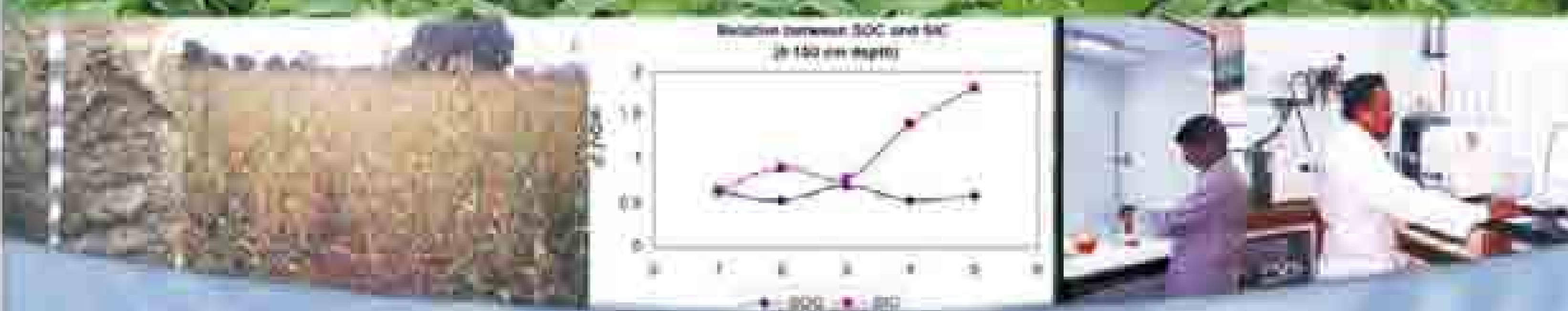
Global Theme on Agroecosystems

Report no. 35

Physical and Chemical Properties of Red and Black Soils of Selected Benchmark Spots for Carbon Sequestration Studies in Semi-Arid Tropics of India



International Crops Research Institute for the Semi-Arid Tropics

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Abstract

Physical (nine characteristics) and chemical (14) properties of red and black soils are described: sand, silt, clay, fine clay, BD, COLE, HC (hydraulic conductivity) and WDC; pH (H_2O and KCl), EC, OC, $CaCO_3$, clay CO_3, extractable Ca, Mg, Na, K, CEC, clay CEC, BS and ESP are described in three ecosystems, namely sub-humid (moist and dry) [SH (m) and SH (d)], semi-arid (moist and dry) [SA (m) and SA (d)] and arid in SAT, India.

Clay contents vary between 30% in arid system to 82% in sub-humid (dry) system and 79% in semi-arid (dry) system. The red soils contain 8--55% clay. Fine clay (<0.2 μm) content ranges between 9–54% in red soils; for black soils nearly 50% of total clay (<2 μm) remains in finer (<0.2 μm) fractions. The overall relation between SOC and BD is negative; however, the correlation between SIC and BD within a depth of 0–30 cm soil depth is positive. Increase in relative proportion of coarse fragments increases the pore space, effecting decrease in BD values. The inherent relation between total clay and COLE in different bioclimatic systems indicates a positive correlation with a relatively high value (r = 0.83) in arid bioclimatic system. Except sub-humid (moist) and arid bioclimates, a positive correlation between COLE and slickensides is observed in most of the Vertisols in SAT India. A general decreasing trend of SOC with increase in HC is observed. Conversely, an increasing trend of HC has been found with decrease in SIC. In all the bioclimates, there is an increasing trend of SOC with decrease in ESP and an increasing trend of SIC with increase in ESP. This is due to preferential release of Ca^{2+} ions and their precipitation as $CaCO_3$ in soil, thereby increasing the relative concentration of Na^+ ions in the exchange complex effecting high value of ESP. In general, a positive correlation between amount of fine clay and SOC in surface soils has been found.

The SOC values in the surface (0–30 cm) follow the trend of forest system > permanent fallow (grassland), horticultural system > agricultural system > wasteland. Surface soils of agricultural and horticultural systems store higher SIC as compared to other systems. The surface soils of semi-arid (moist) show higher SOC under agricultural system due to inclusion of sun hemp for green manuring in crop rotation. The average SOC values follow the trend of SA (m) (0.825%) > SH (d) (0.804%) > SH (m) (0.642%) > SA (d) (0.633%) > arid (0.594%) for black soils under agricultural system. The values of SOC follow the trend of SH (m) (1.35) > SA (d) (0.84) > SA (m) (0.70) for the red soils used for cultivation.

The level of SIC values in surface soils under agricultural system followed the trend of arid (2.34%) > SH (d) (1.06%) > SA (m) (0.99%) > SA (d) (0.94%) > SH (m) (0.54%) for black soils. In red soils, $CaCO_3$ in general is not found except in soils of semi-arid (dry) bioclimatic system.

The SOC in surface horizon under agricultural systems shows higher values for cereal-based system (0.79%), followed by soybean systems (0.70%) and cotton-based systems (0.68%). Interestingly, the SIC values have been found to be the highest in cotton-based systems (1.53%), followed by soybean-based systems (0.66%) and cereal-based systems (0.29%). This trend is opposite to that of the corresponding SOC values.

With the help of data generated, 14 systems (five in cotton, three in soybean, four in cereals, one in horticulture and one under forest) have been identified as ideal for organic carbon sequestration, keeping in view the existing level of management practices vis-à-vis soil health.

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Chapter 1: Introduction

Physical properties of black and associated soils—particle-size distribution, namely sand, silt, clay, bulk density (BD), coefficient of linear extensibility (COLE), saturated hydraulic conductivity (HC) and water dispersible clay (WDC)—were determined. The chemical properties of black soils include pH, electrical conductivity (EC), organic carbon, calcium carbonate, clay carbonate, cation exchange capacity (CEC), extractable bases and exchangeable sodium percentage (ESP).

The basic property of Vertisols is that they have high water-holding capacity. This is controlled primarily by the relative proportion of different soil-size fractions. Vertisols are usually dominated by clay, which commonly ranges from 40 to 60%, but may be as high as 80% (Dudal 1965; DeVos and Virgo 1969; Bhattacharyya et al. 2003). In general, surface soils show low amount of clay that increases with depth. Clay content of black soils is uniformly high to a depth of 50 cm (Raychaudhuri et al. 1963; Dudal 1965, Yule and Ritchie 1980). Although typical Vertisols show high clay content in the subsurface, there are reports of Vertisols with sandy-textured subsurface (Cocheme and Franquin 1967; De Vos and Virgo 1969; Ray and Reddy 1997). In contrast, the red soils (Alfisols) show an increasing trend of clay down the depth, followed by a decrease in clay content.

The dominant clay mineral in Vertisols is smectite (Pal and Deshpande 1987b). It has been stated recently that Vertisols showing typical *vertic* properties can only be because of smectite content (Bhattacharyya et al. 1997) to the tune of at least 20% (Shirsath et al. 2000). The presence of dominating amounts of clay fractions offer more surface charge density (SCD), which is an important prerequisite of increasing SOC (Poonia and Niederbudde 1990; Bhattacharyya et al. 2000).

Another important physical property which largely determines the stock of both organic and inorganic form of carbon is bulk density (BD). The BD of Vertisols varies greatly because of their swelling and shrinking nature, which changes with moisture content. The soils have high BD when they are dry, and have low BD when they are in a swollen state. Bulk density has been reported to vary from 1.0 to 2.0 g/cm^3, depending on the moisture content. Bulk density usually tends to increase with depth, due to compression caused by overburden weight. It has been observed that a volume change of nearly 60% occurs when a dry Vertisol is saturated with water (Rao et al. 1978). Various other physical properties of soils have been detailed by other authors (Ghosh and Raychaudhuri 1974).

Due to relatively lower values of clay and/or extractable bases and ESP, the hydraulic conductivity (HC) of Vertisols show initial higher values in the surface horizons, followed by drastic reduction in the subsurface horizons. It was reported that HC values decreased from 7.6 to 3.4 cm/hr for the first one hour, to 0.4 cm/hr over one to two hours, and further to 0.02 cm/hr after 144 hours when soils were saturated (Krantz et al. 1978). It has been reported that hydraulic conductivity gets impaired in Vertisols with increasing content of $CaCO_3$ and exchangeable sodium percentage (Pal et al. 2000; Srivastava et al. 2002; Pal et al. 2003). It therefore appears that soils sequestering more inorganic carbon will have highly impaired hydraulic conductivity value. This value could be as low as 0.1 to 0.2 cm/hr. Recently, hydraulic conductivity has been reported as a single-index parameter to judge the quality of Vertisols with respect to yields of crops in the semi-arid tropics of India (Kadu et al. 2003).

In view of the importance of soil characteristics, nearly 52 pedons were selected from Indian SAT to study the physical and chemical properties of Vertisols and associated soils in order to identify the systems for carbon sequestration and increased productivity in semi-arid tropical environments.

Chapter 2: Materials and Methods

2.1 Materials

2.1.1 Background

Recent studies of red soils (Alfisols of eastern India, Saikh et al. 1998a,b) and associated red and black soils (Bhattacharyya and Pal 1998; Naitam and Bhattacharyya 2001) indicate that soil organic carbon (SOC) content of soils sharply declines when put to cultivation. Reduction of SOC level is significant even within 15 to 25 years of cultivation. These authors have hypothesized that irrespective of the initial organic carbon levels of these red soils, there is a tendency to reach the quasi-equilibrium value of 1 to 2% SOC. These values could be as high as 2–5% for black soils. Since such studies are limited to a specific geographical region, a generalized view about carbon-carrying capacity of the soils may not be advisable, because quality of soil substrate and its surface charge density (SCD) varies from one place to another.

It has been reported that increase in SOC increases the SCD of soils and the ratio of internal/external exchange sites (Poonia and Niederbudde 1990). It may be mentioned that the dominant soils in the semi-arid tropics (SAT) are black soils (Vertisols and their intergrades, with some inclusions of Entisols in the hills and pediments) and associated red soils. All these soils are dominated by smectites and smectite-kaolinite (Bhattacharyya et al. 1993; Pal and Deshpande 1987a, 1987b; Pal et al. 1989, 2000). Presence of smectite increases the SCD of soils, which offers greater scope of carbon sequestration in these soils. Black soils, therefore, may reach a higher quasi-equilibrium value (>2%) compared to red soils, dominated by kaolinites with low SCD.

Bhattacharyya and Pal (1998) reported 2–5% of SOC in black soils in the surface soils from Mandla and Dindori districts of Madhya Pradesh. More recently, it was also indicated the scope of higher SOC content in the shrink-swell soils of Australia. To find out the sufficient and deficient zones for SOC in different agro-ecoregions, Velayutham et al. (2000) adopted the lower limit of the quasi-equilibrium value of 1%. In view of higher SCD of the dominant soils of the SAT and considering a quasi-equilibrium value of 2% of SOC in the first 30 cm depth of soils, the SOC stock is worked out as 10.5 Pg for an area of 116.4 m ha. This value is more than three times the existing SOC stock of SAT (Bhattacharyya et al. 2000). It, therefore, appears that effective sequestration processes can increase the SOC stock by three times or more, suggesting that the SAT could be fruitfully prioritized for carbon management in the Indian subcontinent.

2.1.2 Area

Keeping the above points in view, the study area was chosen in the SAT as well as in the relatively dry sub-humid agro-eco subregions (AESRs 9.1, 9.2, 10.1, 10.2, 10.3, 10.4) (Velayutham et al. 1999). Area-wise, the vast plains of sub-humid, semi-arid and arid ecosystems cover 150.9 m ha area in this subcontinent. While selecting the soil-sites, the specific bioclimatic systems were identified in view of the rainfall (mean annual) as mentioned below:

Sub-humid (moist) SH (m) : >1100 mm
Sub-humid (dry) SH (d) : 1100-1000 mm

Semi-arid (moist) SA (m) : 1000-850 mm
Semi-arid (dry) SA (d) : 850-550 mm
Arid (A) : <550 mm

The rainfall variation in different bioclimatic systems is shown in Figure 2.1.

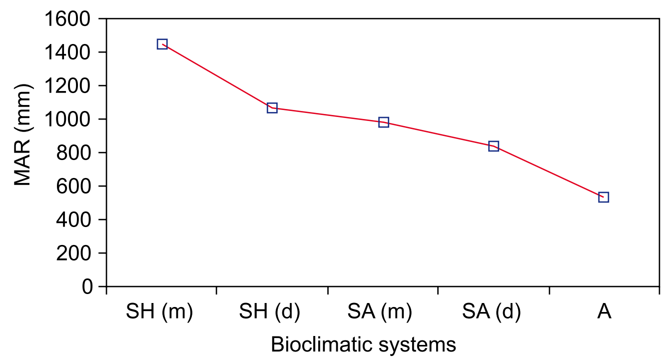


Figure 2.1. Rainfall variation in different bioclimatic systems.

2.1.3 Soils

The soils for the present study were chosen from the established benchmark (BM) sites, the reason being that each soil would cover a widely extensive area in the landscape and monitoring these BM sites would be easy. Though a few selected soils do not belong to the benchmark sites, it has been ascertained that each of these soil series covers an area much larger than 20,000 ha (area required for any soil series to have benchmark status).

In order to make meaningful comparisons, the soils were so chosen that their substrate quality remains similar. Therefore, the study area and the soil series representing Vertisols and their vertic intergrades and other benchmark sites were selected. Some associated black soils under forest were also, however, included as control. In addition, some red soils from both cultivated and forest areas (as control) were selected for the study. These controls have been taken to compare the substrate quality vis-à-vis carbon-storage capacity of black soils with the red soils.

For the present study, 28 benchmark (BM) spots were selected which included 52 pedon sites. The relative proportion of black and red soils in different BM spots as well as ecosystems is shown in Figures 2.2, 2.3, 2.4 and 2.5.

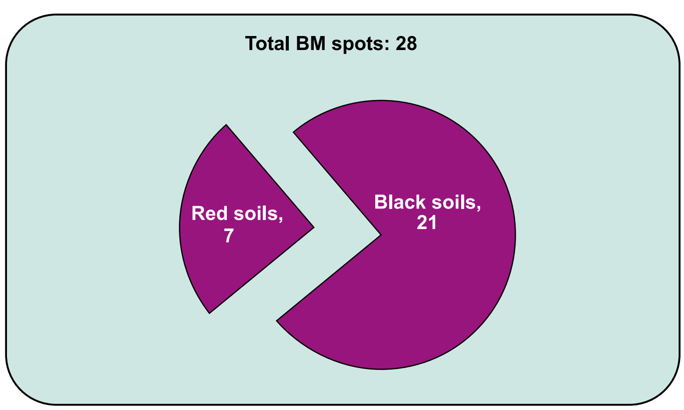


Figure 2.2. Distribution of BM spots in the study area.

