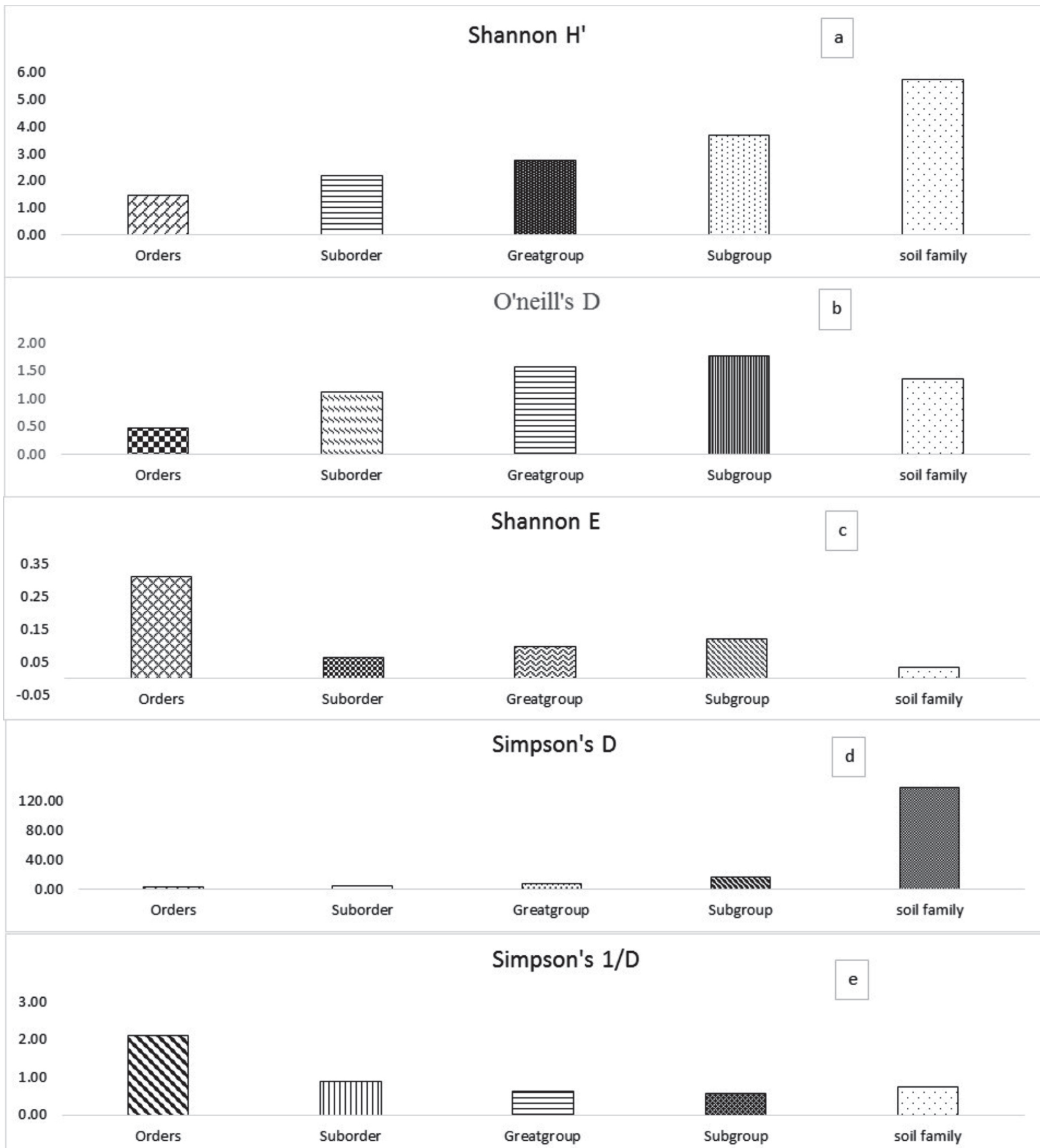

Fig. 7. Various parameters of Pedodiversity Index (PDI): (a) Shannon H′ as a measure of PDI; (b) O'Neil's D as a measure of relative dominance of one taxon over others, and (c) Smith's Evenness Index as a measure of area equitability of the soil taxa, (d) Simpson's D and (e) Simpson's 1/D as a measure of relative dominance