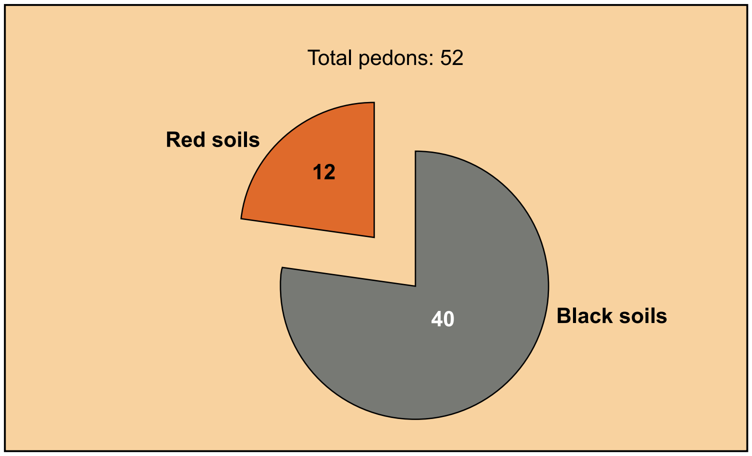


Figure 2.3. Distribution of pedons by soil type.

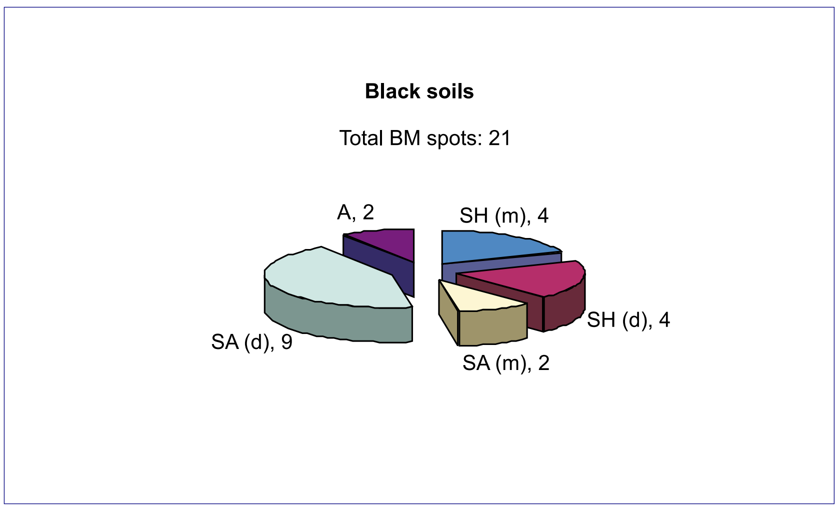


Figure 2.4. Distribution of BM spots (black soils) in different bioclimatic systems.

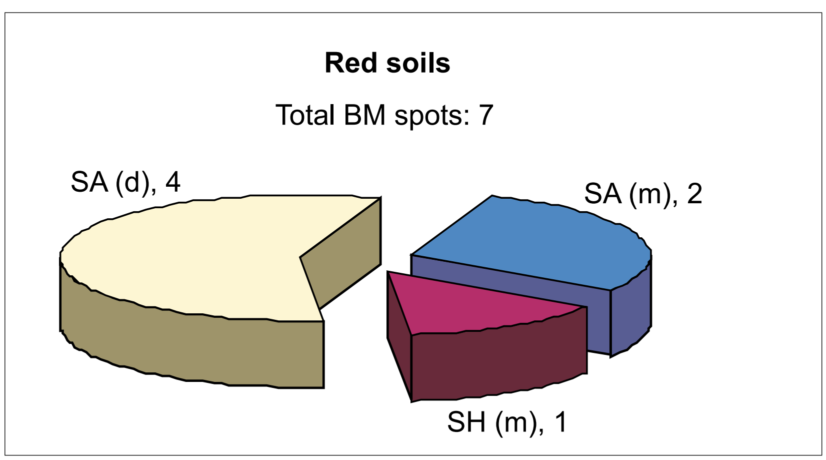


Figure 2.5. Distribution of BM spots (red soils) in different bioclimatic systems.

2.1.4 Systems

The selected BM spots in the black and red soils area were given another dimension in the form of systems. A total of five broadly classified systems, viz. agriculture, horticulture, forest, wasteland and permanent fallow were selected. By far, agricultural systems dominate the chosen BM spots as well as the total number of pedons (Figs. 2.6 and 2.7).

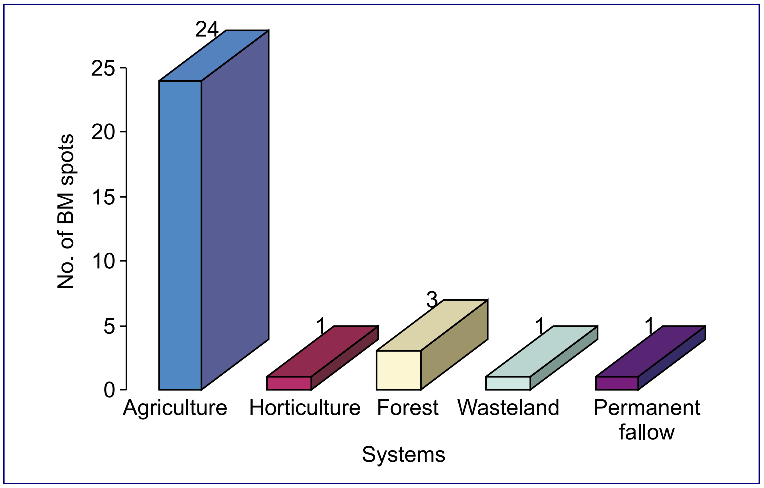


Figure 2.6. Distribution of BM spots by production systems.

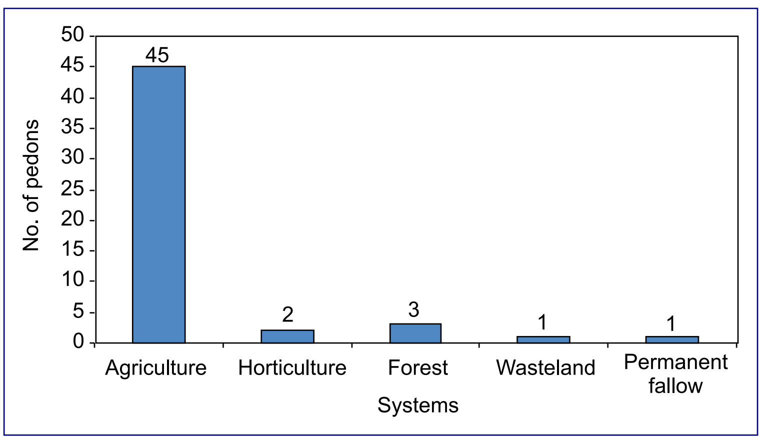


Figure 2.7. Distribution of pedons by production systems.

The soil series were selected in such a way that in any system (for example, agricultural system) under a particular cropping pattern, two representative pedons (under the same soil series) were included—one under farmers' management (FM) (generally low management, LM) and the other under high management (HM). Wherever possible, within the same soil series different cropping patterns under farmers' management were also chosen. The level of management describing high and low levels is indicated in Table 2.1.

Table 2.1. Level of management in different BM sites.

Sl. No.	High Management (HM)	Low Management (LM)
1.	Higher NPK	Low NPK
2.	Regular application of manures	Manures rarely applied
3.	Intercropping with legumes	Sole crop
4.	Incorporation of residues	Removal of residues & biomass
5.	Soil moisture conservation (ridge furrows, bunding, broad bed and furrow)	Nil

Within the agricultural system, three major dominant cropping patterns were selected, namely cotton, soybean and cereals (Tables 2.2, 2.3, 2.4).

Following the concept of BM spots, Vertisols and their vertic intergrades (black soils) and Alfisols (red soils) as pedons representing soil series, the various land-use systems, the database generated through this project has been arranged, following mainly the five bioclimatic systems. Details of materials and study area are shown in Table 2.5.

Table 2.2. Agricultural systems with cotton as dominant crop, covering twelve pedons.

Cropping pattern	Pedons
Cotton	P4
Cotton+Pigeonpea	P48, P49
Cotton+Pigeonpea/Soybean-Chickpea	P12
Cotton+Pigeonpea/Sorghum	P13, P14
Cotton/Green gram+Pigeonpea	P10
Cotton+Black gram	P21
Cotton/Groundnut-Wheat	P29
Cotton-Pearl millet	P30
Cotton-Pearl millet/Linseed	P31
Cotton-Wheat/Chickpea	P51

Table 2.3. Agricultural systems with soybean as dominant crop, covering eleven pedons.

Cropping pattern	Pedons
Soybean/Paddy-Wheat	P28
Soybean-Wheat	P5, P6, P7, P8, P32
Soybean	P50
Soybean-Chickpea	P9
Soybean-Chickpea/Wheat	P2
Soybean+Pigeonpea	P11, P39

2.2 Methods

The international pipette method was applied for particle-size analysis for quantifying the sand, silt and clay fractions according to the size segregation procedure of Jackson (1979). COLE was determined according to Schafer and Singer (1976). Bulk density was determined by field-moist method using core samples (diameter 50 mm) of known volume (100 ml) (McIntyre 1974; Klute 1986).

Table 2.4. Agricultural systems with cereals, covering fourteen pedons.

	Cropping Pattern	Pedons
Paddy	Paddy-Wheat	P27, P33
	Paddy-Paddy	P36, P44
Millets	Finger millet	P16
	Finger millet/Pigeonpea/Red gram/Groundnut	P17
	Finger millet	P18
	Minor millet/Sweet potato	P26
Sorghum	Sorghum+Pigeonpea/Black gram-Chickpea	P42
	Sorghum/Pigeonpea+Green gram	P35
	Sorghum/Sunflower/Cotton	P19
	Sorghum-Castor	P37, P38
Maize	Maize/Mustard	P23

The water dispersible clay was determined by taking 10 g of soil and then shaking with water on an end-to-end shaker for eight hours. Suspension aliquots were drawn by following the international pipette method (USDA 1972). Hydraulic conductivity (HC) was measured by taking 200 g of soil, uniformly tapped and saturated overnight. It was measured by taking an hourly observation until three constant observations were obtained. It was measured in cm/hr (Richards 1954). The chemical characteristics of soils were determined by standard procedures (Jackson 1973).

Table 2.5. Benchmark spots and their site characteristics in order of decreasing rainfall from sub-humid to arid bioclimatic system.

Sl. No.	BM spot	District/State	Series	System	Mean annual rainfall (mm)	Profile no.
			Black soils			
			Sub-humid (moist): Mean annual rainfall >1100 mm			
1.	13	Jabalpur/Madhya Pradesh	Kheri	Agriculture (HM) Paddy-Wheat	1448	P27
2.	13	Jabalpur/Madhya Pradesh	Kheri 1	Agriculture (LM) Soybean/Paddy-Wheat	1448	P28
3.	7	Nagpur/Maharashtra	Boripani	Forest (Teak)	1279	P15
4.	3	Bhopal/Madhya Pradesh	Nabibagh	Agriculture (HM) Soybean-Wheat	1209	P5
5.	3	Bhopal/ Madhya Pradesh	Nabibagh	Agriculture (FM) Soybean-Wheat	1209	P6
6.	2	Nagpur/Maharashtra	Panjri	Agriculture (HM) Cotton	1127	P4

Continued...

Table 2.5. *Continued.*

Sl. No.	BM spot	District/State	Series	System	Mean annual rainfall (mm)	Profile no.
Sub-humid (dry): Mean annual rainfall 1100 – 1000 mm						
7.	26	Adilabad/Andhra Pradesh	Nipani	Agriculture (FM) Cotton+Pigeonpea	1071	P48
8.	27	Adilabad/Andhra Pradesh	Pangidi	Agriculture (FM1) Cotton+Pigeonpea	1071	P49
9.	27	Adilabad/Andhra Pradesh	Pangidi 1	Agriculture (ITDA) Soybean	1071	P50
10.	4	Indore/ Madhya Pradesh	Sarol	Agriculture (HM) Soybean-Wheat	1053	P7
11.	4	Indore/ Madhya Pradesh	Sarol	Agriculture (FM) Soybean-Wheat	1053	P8
12.	4	Indore/ Madhya Pradesh	Sarol	Agri-horticulture (HM) Soybean-Gram in mango orchard	1053	P9
13.	1	Nagpur/Maharashtra	Linga	Horticulture (HM) Citrus	1011	P1
14.	1	Nagpur/Maharashtra	Linga	Horticulture (LM)* Citrus	1011	P3
15.	1	Nagpur/Maharashtra	Linga	Agriculture (FM) Soybean-Gram/ Wheat	1011	P2
Semi-arid (moist): Mean annual rainfall 1000–850 mm						
16.	22	Bidar/Karnataka	Bhatumbra	Agriculture (FM) Sorghum+Pigeonpea/ Black gram-Chickpea	977	P42
17.	5	Amravati/Maharashtra	Asra	Agriculture (FM)* Cotton/Green gram+Pigeonpea	975	P10
18.	5	Amravati/Maharashtra	Asra	Agriculture (FM) Soybean+Pigeonpea	975	P11
19.	5	Amravati/Maharashtra	Asra	Agriculture (HM) Cotton+Pigeonpea/ Soybean-Gram	975	P12
Semi-arid (dry): Mean annual rainfall 850–550 mm						
20.	16	Kota/Rajasthan	Jhalipura	Agriculture (FM1) Soybean-Wheat	842	P32
21.	16	Kota/Rajasthan	Jhalipura	Agriculture (FM2) Paddy-Wheat	842	P33
22.	6	Akola/Maharashtra	Paral	Agriculture (LM) Cotton+Pigeonpea/ Sorghum	794	P13

Continued...

Table 2.5. *Continued.*

Sl. No.	BM spot	District/State	Series	System	Mean annual rainfall (mm)	Profile no.
23.	6	Akola/Maharashtra	Paral	Agriculture (HM) Cotton+Pigeonpea/ Sorghum	794	P14
24.	18	Mehboobnagar/Andhra Pradesh	Jajapur	Agriculture (FM1) Sorghum/ Pigeonpea+Green gram	792	P35
25.	18	Mehboobnagar/Andhra Pradesh	Jajapur 1	Agriculture (FM2) Paddy-Paddy	792	P36
26.	20	Medak/Andhra Pradesh	Kasireddipalli	Agriculture (HM) Soybean+Pigeonpea	764	P39
27.	20	Medak/Andhra Pradesh	Kasireddipalli	Agriculture (TM) Fallow-Chickpea	764	P40
28.	24	Solapur/Maharashtra	Konheri	Agriculture (FM) Pigeonpea/Sunflower-Sorghum	742	P45
29.	24	Solapur/Maharashtra	Konheri 1	Agriculture (LM) Fallow-Sorghum+Safflower	742	P46
30.	25	Nasik/Maharashtra	Kalwan	Agriculture (FM) Sugarcane/Jowar-Wheat/Gram	692	P47
31.	9	Tuticorin/Tamil Nadu	Kovilpatti	Agriculture Sorghum/Sunflower/ Cotton	660	P19
32.	9	Tuticorin/Tamil Nadu	Kovilpatti 1	Wasteland	660	P20
33.	9	Tuticorin/Tamil Nadu	Kovilpatti	Agriculture (HM) Cotton+Black gram	660	P21
34.	14	Rajkot/Gujarat	Semla	Agriculture Cotton/Groundnut-Wheat	635	P29
35.	23	Bellary/Karnataka	Teligi	Agriculture (LM) Paddy-Paddy	632	P43
36.	23	Bellary/Karnataka	Teligi 1	Agriculture (HM) Paddy-Paddy	632	P44
			Arid: Mean annual rainfall < 550 mm			
37.	15	Rajkot/Gujarat	Sokhda	Agriculture (FM1) Cotton-Pearl millet	533	P30
38.	15	Rajkot/Gujarat	Sokhda 1	Agriculture (FM2) Cotton-Pearl millet/ Linseed	533	P31

Continued...

Table 2.5. *Continued.*

Sl. No.	BM spot	District/State	Series	System	Mean annual rainfall (mm)	Profile no.
39.	28	Ahmednagar/Maharashtra	Nimone	Agriculture (HM) Cotton-Wheat/ Chickpea	520	P51
40.	28	Ahmednagar/Maharashtra	Nimone	Agriculture (FM) Sugarcane –Soybean/ Wheat/Chickpea	520	P52
			RED SOILS			
			Sub-humid (moist): Mean annual rainfall >1100 mm			
41.	11	Dindori/Madhya Pradesh	Dadarghugri	Agriculture (LM) Maize/Mustard	1420	P23
42.	11	Dindori/Madhya Pradesh	Dadarghugri	Forest (Teak)	1420	P24
43.	12	Umeria/Madhya Pradesh	Karkeli	Forest (Sal)	1352	P25
44.	12	Umeria/Madhya Pradesh	Karkeli 1	Agriculture (LM) Minor millet/Sweet potato	1352	P26
			Semi-arid (moist): Mean annual rainfall 1000–850 mm			
45.	8	Bangalore/Karnataka	Vijaypura	Agriculture (FM) Finger millet	924	P16
46.	8	Bangalore/Karnataka	Vijaypura 1	Agriculture* Finger millet/ Pigeonpea/Red gram/ Groundnut	924	P17
47.	8	Bangalore/Karnataka	Vijaypura 1	Agriculture (HM) Finger millet	924	P18
			Semi-arid (dry): Mean annual rainfall 1000–850 mm			
48.	19	Rangareddy/Andhra Pradesh	Hayatnagar	Agriculture (HM) Sorghum-Castor	764	P37
49.	19	Rangareddy/ Andhra Pradesh	Hayatnagar	Agriculture (LM) Sorghum-Castor	764	P38
50.	21	Medak/Andhra Pradesh	Patancheru	Permanent fallow	764	P41
51.	17	Mehboobnagar/Andhra Pradesh	Kaukuntla	Agriculture (FM) Castor+Pigeonpea	674	P34
52.	10	Coimbatore/Tamil Nadu	Palathurai	Agriculture Horsegram/ Vegetables	612	P22

* Original BM spots

Rainfall range in:

- Sub-humid (moist) ecosystem = >1100 mm
- Sub-humid (dry) ecosystem = 1100–1000 mm
- Semi-arid (moist) ecosystem = 1000– 850 mm
- Semi-arid (dry) ecosystem = 850–550 mm
- Arid ecosystem = <550 mm

Chapter 3: Results and Discussion

The physical and chemical properties of selected benchmark soils are discussed in the following chapters to find out which bioclimatic systems offer greater scope for organic as well as inorganic carbon sequestration.

3.1 Particle-Size Distribution in Soils

For the convenience of characterizing and classifying soil for agricultural and non-agricultural purposes, the soil materials are separated into coarse and fine particles. Several systems of classification of soils on the basis of particle-size classes are used to interpret soils for their uses—agricultural or non-agricultural. The particle-size distribution data in fine-earth fractions are used mainly to substitute the field-texture data obtained by 'feeling method'. The data on particle sizes serve as a check on the homogeneity of soil profiles.

The soils selected for the present study belong to Vertisols and their intergrades. Logically, the sand, silt and clay content should be within the range to qualify them as Vertisols (Soil Survey Staff 1999). However, depending on geological formation and the bioclimatic region, the contents of sand, silt and clay vary as shown in Table 3.1.

The clay content varies from 30% in arid system to 82% in sub-humid (dry) and 79% in semi-arid (dry) system. The sand content in sub-humid moist system varies from 0.3 to 16.8%. However, the Kheri-1 soils (P28) indicate higher content of sand (6–18%). This might be due to the effect of a nearby stream and land filling by relatively coarser materials.

The sub-humid (dry) bioclimate represents four benchmark spots. The Linga soils and Sarol soils have a very low sand content (0.2 to 2%). The soils developed from the basaltic alluvium in Nipani and Pangidi have higher sand content, ranging from 1 to 8%. The clay content of Linga soils varies from 60 to 70%, whereas the soils in Pangidi show very high clay content, often exceeding 82%.

Table 3.1. Percentage range of sand, silt and clay in black and red soils in different bioclimatic zones.

Bioclimate	Sand (2–0.05 mm)	Silt (0.05–0.002 mm)	Clay (<0.002 mm)
Black soils			
SH (m)	0.3–16.8	31.0–46	47–68
SH (d)	0.2–6.4	22.6–44.0	49–82
SA (m)	0.8–5.6	26–36	60–73
SA (d)	0.5–34	17–44	41–79
A	4–28	26–40	30–69
Red soils			
SH (m)	6–10[1]	37–40[1]	40–55[1]
	49–80[2]	12–30[2]	8–33[2]
SA (m)	50–62[3]	7–20[3]	27–65[3]
SA (d)	35–76[3]	4–19[3]	14–53[3]

1: Basalt; 2: Sandstone; 3: Granite-gneiss

In semi-arid (moist) system, clay content is more than 60% in all the soils. The sand content ranges from 0.8 to 5.6%, with Bhatumbra soils having more sand than Asra soils.

In semi-arid (dry) zone, the sand content ranges from 0.5 to 34%. The lower content of sand is found in Paral and Konheri soils. The clay content also shows a wide range from 41 to 79%. The lower content of clay is common in Semla, Jhalipura, Jajapur, Kasireddipalli, Teligi and Konheri soils where the range is 41 to 55%.

The seat of charge in soil mostly lies in clays and fine-silt fractions. Therefore, both the physical and chemical activities of soils are expected to be controlled by clay and silt. The major emphasis being the status of carbon in the soils, it seems prudent to establish relationships of organic carbon (SOC) and inorganic carbon in soils (SIC) with the reactive components, namely clay (<2 μ), fine clay (<0.2 μ) and clay+silt (<50 μ). With this in view, fine clay, clay, clay + silt percentage values were compared with SOC and SIC percentage values for black soils in different bioclimatic systems. A relationship with all the data sets was also found, irrespective of the bioclimatic systems.

The relationships of clay, fine clay, clay + silt with SOC in surface horizons are shown in Figures 3.1, 3.2 and 3.3. Similarly, a general relationship between clay, fine clay, clay + silt and SIC in 50–100 cm depth is shown in Figures 3.4, 3.5 and 3.6.

The clay content in red soils varies between 8 and 55% (Table 3.1). The red soils formed in basalt contain more clay as compared to those formed in sandstone. Figure 3.7 indicates substrate quality for both red and black soils. For all the soils, the FC/TC is low in SA (m) bioclimatic system and high in SH (m) and SH (d) bioclimatic systems.

Fine clay (FC) (<0.2 μm) is considered as the most reactive part of soils in terms of actual seat of reactions due to its small size and high surface area. This is more so in black soils which contain nearly 50% fine clay in the total clay fractions (Table 3.2). For red soils, these values range between 9 and 54% (Table 3.2). The content of total clay and the ratio of FC : TC has been plotted against each bioclimatic system to indicate the substrate quantity for C sequestration. The TC content increases from SH (m) and maintains a value of 41–79% in SH (d), SA (m) and SA (d) bioclimatic zones.

Table 3.2. Percentage range of clay fractions and their ratios.

Bioclimatic system	Total clay (TC) (<2 μm)	Fine clay (FC) (<0.2 μm)	Coarse clay (CC) (2–0.2 μm)	FC/TC
Black soil				
SH-M	47–68	32–54	46–68	49–88
SH-D	49–79	30–65	35–70	61–93
SA-M	59–73	27–45	55–73	41–65
SA-D	41–79	19–40*	60–81*	42–77*
A	30–69	13–50	50–87	44–80
Red soil				
SH-M	40–55	33–54[1]	46–67	67–90[1]
	8–33	9–22[2]	78–91	49–71
SA-M	27–55	12–39	61–88	39–72
SA-D	14–53	12–46	54–88	77–85

* Except Kovilpatti soil
1: Basalt; 2: Granite-gneiss

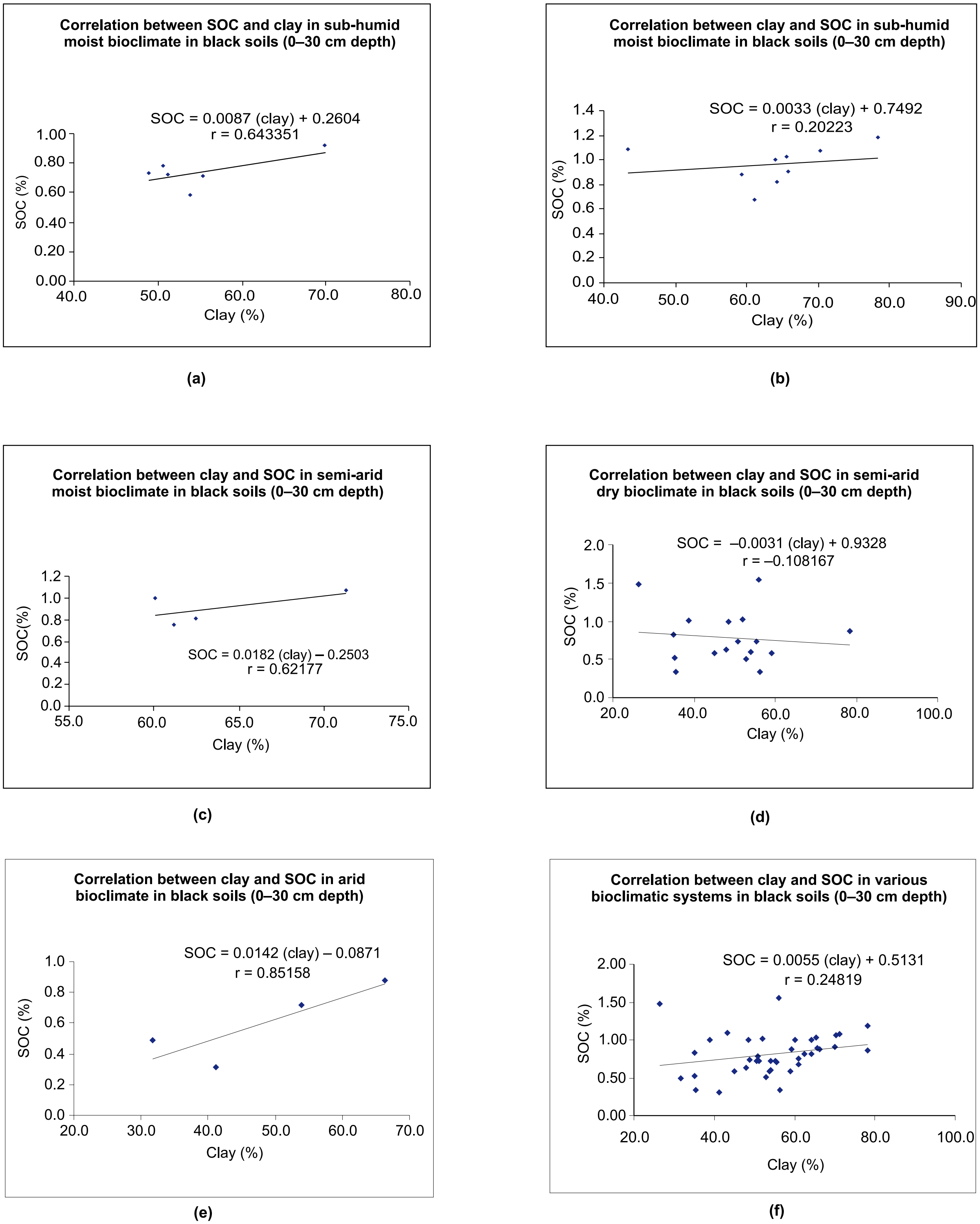


Figure 3.1. Correlation between soil organic carbon (SOC) and clay content in black soils of SAT, India.