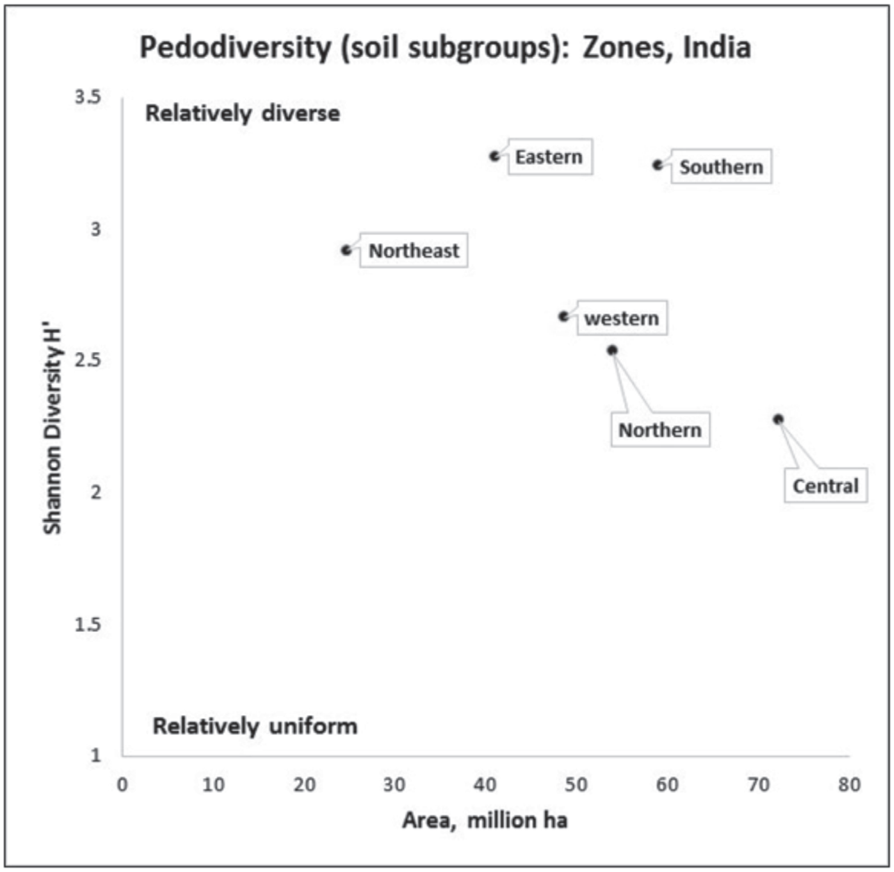

Fig. 8. Pedodiversity index (H′) and area relationship at soil subgroup level in different zones in India

few and far between. Quantified values of pedodiversity can be used to preserve, or even reconstruct the history of soil formation. Just as biologists argue that organisms need to be maintained, soil scientists opined that conservation of soils would maintain organisms as well as other unique soil materials for posterity (Guo *et al*. 2003) to maintain biodiversity and ecological balance. This suggests a close relation between pedodiversity and biodiversity as shown by the diversity index estimation (Shannon index) using biological data and soil groups (Velumourgone *et al*. 2014a). Pedodiversity, indirectly through basic pedological studies (Bhattacharyya *et al*. 2016; Pal *et al*. 2016), helps in understanding soil degradation. The quantified value of pedodiversity may help to comprehend the influence of soil forming factors in a country, districts and blocks.

The diversity index (H′) increased from 1.47 to 5.77 from order to soil family level (Fig. 7a). The D values (Fig. 7b) showed that it is at the great group and subgroup levels the extent is dominated by one or few taxa (Fig. 7b). Smith's E index (E) gradually decreased at the level of soil family (Fig. 7c). The soil orders in India are relatively more equitably distributed in their extent compared to other taxa. Soil families show exactly opposite tendencies. In this form, as diversity increased, Ds values got smaller (Fig. 7d). Inverse of Simpson's index (Ds) generated Simpson's 1/D index. Thus, larger the value of 1/D, more was soil diversity (Fig. 7e).