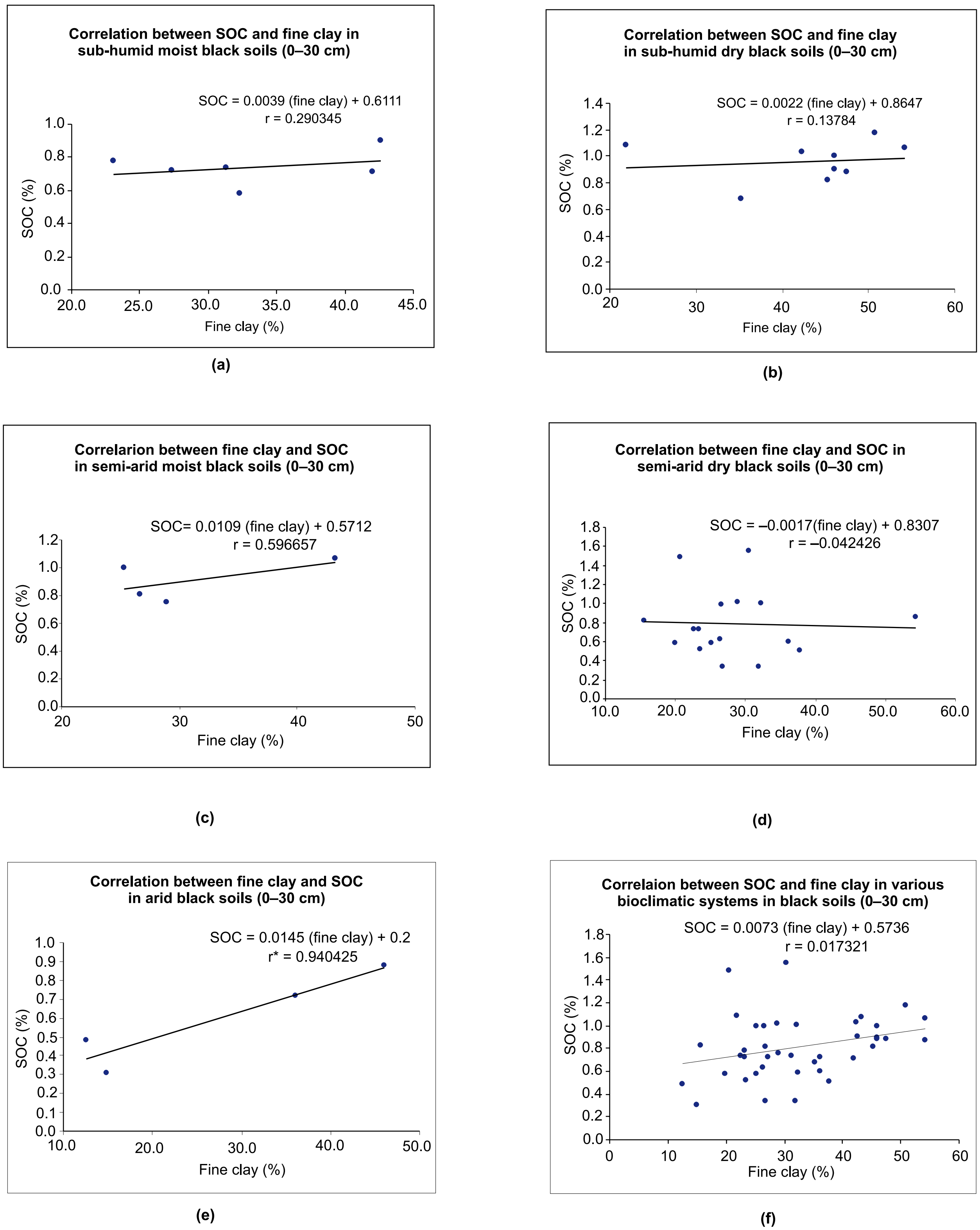


Figure 3.2. Correlation between soil organic carbon (SOC) and fine-clay content in black soils of SAT, India.

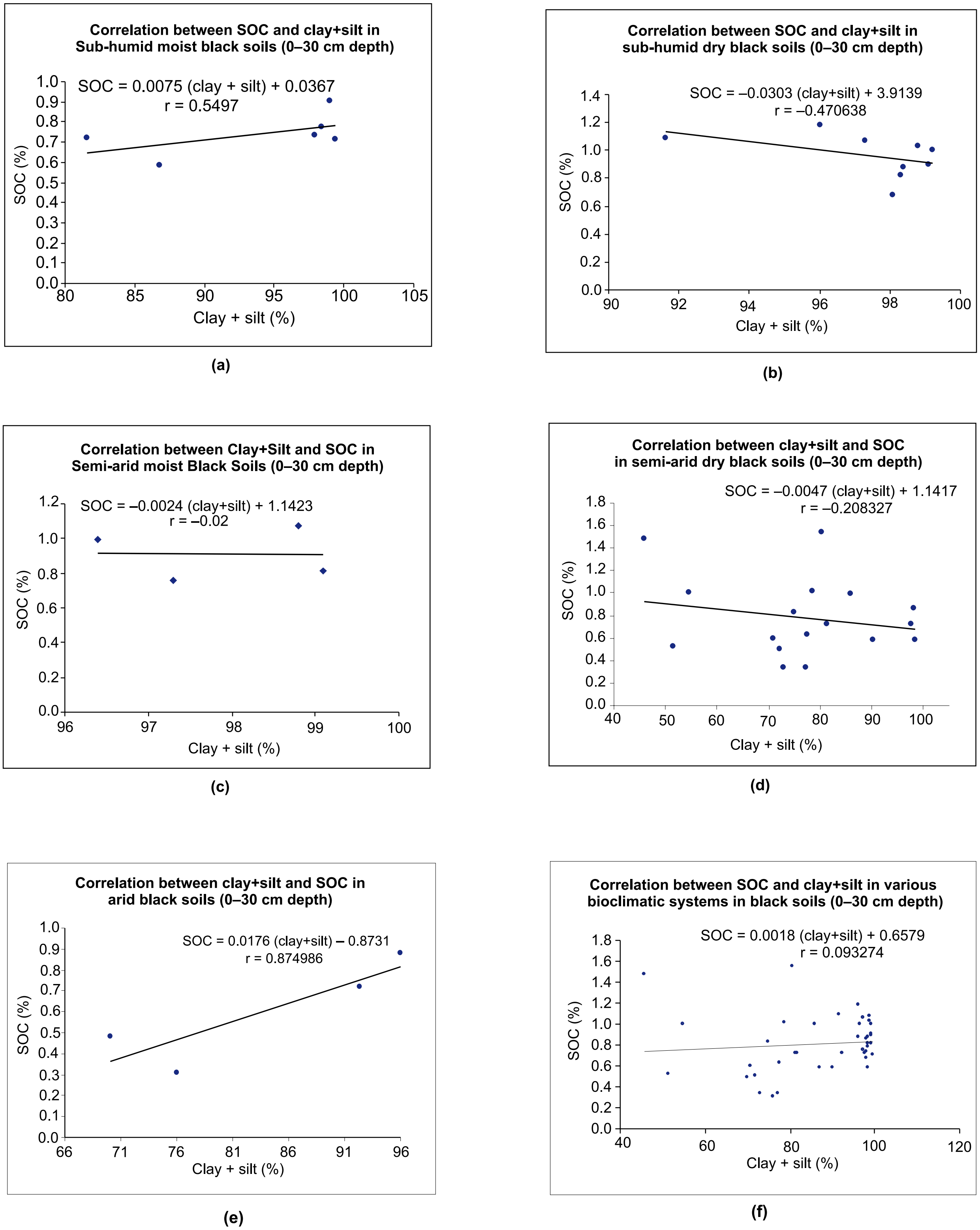


Figure 3.3. Correlation between soil organic carbon (SOC) and clay+silt content in black soils of SAT, India.

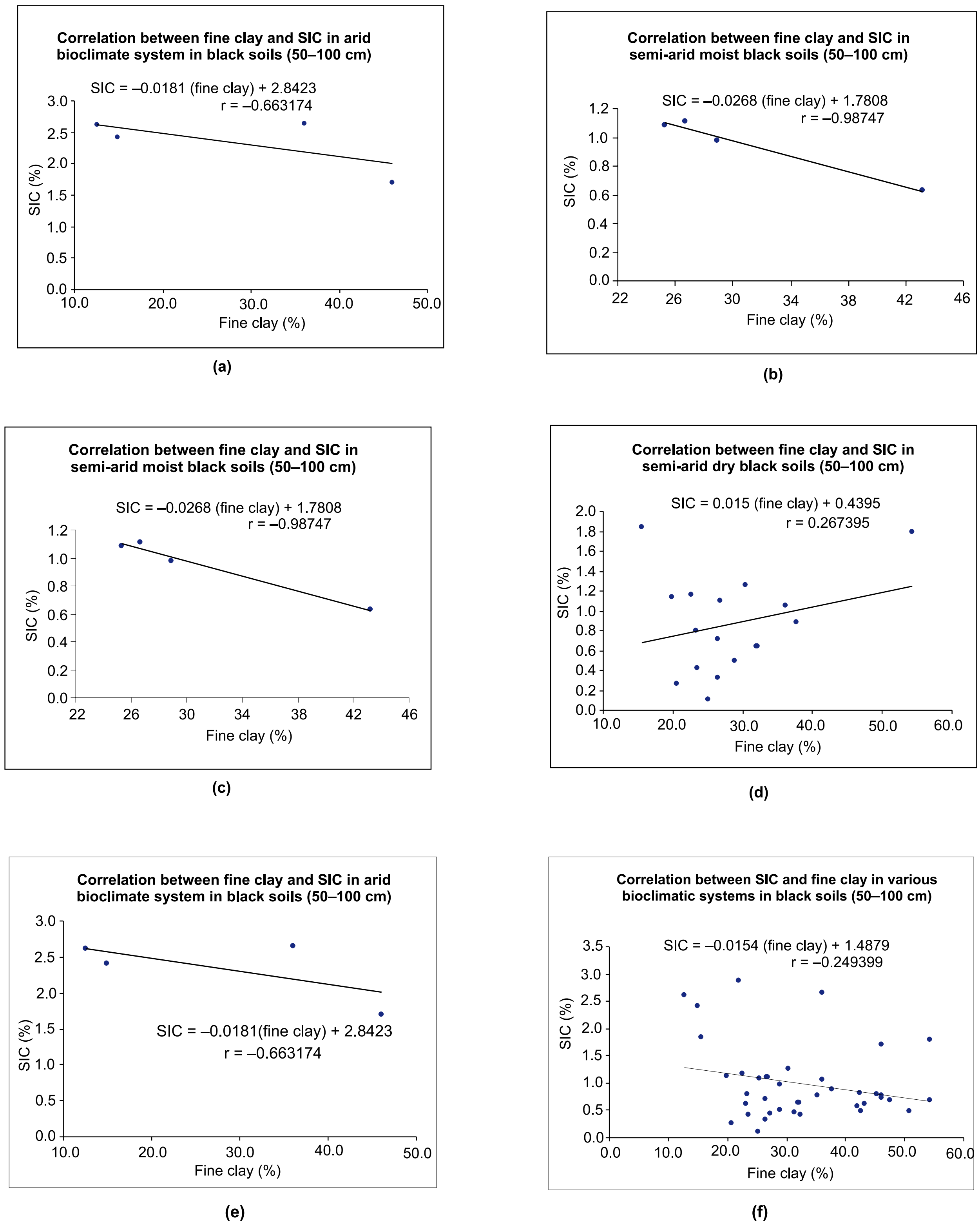


Figure 3.4. Correlation between soil inorganic carbon (SIC) and fine-clay content in black soils of SAT, India.

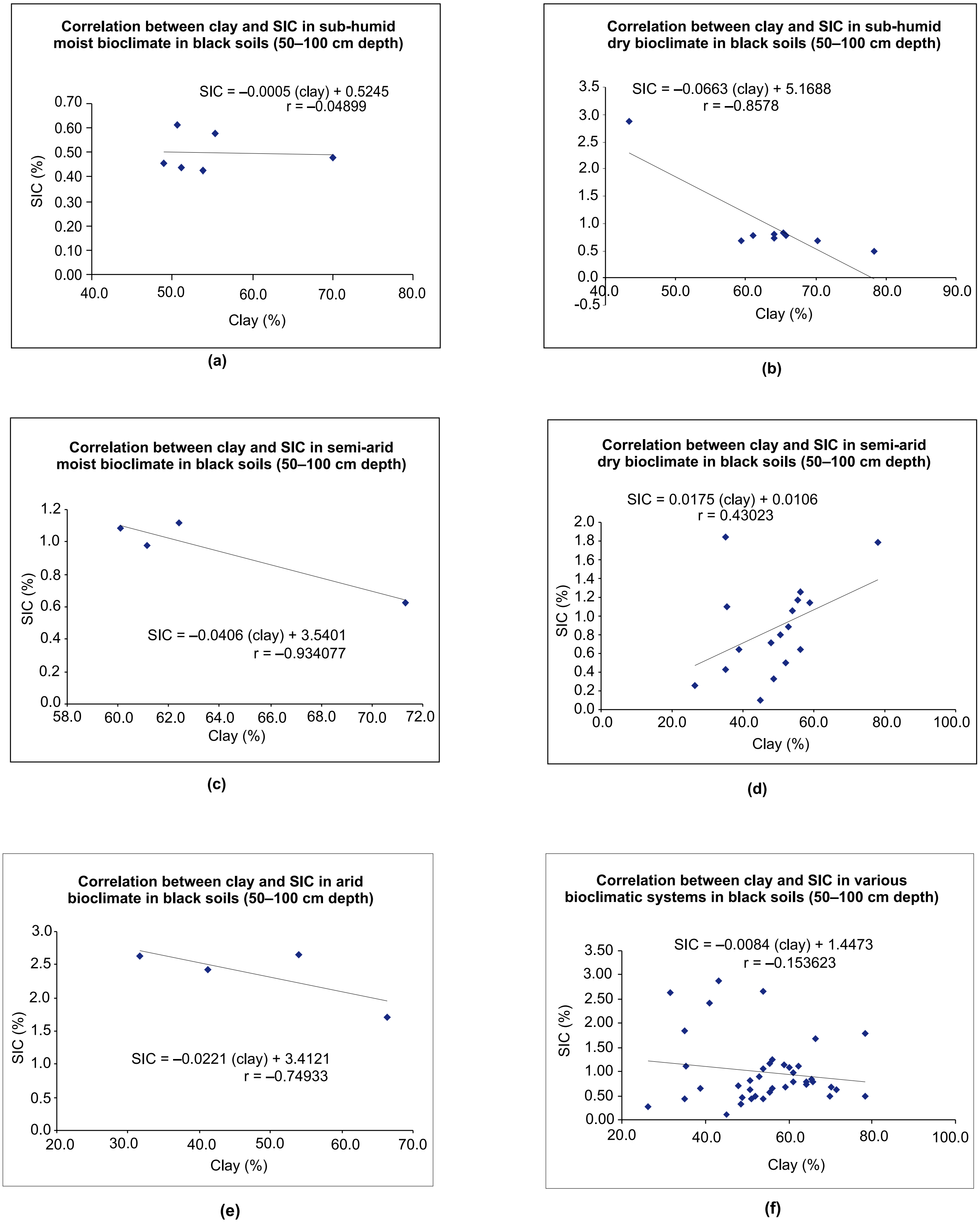


Figure 3.5. Correlation between soil inorganic carbon (SIC) and clay content in black soils of SAT, India.