Pedodiversity and Biodiversity

The pedodiversity index (PDI) (H′) estimated at the level of soil subgroups and the areal extent of various zones in India (Bhattacharyya *et al.* 2013) indicates a trend between areas of different zones studied versus pedodiversity (Fig. 8). The northeastern, eastern and southern zones are showing more pedodiversity which support commonly found large biodiversity in these three zones; however, this relation is not in line with the previous results of pedodiversity for the USA (Guo *et al*. 2003) and the world (Iba´n˜ez *et al*. 1998; MacBratney *et al*. 2000). This might be due to the fact that PDI has been related with soil subgroups unlike the series used in case of the USA. Pedodiversity (Beckett and Bie 1978) and biodiversity (Kilburn 1966) was reported to have a strong species–area relationship. To justify area dependency of taxa richness larger scale of mapping and soil datasets are required.

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

Way Forward

Pedodiversity indices for soil orders, suborders, great groups, subgroups and family for only India are presented in this article. Due to huge increase in taxa richness (S) (number of taxonomic categories, Soil Survey Staff 2014) Shannon's diversity index (H′) increases. In terms of taxa evenness, taxa in all taxonomic categories are not of equal area (the maximum E=1 occurs when all taxa in a certain category have equal area). Lower evenness of taxa indicates some taxa are relatively rare while some others have a large area abundance. Different parameters used to assess pedodiversity can be evaluated more closely only when database for all the zones, states and UTs will be compared.

The data generated through soil survey vary in different parts of the country depending on topography and the ease to access. This leads to variation in exact number of their aerial extent which leads to artifacts in the soil survey process. There are different opinions about accepting the concept of diversity which is normally used in biological specimen and not in other earth science disciplines, although it has been used by many for soils, also. Soil diversity and pedodiversity did not get the deserved attention in India. It is a preliminary exercise which shall be addressed with larger datasets in future.

Acknowledgements

Grateful acknowledgements to Dr. V.K. Patil, DBSKKV, Dapoli, Dr. K. Velmourougane, CICR, Nagpur and Dr. D.K. Pal, Nagpur for their technical inputs.

References

Beckett, P.H.T. and Bie, S.W. (1978) Use of soil and land-system maps to provide soil information in Australia. Division of soils technical paper, vol. 33. Commonwealth Scientific and Industrial Research Organization, Australia.

Bhattacharyya, T. (2014) Pedology: the grammar of soil science. *Journal of the Indian Society of Soil Science* **62**, S25-S39.

Bhattacharyya, T. (2016) Mapping and soil mapping. *Indian Farming* **65**, 5-7.

Bhattacharyya, T.and Pal, D.K. (2016) U.S. Soil Taxonomy: Indian Scenario, Encyclopedia of Soil Science, Taylor and Francis (Third Edition) (in press).

Bhattacharyya, T., Chandran, P. and Ray, S.K. (2015) Soil classification following US taxonomy: An Indian Commentary. *Soil Horizon* 1-16.

Bhattacharyya, T., Nagar, A.P., Nimkhedkar, S.S., Sehgal, J.L., Velayutham, M., Gajbhiye, K.S. and Sarkar, D. (2009) Soil Taxonomic Database of India and the States (1:250,000 scale). NBSS&LUP Publication 143, NBSS&LUP, Nagpur, India.

Bhattacharyya, T., Pal, D.K., Chandran, P., Ray, S.K., Durge, S.L., Mandal, C. and Telpande, B. (2007) Available K reserve of two major crop growing regions (Alluvial and shrink-swell soils) in India. *Indian Journal of Fertilisers* **3**, 41-52.

Bhattacharyya, T.,Pal, D.K., Lal, S., Chandran, P. and Ray, S.K. (2006) Formation and persistence of Mollisols on Zeolitic Deccan basalt of humid tropical India. *Geoderma* **136**, 609-620.