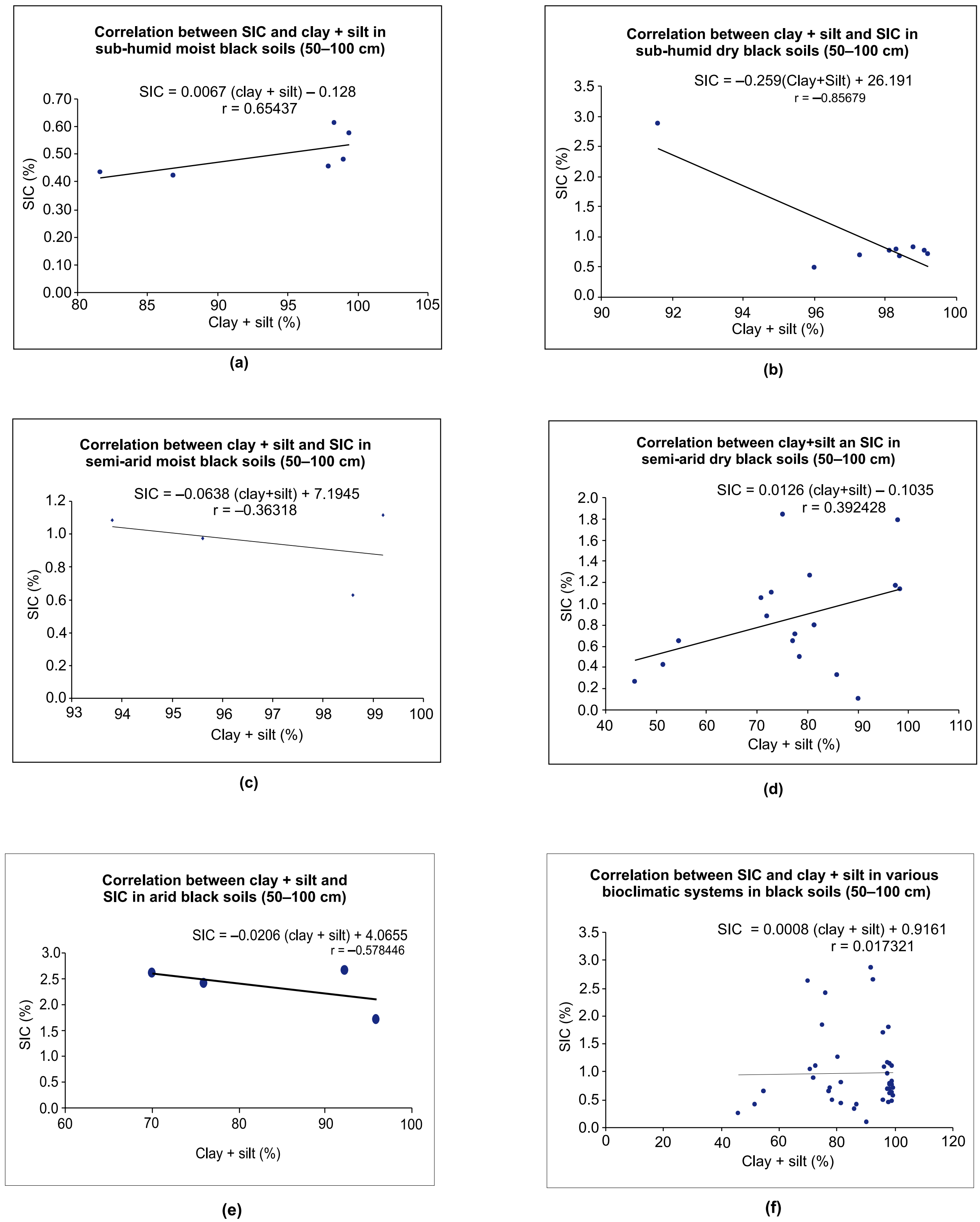


Figure 3.6. Correlation between soil inorganic carbon (SIC) and clay+silt content in black soils of SAT, India.

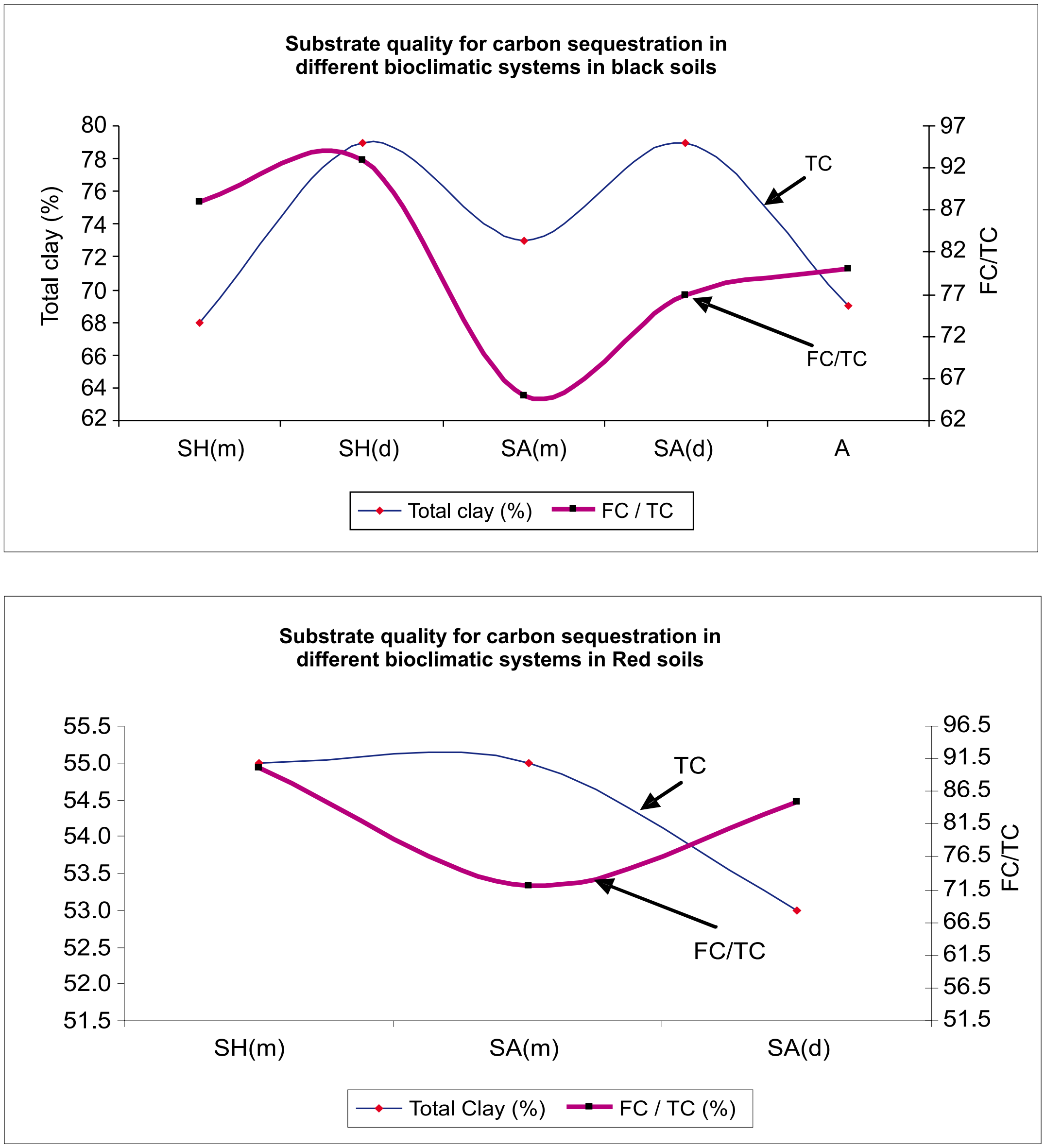


Figure 3.7. Substrate quality for carbon sequestration in different bioclimatic systems in black and red soils.

The TC content falls in arid bioclimatic system. Interestingly, an almost reverse trend is found when FC/TC ratio is calculated and compared in different bioclimatic systems. This shows that FC/TC offers better and more surfaces for organic C sequestration as has been amply observed in higher SOC values in soils of arid bioclimatic system (Fig. 3.2a). The corresponding figures in red soils show a similar trend, indicating the role of FC in overall carbon sequestration.

The detailed dataset on physical and chemical properties of soils are given in Appendices I and II.

3.2 Bulk Density

Bulk density (BD) indicates the weight of all the organic and inorganic materials of a given volume of soil. Higher SOC lowers BD. High clay content and introduction of farm machinery causes compaction of subsurface layer, which increases the BD. Bulk density also varies with the content of coarser fragments in soils. There is a growing acceptance of the view that BD changes due to change in land-use pattern. A study was conducted with soil profiles from an undisturbed 30-to-40-year-old forest, a completely deforested area used for field crops for 20 years (wheat), and an agroforestry system. The soils were coarse silty, carbonaceous, calcixerollic xerochrept. Deforestation and subsequent cultivation resulted in almost a 20% increase in soil bulk density (Hajabassi et al. 1997).

The BD of Vertisols varies greatly because of their swelling and shrinking nature. Since shrink-swell phenomenon depends on soil moisture content, a change in moisture level changes BD values. In general, the Vertisols have higher BD when they are dry and lower BD in a swollen stage. Depending on moisture content, the BD values are reported to vary from 1 to 2 g/cc (Jewitt et al. 1979). Due to compression caused by overburden weight, the BD values usually increase with soil depth. It has been reported that Vertisols may have BD values as high as 2.1 gm/cc (Dudal 1965). It has been also shown that at the swelling limit, the gravimetric water content decreases and BD values increase with depth (Yule and Ritchie 1980). They also reported that the depressions of the two gilgai sites showed higher water content and lower BD at swelling limit than the mounds. A dry Vertisol suffers a volume change of nearly 60% when it is saturated with water. It is suggested that the BD of such soils should be corrected to a reference moisture level (25% w/w) to minimize error caused by the initial moisture content of the soils (Rao et al. 1978).

Since the content of SOC and SIC varies depending on rainfall and atmospheric temperature (Jenny and Raychaudhuri 1960; Bhattacharyya et al. 2000; Pal et al. 2000), the BD is supposed to change in different bioclimatic systems. However, in black soils BD values appear similar, cutting across the three bioclimatic systems SH (m), SH (d) and arid bioclimatic systems (Fig. 3.8a). The corresponding SOC values show changes, which are marginal. In general, red soils under forest show very high SOC. The SOC and BD values of the black soils have been shown in Figure 3.8b.

Figure 3.9 shows the negative correlation (not significant) between SOC content and BD in the first 30 cm depth of soil. Except in semi-arid dry climate, the overall relation between SOC and BD is negative. Figure 3.10 shows the negative correlation between SOC and BD for all the soil samples from different bioclimatic zones.

Usually, $CaCO_3$ content in black soils increases from a depth of 50 cm downwards. The correlation between SIC and BD within 0 to 30 cm soil depth in various bioclimatic systems is positive

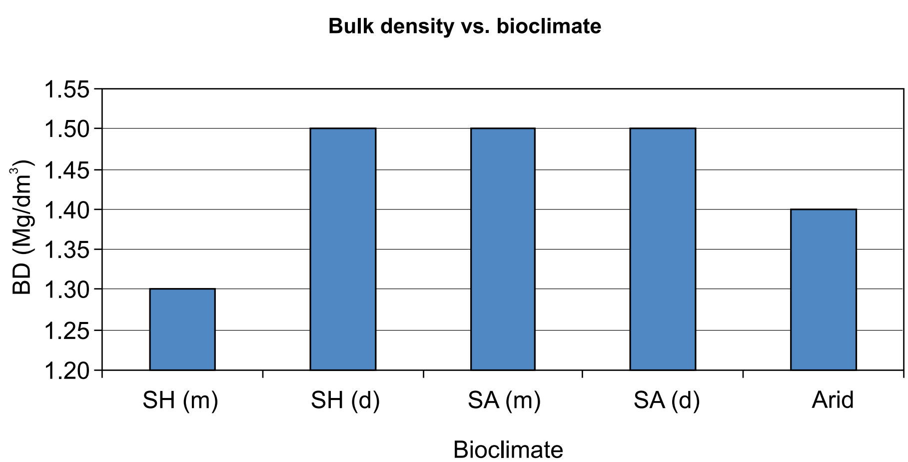


Figure 3.8a. Bulk density values (0–30 cm) in black soils in different bioclimatic systems.

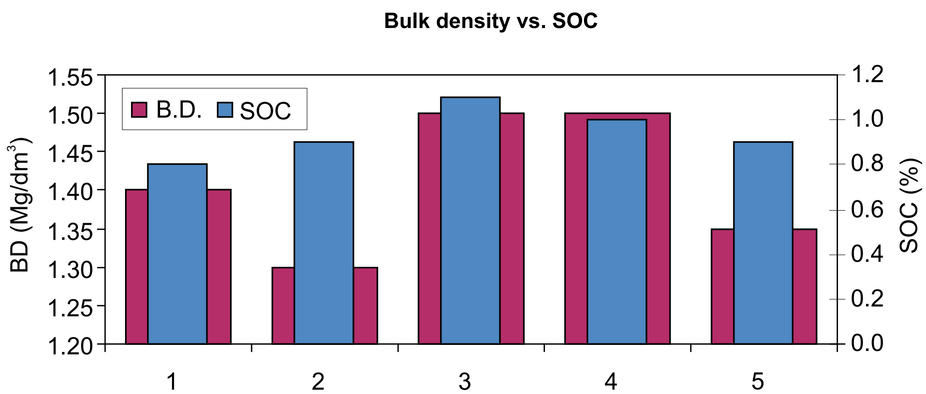


Figure 3.8b. Bulk density values in black soils as influenced by SOC (0–30 cm depth).