Bhattacharyya, T., Pal, D.K., Mandal, C., Chandran, P., Ray, S.K., Sarkar, Dipak, Velmourougane, K., Srivastava, A., Sidhu, G.S., Singh, R.S., Sahoo, A.K., Dutta, D., Nair, K.M., Srivastava, R., Tiwary, P., Nagar, A.P. and Nimkhedkar, S.S. (2013) Soils of India: Historical perspective, classification and recent advances in knowledge; A review. *Current Science* **104**, 1308-1323.

Bhattacharyya, T., Sarkar, D. Sehgal, J.L., Velayutham, M., Gajbhiye, K.S., Nagar, A.P. and Nimkhedkar, S.S. (2009) Soil taxonomic database of India and the states (1:250, 000 scale), NBSS&LUP Publ. 143, NBSS&LUP, Nagpur, India, 266p.

Bhattacharyya, T., Sarkar, D., Ray, S.K., Chandran, P., Pal, D.K., Mandal, D.K., Prasad, J., Sidhu, G.S., Nair, K.M., Sahoo, A.K., Das, T.H., Singh, R.S., Mandal, C., Srivastava, R., Sen, T.K., Chatterji, S., Obireddy, G.P., Patil, N.G., Mahapatra, S.K., Anil Kumar, K.S., Das, K., Singh, A.K., Reza, S.K., Dutta, D., Srinivas, S., Tiwary, P., Karthikeyan, K., Venugopalan, M.V., Velmourougane, K., Srivastava, A., Raychaudhuri Mausumi, Kundu, D.K., Mandal, K.G., Kar, G., Durge, S.L., Kamble, G.K., Gaikwad, M.S., Nimkar, A.M., Bobade, S.V., Anantwar, S.G., Patil, S., Sahu, V.T., Gaikwad, K.M., Bhondwe, H., Dohtre, S.S., Gharami, S., Khapekar, S.G., Koyal, A., Sujatha, Reddy, B.M.N., Sreekumar, P., Dutta, D.P., Gogoi, L., Parhad, V.N., Halder, A.S., Basu, R., Singh, R., Jat, B.L., Oad, D.L, Ola, N.R., Wadhai, K., Lokhande, M., Dongare, V.T., Hukare, A., Bansod, N., Kolhe, A., Khuspure, J., Kuchankar, H., Balbuddhe, D., Sheikh, S., Sunitha, B.P., Mohanty, B., Hazarika, D., Majumdar, S., Garhwal ,R.S., Sahu, A., Mahapatra, S., Puspamitra, S., Kumar, A., Gautam, N., Telpande, B.A., Nimje, A.M., Likhar, C. and Thakre, S. (2014) Georeferenced soil information system : assessment of database. *Current Science* **10**, 1400-1419.

Bhattacharyya, T., Sen. T.K., Singh. R.S., Nayak, D.C. and Sehgal, J.L. (1994) Morphological characteristics and classification of Ultisols with Kandic horizon in North Eastern Region. *Journal of the Indian Society of Soil Science* **42**, 301-306.

Bhattacharyya, T.,Wani, S.P., Pal, D.K., Sahrawat, K.L., Pillai, Nimje, A., Telpande, Chandran, P. and Chaudhury, S. (2016) ICRISAT, India soils: yesterday, today and tomorrow. *Current Science* **110**, 1652-1670.

Bockheim, J.G., Genadiyev, A.N., Hartemink, A.E. and Brevik, E.C. (2014) Soil-forming factors and soil taxonomy. *Geoderma* **226–227**, 231–237.

Buol, S.W., Southard, R.J., Graham, R.C. and McDaniel, P.A. (2011) *Soil Genesis and Classification*. 6th edition, Wiley-Blackwell, New York.

Govinda Rajan, S.V. (1971) Soil map of India. In *Review of Soil Research in India* (J.S. Kanwar and S.P. Raychaudhuri, Eds.).

Guo, Y., Gong, P. and Amundson, R. (2003) Pedodiversity in the United States of America. *Geoderma* **117**, 99–115.