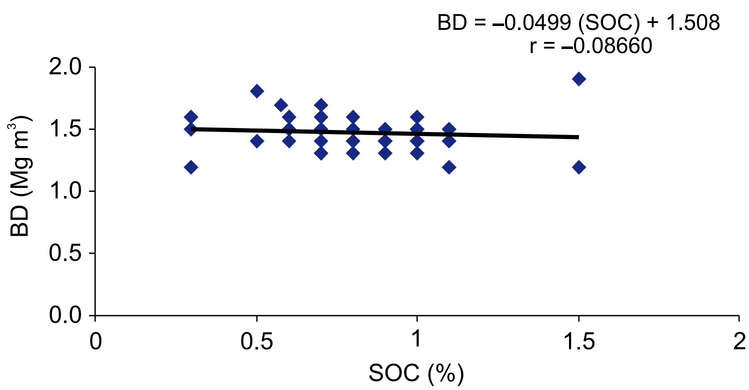


Figure 3.9. Correlation between SOC & bulk density (0–30 cm) in various bioclimatic systems.

(Fig. 3.11). A similar relation was observed in sub-humid (moist), sub-humid (dry) and arid climatic zones, with semi-arid (moist) and semi-arid (dry) zones being exceptions (Fig. 3.12).

If $CaCO_3$ content contributes to BD, then the coarser fragments in black soils responsible for $CaCO_3$ should increase BD of soils. Interestingly, a negative correlation is found between coarse fragments and BD in sub-humid (moist), sub-humid (dry) and semi-arid (dry) climates, with semi-arid (moist) and arid climates as exceptions. Increase in relative proportion of coarse fragments increases the pore space leading to a decrease in BD values (Figs. 3.13, 3.14). This is in sharp contrast to earlier observations made with regard to $CaCO_3$ and BD values. The calcium carbonate present as a chemical compound helps in binding soil particles, causing a greater cohesion between soil particles. This leads to greater compaction that increases BD values. It would seem, therefore, that the $CaCO_3$ present as powdery lime and $CaCO_3$ present as calcium concretions will have opposite effects on BD values in soils. Interestingly, both forms of $CaCO_3$ (lime and *conca*) will increase the inorganic carbon concentration in soil. Irrespective of the physical form of $CaCO_3$, its content will decide high or low degree of SIC stock. The range of BD values, SOC, SIC and coarse fragment contents are shown in Tables 3.3 and 3.4, respectively. Tables 3.5 and 3.6 show the correlations between SOC and BD, and SIC and BD.

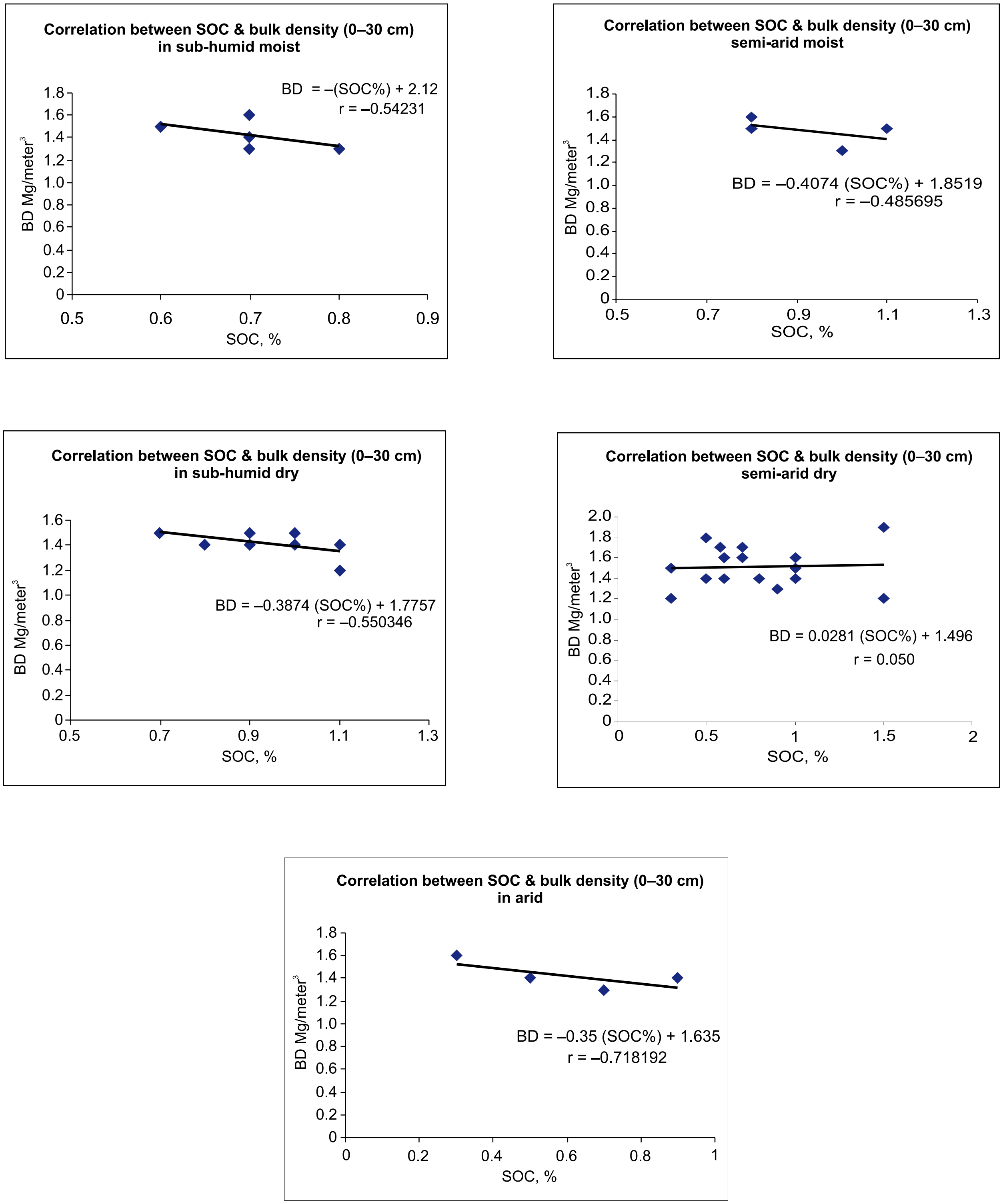


Figure 3.10. Correlation between SOC and BD in sub-humid (moist), sub-humid (dry), semi-arid (moist), semi-arid (dry) and arid climates.

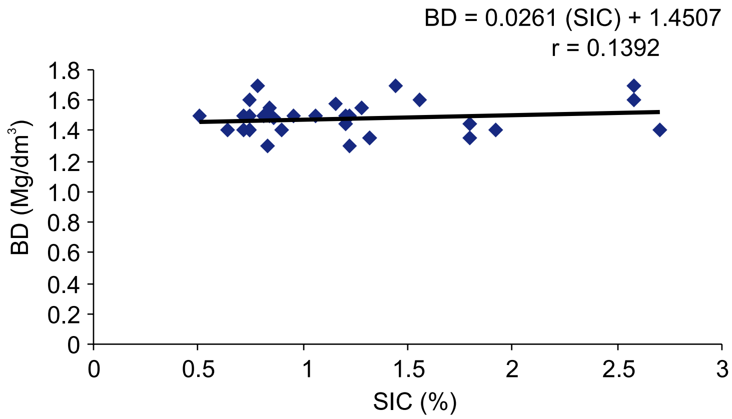


Figure 3.11. Correlation between SIC and bulk density (0–30 cm) in various bioclimatic systems.

Table 3.3. Bulk density, soil organic carbon and soil inorganic carbon in soils under different bioclimatic systems.

	BD Mg/m³			Carbon	
	0–30 cm	50–100 cm*	Range**	SOC (0–30) (%)	SIC (50–100) (%)
Black soils					
SH (m)	1.4	1.5	1.3–1.6	0.700	0.634
SH (d)	1.4	1.4	1.1–1.7	0.937	0.811
SA (m)	1.5	1.5	1.3–1.7	0.925	1.095
SA (d)	1.4	1.5	1.2–1.7	0.770	1.206
A	1.4	1.5	1.3–1.9	0.600	2.415
Red soils					
SH (m)	nd	nd	nd	2.075	0
SA (m)	1.7	1.55	1.5–1.7	0.967	0
SA (d)	1.5	1.60	1.5–1.9	1.000	0.12

* Corresponds to average depth of first occurrence of slickensides in black soils.
** Minimum and maximum.
nd: not done

Table 3.4. Bulk density and coarse fragments in soils under different bioclimatic systems.

	BD Mg/m³		Coarse fragments v/v	
	0–30 cm	50–100 cm*	0–30 cm	50–100 cm
Black soil				
SH (m)	1.4	1.5	3.75	4.00
SH (d)	1.4	1.4	5.23	5.464
SA (m)	1.5	1.5	2.50	2.625
SA (d)	1.4	1.5	5.732	5.054
A	1.4	1.5	8.875	9.25
Red soil				
SH (m)	nd	nd	--	--
SA (m)	1.7	1.55	--	--
SA (d)	1.5	1.60	--	--

* Corresponds to average depth of first occurrence of slickensides in black soils.
nd: not done

Table 3.5. Correlation between SOC vs. BD in the first 30 cm depth of black soil in SAT, India.

Bioclimate (MAR)	Regression equation	Correlation coefficient (r)	No. of samples
Sub-humid moist (>1100 mm)	BD = -(SOC) + 2.12	- 0.5423	5
Sub-humid dry (1100–1000 mm)	BD = -0.4074 (SOC) + 1.8519	- 0.4860	4
Semi-arid moist (1000–850 mm)	BD = -0.3874 (SOC) + 1.7757	- 0.5504	9
Semi-arid dry (850–550 mm)	BD = -0.0281(SOC) + 1.496	- 0.050	16
Arid (<550 mm)	BD = -0.35 (SOC) + 1.635	- 0.7182	4
All bioclimatic systems	BD = -0.0499 (SOC) + 1.508	- 0.0866	38

Table 3.6. Correlation between SIC vs. BD in 50–100 cm depth of black soil in SAT, India.

Bioclimate (MAR)	Regression equation	Correlation coefficient (r)	No. of samples
Sub-humid moist (>1100 mm)	BD = 0.0449 (SIC) + 1.4383	+ 0.1568	4
Sub-humid dry (1100-1000 mm)	BD = 0.2295 (SIC) + 1.2425	+ 0.3569	6
Semi-arid moist (1000-850 mm)	BD = -0.0601 (SIC) + 1.5483	- 0.1220	4
Semi-arid dry (850-550 mm)	BD = -0.0992 (SIC) + 1.6255	- 0.3160	16
Arid (<550 mm)	BD = 0.2204 (SIC) + 0.9803	0.5521	4
All bioclimatic systems	BD = 0.0261 (SIC) + 1.4507	0.1393	34

The detailed information pertaining to BD, SOC and SIC is given in Appendix 1.

3.3 Coefficient of Linear Extensibility (COLE)

Linear Extensibility (LE) helps to predict the potential of a soil to shrink and swell. The LE of a soil layer is the product of the thickness in centimeters, multiplied by the COLE of the layer in question. The LE of a soil is the sum of these products for all soil horizons (Soil Survey Staff 1999). The COLE has been defined as the ratio of the moist length and dry length. It is expressed as COLE = (Lm-Ld) / Ld, where Lm = length of soil clod at 33 kPa and Ld = length of dry soil clod (room temperature). According to soil taxonomy, a soil should be qualified for *vertic* subgroups if the LE value is more or equal to 6 between the mineral soil surface and either a depth of 100 cm or a lithic contact, whichever is shallower. In case of Vertisols slickensides, cracks and higher COLE values are mutually inclusive.

Since higher COLE values indicate the presence of more shrink-swell minerals, namely smectite, a positive correlation between LE and smectite content can exist (Shirsath et al. 2000). Such as a relationship was found to hold for more than 93% of Vertisol samples studied in SAT India (Bhuse et al. 2001). Smectite content estimated horizon-wise of the Vertisol pedons are given in Tables 3.7, 3.8, 3.9, 3.10 and 3.11.

Correlations between COLE and clay content, fine clay: total clay, and fine clay indicated correlation coefficients of 0.4, 0.5, 0.32, respectively, in selected black soils in SAT, India (Figs. 3.15, 3.16, 3.17). Correlations between total clay and COLE in different bioclimatic systems are positive. The correlation coefficient is appreciably high (r = 0.83) in arid bioclimatic system (Fig. 3.18) (Vaidya and Pal 2002). The correlation coefficient values are still high when COLE values were correlated with fine clay content in different bioclimatic systems (Fig. 3.19).

Table 3.7 Estimation of smectite content in Vertisols from COLE values in sub-humid (moist) bioclimatic system.

Pedon No.	Soil classification	Horizons	Depth (cm)	LE	Smectite (%)
P4 Panjri Cotton (HM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–13	25.0	92
		Bw1	13–38	26.0	96
		Bss1	38–60	27.0	98
		Bss2	60–89	26.0	96
		Bss3	89–131	28.0	100
		Bss4	131–150	26.0	96
P5 Panjri Soybean-Wheat (HM)	Fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–15	18.0	65
		Bw1	15–42	19.0	69
		Bw2/Bss1	42–69	23.0	85
		Bss2	69–107	18.0	66
		Bss3	107–135	21.0	77
		Bss4	135–150	20.0	73
P6 Nabibagh Soybean-Wheat (FM)	Fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–23	17.0	62
		Bw1	23–42	19.0	69
		Bss1	42–81	20.0	73
		Bss2	81–122	20.0	73
		Bss3	122–150	22.0	81
P15 Boripani Forest (Teak)	Very fine, smectitic, hyperthermic, *Vertic Haplustepts*	A1	0–16	25.0	92
		Bw1	16–44	27.0	100
		Bw2	44–57	23.0	85
		Ck1	57–84	13.0	46
P27 Kheri Paddy-Wheat (HM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–20	20.0	73
		Bw1	20–42	21.0	77
		Bw2	42–63	20.0	73
		Bss1	63–84	19.0	69
		Bss2	84–115	17.0	62
		Bss3	115–160	15.0	54
P28 Kheri Soybean/Paddy-Wheat (LM)	Fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–14	20.0	73
		Bw1	14–32	17.0	62
		Bw2	32–61	18.0	66
		Bss1	61–82	25.0	92
		Bss2	82–112	22.0	81
		Bss3	112–133	19.0	69
		Bss4	133–156	18.0	66

Generally, high quantity of fine clay and smectite content result in high COLE values. Logically, COLE values should have a positive relation with vertic characteristic properties of shrink-swell soils. Pressure faces and slickensides observed in various horizons in Vertisols were coded as follows.

Other features	Numerical code
Pressure faces	2
Weak slickensides	3
Well-developed slickensides	4
Slickensides close to intersect	5

Table 3.8 Estimation of smectite content in Vertisols from COLE values in sub-humid (dry) bioclimatic system.

Pedon no.	Soil classification	Horizon	Depth (cm)	L.E	Smectite (%)
P1 Linga Horticulture (Citrus) (HM)	Very fine, smectitic, hyperthermic *Typic Haplusterts*	Ap	0–15	22.0	81
		Bw	15–41	21.0	77
		Bss1	41–70	23.0	85
		Bss2	70–95	22.0	81
		Bss3	95–135	23.0	85
		Bss4	135–155+	25.0	92
P2 Linga Soybean-Gram/Wheat (FM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–13	23.0	85
		Bw	13–33	22.0	81
		Bw1	33–55	23.0	85
		Bss1	55–81	28.0	100
		Bss2	81–119	25.0	92
		Bss3	119–150	25.0	92
P3 Linga Horticulture (Citrus) (LM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–16	24.00	88
		Bw1	16–44	21.00	77
		Bw2	44–69	22.00	81
		Bss1	69–102	22.00	81
		Bss2	102–128	25.00	92
		Bss3	128–150+	26.00	96
P7 Sarol Soybean-Wheat (HM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–14	21.0	77
		Bw1	14–28	22.0	81
		Bss1	28–57	20.0	73
		Bss2	57–85	26.0	96
		Bss3	85–109	22.0	81
		Bss4	109–130	24.0	88
		Bss5	130–155	22.0	81
P8 Sarol Soybean-Wheat (FM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–18	21.0	77
		Bw1	18–45	22.0	81
		Bw2	45–66	19.0	69
		Bss1	66–90	21.0	77
		Bss2	90–124	23.0	85
		Bss3	124–159	21.0	77
P9 Sarol Soybean (HM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–17	22.0	81
		Bw	17–44	22.0	81
		Bss1	44–79	23.0	85
		Bss2	79–102	23.0	85
		Bss3	102–127	23.0	85
		Bss4	127–152	23.0	85
P48 Nipani Cotton-Pigeonpea (FM)	Fine, smectitic, hyperthermic, *Typic Haplusterts.*	Ap	0–13	20.0	73
		Bw1	13–35	20.0	73
		Bw2	35–62	20.0	73
		Bss1	62–88	10.0	35
		Bss2	88–127	20.0	73
		Bss3	127–155+	20.0	73
P49 Pangidi Cotton+Pigeonpea (FM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts.*	Ap	0–14	6.0	20
		Bw1	14–36	5.0	16
		Bw2	36–62	16.0	58
		Bss1	62–87	23.0	85
		Bss2	87–110	29.0	100
P50 Pangidi Soybean (ITDA)	Very fine, smectitic, hyperthermic, *Vertic Haplustepts*	Ap	0–11	28.0	100
		Bw1	11–27	29.0	100
		Bw2	27–41	28.0	100
		Crk	41–55	10.0	35

Table 3.9. Estimation of smectite content in Vertisols from COLE values in semi-arid (moist) bio-climatic system.

Pedon No.	Soil classification	Horizon	Depth (cm)	L.E	Smectite (%)
P10 Asra Cotton/Green gram+ Pigeonpea (FM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–14	28.0	100
		Bw1	14–40	26.0	96
		Bw2	40–59	26.0	96
		Bss1	59–91	29.0	100
		Bss2	91–125	25.0	92
		Bss3	125–150	25.0	92
P11 Asra Soybean+Pigeonpea (FM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–14	24.0	88
		Bw1	14–35	23.0	85
		Bss1	35–69	21.0	77
		Bss2	69–107	23.0	85
		Bss3	107–150	23.0	85
P12 Asra Cotton+Pigeonpea/ Soybean-Gram (HM)	Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–12	24.0	88
		Bw1	12–40	23.0	85
		Bss1	40–79	28.0	100
		Bss2	79–116	28.0	100
		Bss3	116–150	26.0	96
P42 Bhatumbra Sorghum+Pigeonpea Black gram-Chickpea (FM)	Very fine, smectitic, hyperthermic, *Udic Haplusterts.*	Ap	0–12	28.0	100
		Bw	12–37	24.0	88
		Bss1	37–79	20.0	73
		Bss2	79–110	29.0	100

Table 3.10. Estimation of smectite content in Vertisols from COLE values in arid bioclimatic system.

Pedon no.	Soil classification	Horizon	Depth (cm)	L.E.	Smectite (%)
P13 Paral Cotton+Pigeonpea/ Sorghum (LM)	Very fine, smectitic hyperthermic, *Sodic Haplusterts*	Ap	0–9	22.0	81
		Bw1	9–35	18.0	66
		Bss1	35–69	17.0	62
		Bss2	69–105	19	69
		Bss3	105–132	23.0	85
		Bss4	132–150	22.0	81
P14 Paral Cotton+Pigeonpea/ Sorghum (HM)	Very fine, smectitic, hyperthermic, *Sodic Haplusterts*	Ap	0–8	24.0	88
		Bw1	8–35	23.0	85
		Bss1	35–68	22.0	81
		Bss2	68–97	20.0	73
		Bss3	97–129	20.0	73
		Bss4	129–150	23.0	85
P19 Kovilpatti Sorghum/Sunflower/ Cotton (ORG)	Very fine, smectitic, isohyperthermic, *Gypsic Haplusterts*	Ap1	0–6	21.0	77
		Ap2	6–20	22.0	81
		Bw1	20–41	22.0	81
		Bw2	41–74	22.0	81
		Bss1	74–104	24.0	88

Continued...

Table 3.10. *Continued.*

Pedon no.	Soil classification	Horizon	Depth (cm)	L.E.	Smectite (%)
		Bss2	104–118	25.0	92
		BC	118–128	17.0	62
		2C	128–140	10.0	35
P20 Kovilpatti Wasteland	Fine, smectitic, isohyperthermic, *Leptic Gypsiusterts*	Ap	0–11	16.0	58
		Bw1	11–31	12.0	43
		Bw2	31–55	16.0	58
		Bss	55–79	13.0	46
		2C1	79–91	8.0	27
		2C2	91–105	13.0	46
P21 Kovilpatti Cotton+Black gram (HM)	Very fine, smectitic, isohyperthermic, *Gypsic Haplusterts*	Ap1	0–9	21.0	77
		Ap2	9–20	23.0	85
		Bw1	20–58	22.0	81
		Bss1	58–100	22.0	81
		2C1	100–126	18.0	66
		2C2	126–155	18.0	66
P29 Semla Cotton/Groundnut-Wheat (ORG)	Fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–17	20.0	73
		Bw1	17–42	24.0	88
		Bw2	42–57	23.0	85
		Bss1	57–86	18.0	66
		Bss2	86–115	24.0	88
		Bss3	115–144	16.0	58
		BC	144–155	16.0	58
P32 Jhalipura Soybean-Wheat (FM/1)	Fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–12	19.0	69
		Bw1	12–31	20.0	73
		Bw2	31–48	19.0	69
		Bss1	48–74	21.0	77
		Bss2	74–110	20.0	73
		Bss3	110–148	19.0	69
		Bss4	14–165	20.0	73
P33 Jhalipura Paddy-Wheat (FM/2)	Fine, smectitic, hyperthermic, *Typic Haplusterts*	Ap	0–13	23.0	85
		Bw1	13–36	19.0	69
		Bw2	36–58	20.0	73
		Bss1	58–82	20.0	73
		Bss2	82–107	21.0	77
		Bss3	107–132	21.0	77
		Bss4	132–156	20.0	73
P35 Jajapur Sorghum/Pigeonpea+ Green gram (FM1)	Fine, smectitic, isohyperthermic, *Vertic Haplustepts*	Ap	0–12	14	50
		Bw1	12–35	15.0	54
		Bw2	35–48	13.0	46
		Bw3/Bss	48–76	13.0	46
		Bw4	76–96	13.0	46
		Bw5	96–126	20.0	73
		BcK	126–155	23.0	85
P36 Jajapur Paddy-Paddy (FM 2)	Fine-loamy, smectitic, isohyperthermic, *Vertic Haplustepts*	Ap	0–10	15.0	54
		Bw1	10–28	12.0	43
		Bw2	28–53	12.0	43
		Bw3	53–76	17.0	62
		BCk1	76–98	17.0	62
		BCk2	98–128	19.0	69

Continued...

Table 3.10. *Continued.*

Pedon no.	Soil classification	Horizon	Depth (cm)	L.E.	Smectite (%)
		BCk3	128–150	16.0	58
		BCk4	150+	15.0	54
P39 Kasireddipalli Soybean-Pigeonpea (HM)	Fine, smectitic, isohyperthermic, *Typic Haplusterts*	Ap	0–12	23.0	85
		Bw1	12–31	23.0	85
		Bss1	31–54	24.0	88
		Bss2	54–84	26.0	96
		Bss3	84–118	30.0	100
		Bss4	118–146	30.0	100
		Bssk5	146–157	27.0	100
P40 Kasireddipalli Fallow-Chickpea (TM)	Fine, smectitic, isohyperthermic, *Typic Haplusterts*	Ap	0–12	26.0	96
		Bw1	12–30	24.0	88
		Bss1	30–59	20.0	73
		Bss2	59–101	24.0	88
		Bss3	101–130	25.0	92
		BCk	130–160	23.0	85
P43 Teligi Paddy-Paddy (LM)	Fine, smectitic, isohyperthermic, *Calcic Haplusterts*	Ap	0–10	24.0	88
		Bw1	10–25	26.0	96
		Bw2	25–44	4.0	12
		Bss1	44–69	6.0	20
		Bss2	69–97	11.0	39
		Bss3	97–123	11.0	39
		Bss4	123–150	7.0	24
P44 Teligi Paddy-Paddy (HM)	Very fine, smectitic, isohyperthermic, *Calcic Haplusterts*	Ap	0–10	20.0	73
		Bw1	10–34	20.0	73
		Bss1	34–54	24.0	88
		Bss2	54–89	24.0	88
		Bss3	89–119	17.0	62
		Bss4	119–142	14.0	50
		BCk	142–150	24.0	88
P45 Konheri Pigeonpea/Sunflower-Sorghum (FM)	Fine, smectitic, hyperthermic, *Vertic Haplustepts*	Ap	0–13	17.0	62
		Bw1	13–33	21.0	77
		Bw2	33–69	20.0	73
		Bw3	69–93	23.0	85
		Bw4	93–113	21.0	77
		BC	113–129	15.0	54
		Bss	129–160	26.0	96
P46 Konheri Pigeonpea/Sunflower-Sorghum (LM)	Very fine, smectitic, hyperthermic, *Leptic Haplusterts*	Ap	0–13	15.0	54
		Bw1	13–34	22.0	81
		Bss1	34–53	13.0	46
		Bss2	53–83	23.0	85
		Ck1	83–117	17.0	62
		Ck2	117–155	11.0	39
P47 Kalwan Sugarcane/Sorghum-Wheat/Gram (FM)	Fine, smectitic (cal), hyperthermic, *Typic Haplusterts*	Ap	0–20	21.0	77
		B	20–48	18.0	66
		Bss1	48–70	11.0	39
		Bss2	70–88	17.0	62
		Bk	88–133	11.0	39
		Bw3	133–154	3.0	8

Table 3.11. Estimation of smectite content in Vertisols from COLE values in arid bioclimatic system.

Pedon no.	Soil classification	Horizon	Depth (cm)	L.E.	Smectite (%)
P30 Sokhda Cotton-Pearl millet (FM/1)	Fine, smectitic (cal) hyperthermic, *Leptic Haplusterts*	Ap	0–11	14.0	50
		Bw1	11–32	15.0	54
		Bw2	32–57	13.0	46
		Bw3	57–91	17.0	62
		C1	91–107	16.0	58
		C2	107–135	16.0	58
P31 Sokhda Cotton-Pearl millet/ Linseed FM/2	Fine, smectitic (cal), hyperthermic, *Typic Haplusterts*	Ap	0–11	16.0	58
		Bw1	11–37	15.0	54
		Bw2	37–63	16.0	58
		Bss1	63–98	13.0	46
		Bss2	98–145	11.0	39
		BC	145–160	17.0	62
P51 Nimone Cotton-Wheat/ Chickpea [Irrigated] (HM)	Very fine, smectitic (cal) isohyperthermic *Sodic Haplusterts*	Ap	0–13	23.0	85
		Bw1	13–38	27.0	100
		Bw2	38–55	27.0	100
		Bss1	55–94	27.0	100
		Bss2	94–128	29.0	100
		Bw/Bc	128–150+	23.0	85
P52 Nimone Sugarcane [Ratoon]-Soybean/Wheat/ Chickpea (FM)	Very fine, smectitic (cal), isohyperthermic, *Sodic Haplusterts*	Ap	0–12	21.0	77
		Bw1	12–29	21.0	77
		Bw2	29–50	22.0	81
		Bss1	50–84	25.0	92
		Bss2	84–113	28.0	100
		Bss3	113–148	19.0	69
		Bss4/Bck	148–165+	22.0	81

These coded numerical values were related with COLE values for each horizon. Except in sub-humid (moist) and arid bioclimates, a positive correlation between COLE and slickensides is found in most of the Vertisols in SAT, India (Fig. 3.20).

3.4 Hydraulic Conductivity (HC)

Hydraulic conductivity of Vertisols shows higher values at the beginning of the wet season due to the presence of cracks. With the passage of time the HC decreases drastically in Vertisols. The Vertisols generally have a tendency to show higher BD values in the subsurface horizons due to compaction. It is due to this reason that the HC decreases in the subsurface horizons.

3.4.1 Correlations between HC and BD

The correlation between HC and BD is negative in sub-humid (moist) and semi-arid (dry) bioclimatic zones. In other bioclimatic systems, the correlation is positive which might be due to more gravel in these soils, making them more porous (Fig. 3.21). The overall correlation between BD and HC for all the soils, however, is negative (Fig. 3.22).