Ibáñez Marti, J.J., De-Alba, S., Lobo, A. and Zucarello, V. (1998) Pedodiversity and global soil patterns at coarse scales (with Discussion). *Geoderma* **83**, 171–192.

Jenny, H. (1941) *Factors of Soil Formation*. New York, McGraw– Hill.

Kilburn, P.D. (1966) Analysis of the species–area relation. *Ecology* **47**, 831–843.

Krasilnikov, P., Ibanez Marti,J.J., Arnold, R. and Shoba,S. (2009) A handbook of soil terminology, correlation and classification. Earthscan, London, 440p.

MacBratney, A.B., Odeh, I.O.A., Biship, T.F.A., Dunbar, M.S. and Shatar, T.M. (2000) An overview of pedometric techniques for use in soil survey. *Geoderma* **97**, 293–327.

Magurran, A.E. (1988) *Ecological Diversity and its Measurement*. Princeton University Press, New Jersey.

Mandal, C., Mandal, D.K., Bhattacharyya, T., Sarkar, D., Pal, D.K., Prasad, J., Sidhu, G.S., Nair, K.M., Sahoo, A.K., Das, T.H., Singh, R.S., Srivastava, R., Sen, T.K., Chatterji, S., Chandran, P., Ray, S.K., Obireddy, G.P., Patil, N.G., Mahapatra, S.K., Anil Kumar, K.S., Das, K., Singh, A.K., Reza, S.K., Dutta, D., Srinivas,S., Tiwary, P., Karthikeyan, K.,Venugopalan, M.V., Velmourougane, K., Srivastava, A., Raychaudhuri, Mausumi, Kundu, D.K., Mandal, K.G., Kar, G., Durge, S.L., Kamble, G.K., Gaikwad, M.S., Nimkar, A.M., Bobade, S.V., Anantwar, S.G., Patil, S.,Gaikwad, K.M., Sahu, V.T., Bhondwe, H., Dohtre, S.S., Gharami, S., Khapekar, S.G., Koyal, A., Sujatha, Reddy, B.M.N., Sreekumar, P., Dutta, D.P., Gogoi, L., Parhad, V.N., Halder, A.S., Basu, R., Singh, R., Jat, B.L., Oad, D.L., Ola, N.R., Wadhai, K., Lokhande, M., Dongare, V.T., Hukare, A., Bansod, N., Kolhe, A., Khuspure, J., Kuchankar, H., Balbuddhe, D., Sheikh, S., Sunitha, B.P., Mohanty, B., Hazarika, D., Majumdar, S., Garhwal, R.S., Sahu,A., Mahapatra, S., Puspamitra, S., Kumar, A., Gautam, N., Telpande, B.A., Nimje, A.M., Likhar, C. and Thakre, S. (2014) Revisiting agro-ecological sub regions of India – A case study of two major food production zones. *Current Science* **107**, 1519-1536.

Nair, K.M., Dhanorkar, B.A., Ramesh Kumar, S.C., Sujatha, K., Suresh Kumar, Premachandran, P.N. and Vadivelu, S. (2006) Soil of Kozhinjampara Panchayat, NBSS&LUP Publ. No. 960, National Bureau of Soil Survey and Land Use Planning, Nagpur.

NBSS&LUP (1985) Soils of India (suborder association 1: 7 M). National Bureau of Soil Survey and Land Use Planning, Nagpur.

O'Neill, R.V., Krummel, J.R. and Gardner, R.H. (1988) Indices of landscape pattern. *Landscape Ecology* **3**, 153–162.

Pal, D.K., Bhattacharyya, **T**., Sahrawat, K.L. and Wani, S.P. (2016) Natural chemical degradation of soils in the Indian SAT, and remedial measures: A review. *Current Science* **110**, 1675-1682.

Raychaudhari, S.P. (1979) Evolution of classification of soils of India. *Indian Agriculturist* **19**, 163–173.

Raychaudhuri, S.P., Aggarwal, R.R., Datta Biswas, N.R. Gupta, S.P. and Thomas, P.R. (1963) Soils of India, Indian Council of Agricultural Research, New Delhi.

Sehgal, J.L., Mandal, D.K., Mandal, C. and Vadivelu, S. (1992) Agro-Ecological Regions of India, *Technical Bulletin* No. 24, NBSS&LUP, Nagpur, 2nd edition, 130p.

Shannon, C.E. and Weaver, W. (1949) *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.

Smith, B. and Wilson, J.B. (1996) A consumer's guide to evenness indices. *Oikos* **76**, 70–82.

Smith, G.D. (1986) The Guy Smith interview: Rationale for concepts in Soil Taxonomy. SMSS Technical Monograph 11. SMSS, SCS, USDA. US Gov. Print. Office, Washington, DC.

Soil Survey Staff (2014) Keys to Soil Taxonomy, United States Department of Agriculture, Natural Resources Conservation Service, Washington, DC, 2006, 12th edition.

Velayutham, M.V., Bhattacharyya, T. and Pal, D.K. (2016) Classification Systems: Indian, Encyclopedia of Soil Science, Taylor and Francis (Third Edition) (in press).

Velayutham, M., Mandal, D. K., Mandal, C. and Sehgal, J.L. (1999) Agroecological Subregions of India for Development and Planning, NBSS&LUP, Nagpur Publication 35, 452p.

Velmourougane, K., Srivastava, A., Venugopalan, M.V., Bhattacharyya, T., Sarkar, D., Ray, S.K., Chandran, P.,Pal,D.K., Mandal, D.K., Prasad, J., Sidhu, G.S., Nair, K.M., Sahoo, A.K., Anil Kumar, K.S., Das, T.H., Singh, R.S., Mandal, C., Srivastava, R.,Sen, T.K., Chatterji, S.,Patil, N.G., Obireddy,G.P., Mahapatra, S.K., Das, K., Singh, A.K., Reza, S.K., Dutta, D., Srinivas,, S.,Tiwary, P., Karthikeyan, K., Raychaudhuri, Mausumi, Kundu, D.K., Mandal, K.G., Kar, G., Durge, S.L., Kamble, G.K., Gaikwad, M.S., Nimkar, A.M., Bobade, S.V.,Anantwar, S.G., Patil, S.,Gaikwad, M.S., Sahu, V.T., Bhondwe, H., Dohtre, S.S., Gharami, S., Khapekar, S.G., Koyal, A.,Sujatha, Reddy, B.M.N., Sreekumar, P., Dutta, D.P., Gogoi, L., Parhad, V.N., Halder, A.S., Basu, R., Singh, R., Jat, B.L., Oad,D.L., Ola, N.R., Wadhai, K., Lokhande, M., Dongare, V.T., Hukare, A., Bansod, N., Kolhe, A., Khuspure, J., Kuchankar,H., Balbuddhe, D., Sheikh, S., Sunitha, B.P., Mohanty, B., Hazarika, D., Majumdar, S., Garhwal, R.S., Sahu, A., Mahapatra, S., Puspamitra, S. Kumar, A., Gautam, N., Telpande, B.A., Nimje, A.M., Likhar, C. and Thakre, S. (2014b) Soil *Biological Properties of Indo-Gangetic Plains (IGP) and Black Soil Region (BSR)*. Working Report No.6, NAIP Component - 4 Project on "Georeferenced Soil Information System for Land Use Planning and Monitoring Soil and Land Quality for Agriculture", NBSS Publication No. 1067, NBSS&LUP, Nagpur, 98p.

Velmourougane, K., Venugopalan, M.V., Bhattacharyya, T., Sarkar, D., Ray, S.K., Chandran, P., Pal, D.K., Mandal, D.K.., Prasad, J., Sidhu, G.S. , Nair, K.M., Sahoo, A.K., Anil Kumar, K.S., Srivastava, A., Das, T.H., Singh, R.S., Mandal, C., Srivastava, R., Sen, T.K., Chatterji, S., Obireddy, G.P., Patil, N.G., Mahapatra, S.K., Das, K., Singh, S.K., Reza, S.K., Dutta, D., Srinivas, S.,Tiwary, P., Karthikeyan, K., Raychaudhuri, Mausumi, Kundu, D.K., Mandal, K.G., Kar G., Durge, S.L., Kamble, G.K., Gaikwad, M.S., Nimkar, A.M., Bobade, S.V., Anantwar, S.G., Patil, S., Gaikwad, M.S., Sahu, V.T., Bhondwe, H., Dohtre, S.S., Gharami, S., Khapekar, S.G., Koyal, A., Sujatha, Reddy, B.M.N., Sreekumar, P., Dutta, D.P., Gogoi, L., Parhad, V.N., Halder, A.S., Basu, R., Singh, R., Jat, B.L., Oad, D.L., Ola, N.R., Sahu, A., Wadhai, K., Lokhande, M., Dongare, V.T., Hukare, A., Bansod, N., Kolhe, A., Khuspure, J., Kuchankar, H., Balbuddhe, D., Sheikh, S., Sunitha, B.P., Mohanty, B., Hazarika, D., Majumdar, S., Garhwal, R.S., Mahapatra, S., Puspamitra, S., Kumar, A., Gautam, N., Telpande, B.A., Nimje, A.M. , Likhar, C. and Thakre, S. (2014a) Impacts of bio-climates, cropping systems, land use and management on the cultural microbial population at different soil depths in black soil regions of India. *Current Science* **107**, 1452-1463.

Vishwanath, B. and Ukil, A.C. (1943) *Soil Map of India*. Indian Agricultural Research Institute, New Delhi.

Dr. S.P. Raychaudhuri Memorial Lecture - A brief introduction

Dedicated to the memory of Dr. S.P. Raychaudhuri, one of the stalwarts among the Soil Scientists of this country during the 20th century, this lecture is arranged annually by the Indian Society of Soil Science through one of its Chapters spread all over the country. The institution of this lecture is facilitated by a donation of Rs. 30,000 made over to this Society by the Dr. S.P. Raychaudhuri Memorial Fund Committee for this purpose. Appropriately enough during 1990 the first lecture in this series was organized on 23rd April, the birthday of Dr. Raychaudhuri, by the Delhi Chapter of ISSS at the Indian Agricultural Research Institute, New Delhi; the institution with which he was associated, both officially as well as informally, for about four decades. The honour of delivering the first lecture went to Dr. N.S. Randhawa. The subsequent lectures in this series were delivered by Dr. B.P. Ghildyal (1991), Dr. J.S.P. Yadav (1992), Dr. N. Sethunathan (1993), Dr. R.L. Narasimham (1994), Dr. N. Panda (1995), Dr. A. Sankaram (1996), Dr. J.S. Kanwar (1997), Dr. B.R. Tripathi (1998), Dr. N.N. Goswami (1999), Dr. M. Velayutham (2000), Dr. Ram Sakal (2001), Dr. B.S. Bhargava (2002), Dr. J.C. Katyal (2003), Dr. U.K. Misra (2004), Dr. Jagdish K. Ladha (2005), Dr. P.D. Sharma

(2006), Dr. P. Singaram (2007), Dr. Anil Kumar Singh (2008), Dr. S.D. More (2009), Dr. B. Venkateswarlu (2010), Dr. Dipak Sarkar (2011), Dr. P. Chandrasekhar Rao (2012), Dr. Jagdish Prasad (2013), Dr. A. Raja Rajan (2014), Dr. B.B. Mishra (2015) and Dr. Tapas Bhattacharyya (2016). To this Society, arranging this series of lecture is a source of inspiration, for thereby it not only pays its respects to a doyen among the Soil Scientists but also to one who besides being a Founder Member of this Society virtually resurrected it in 1952 when it was on the verge of collapse and started the publication of the Journal of the Society, notwithstanding the precarious financial position of the Society prevailing then. For a biographical sketch of Dr. Satya Prasad Raychaudhuri, readers can refer to the Journal of the Indian Society of Soil Science, Vol. 38, pp 366-372 (1990).