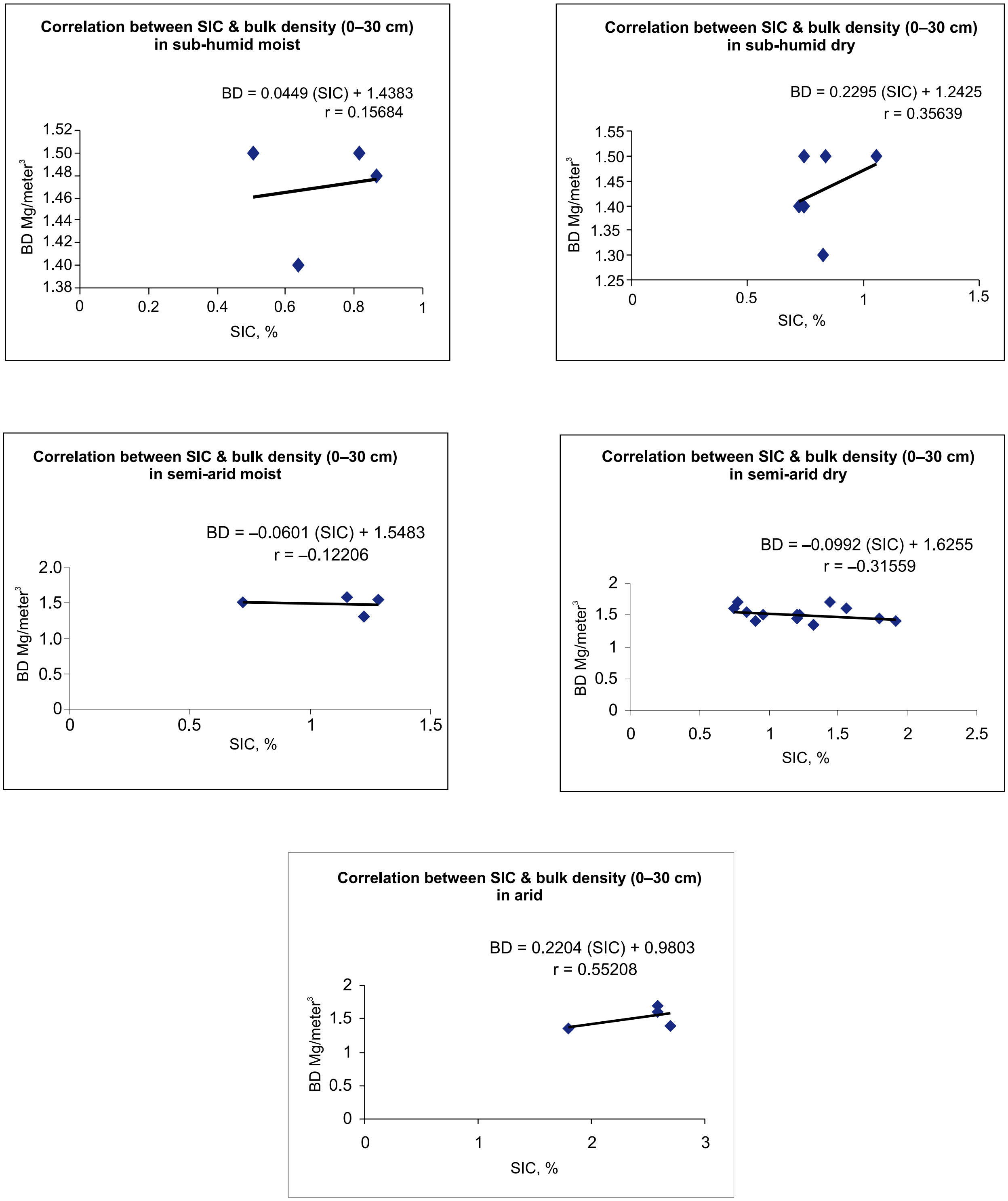


Figure 3.12. Correlation between SIC and BD in sub-humid (moist), sub-humid (dry), semi-arid (moist), semi-arid (dry) and arid climates.

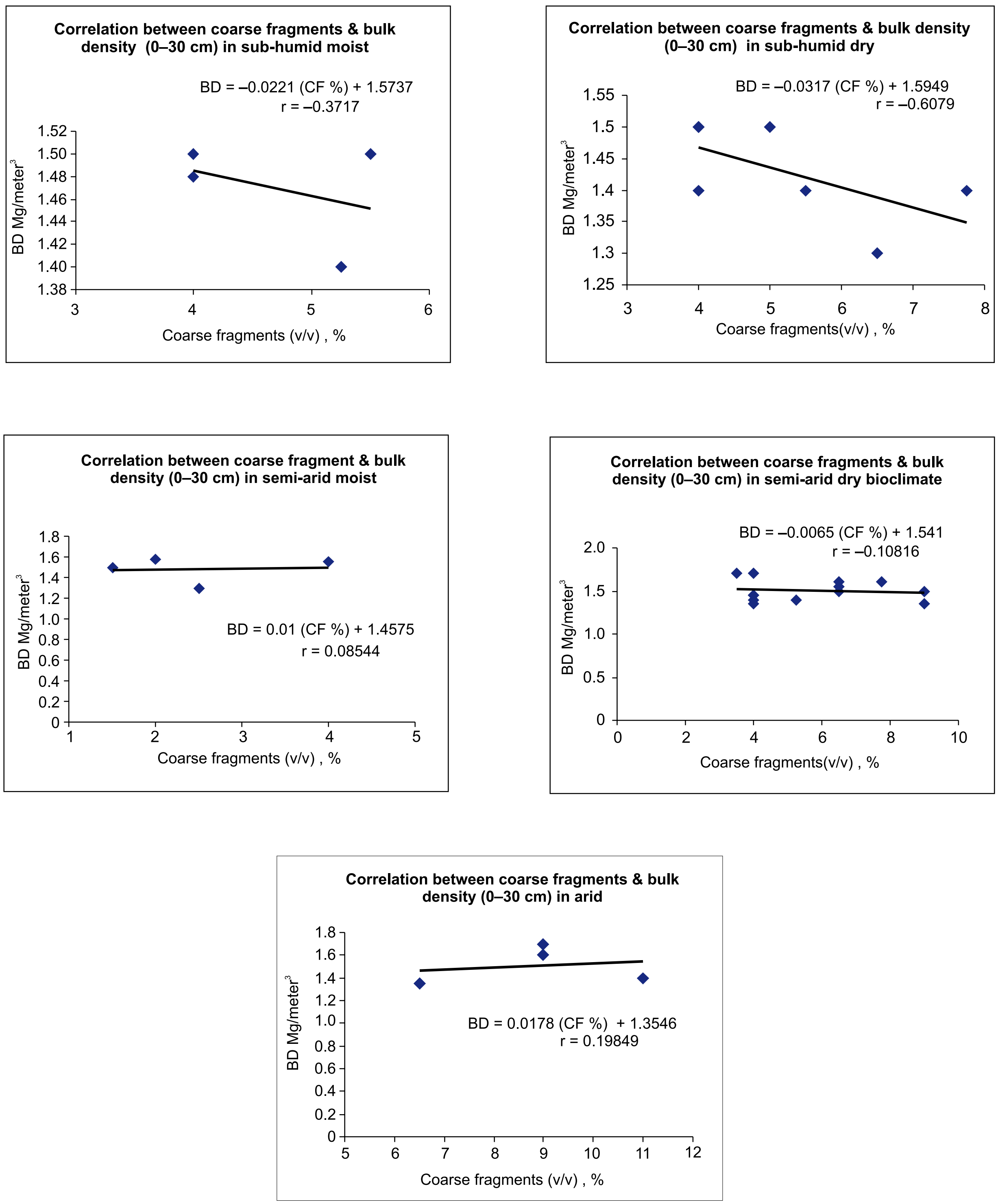


Figure 3.13. Correlation between coarse fragments and bulk density (0–30 cm) in soils under sub-humid (moist), sub-humid (dry), semi-arid (moist), semi-arid (dry) and arid climates.

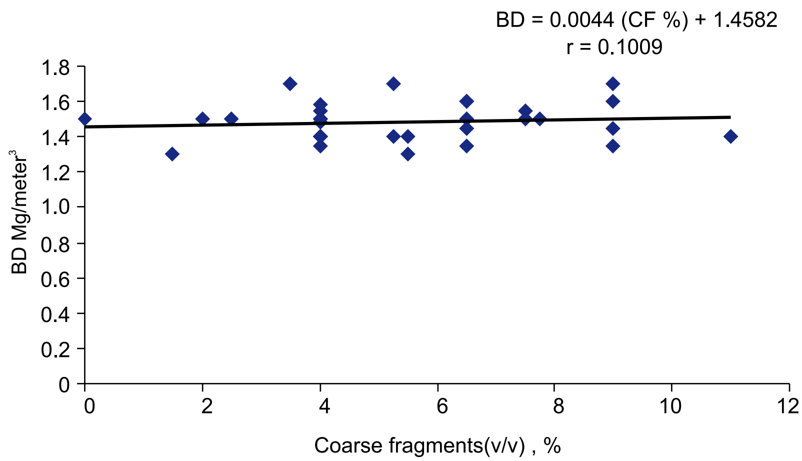


Figure 3.14. Correlation between coarse fragments and bulk density (0–30 cm) in soils under various bioclimatic systems.

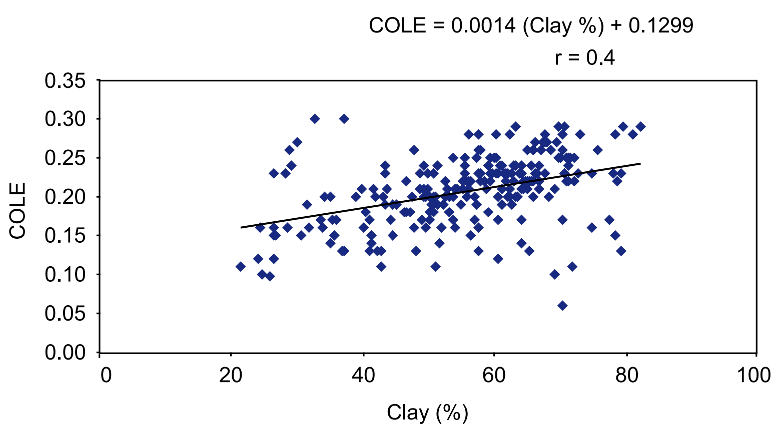


Figure 3.15 Correlation between clay content and COLE of selected black soils in SAT, India.

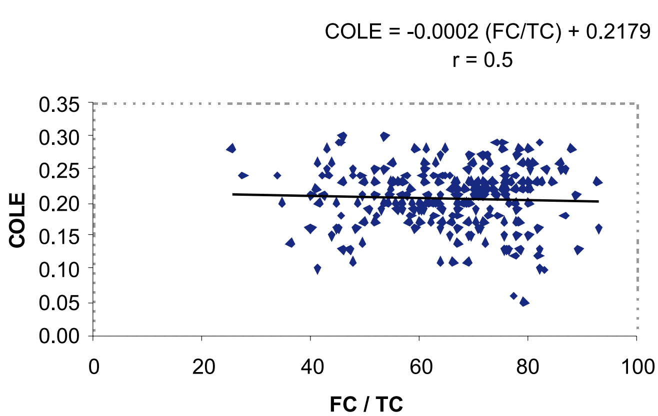


Figure 3.16. Correlation between FC / TC and COLE of selected black soils in SAT, India.

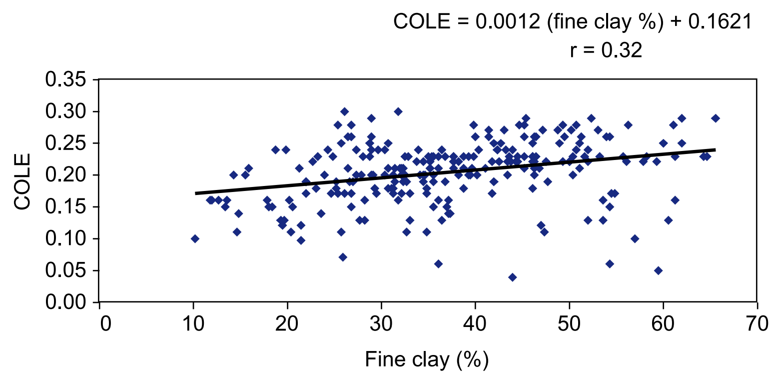


Figure 3.17. Correlation between fine clay and COLE of selected black soils in SAT, India.

High ESP values in Vertisols cause dispersion of fine particles, leading to blockade of pore spaces. This ultimately renders the soils non-porous as reflected by low HC. Poor drainage conditions lower the rate of organic matter decomposition. The soils with high ESP and low HC, therefore, should be prioritized for organic carbon sequestration (Pal et al, 2000; Bhattacharyya et al. 2000).

3.4.2 Correlation between HC and ESP

Ideally, higher ESP renders a soil less porous showing low HC (Pal et al. 2000; Kadu et al. 2003). This is reflected in the negative correlation between HC and ESP in soils of all bioclimatic systems with the exception of sub-humid (moist) (Fig. 3.23). The overall correlation between HC and ESP for all the soils is also negative (Fig. 3.24).

3.4.3 Relationship between HC and SOC in Black Soils

In sub-humid (moist) bioclimate, SOC values show a decreasing trend with increasing HC. The same trend is observed in semi-arid (moist) and arid bioclimates. In sub-humid (dry) and semi-arid (dry) bioclimates there is, however, an increasing trend of SOC with HC (Fig. 3.25). The overall trend shows increasing values of SOC with HC (Fig. 3.26). The r values indicate low positive correlation between the two. This may be because SOC has an indirect positive relationship with HC. It is known that increase in SOC solubilizes native $CaCO_3$ and decreases soil pH (Bhattacharyya et al. 2000; Bhattacharyya and Pal 2003), which would in turn decrease the ESP/SAR and increase the HC of soils (Balpande et al. 1996).

3.4.4 Relationship between HC and SIC in Black Soils

In sub-humid (moist), sub-humid (dry) and semi-arid (moist) bioclimates, HC increases with decrease in SIC (Fig. 3.27). The r value is the highest (0.32) in semi-arid (moist) bioclimate. The data show an opposite trend where the HC increases with increase in SIC (Fig. 3.27). Considering all the bioclimates together, an increasing trend of HC with SIC is observed (Fig. 3.28). The combined sample population in arid and semi-arid (dry) being larger, the overall trend indicated similar observations. In the sub-humid (moist), sub-humid (dry) and semi-arid (moist) bioclimates, the contribution of non-pedogenic carbonates towards SIC is less compared to their semi-arid (dry) and arid counterparts. The increase in HC with decrease in SIC is attributed to decrease in ESP (Pal et al. 2000), following

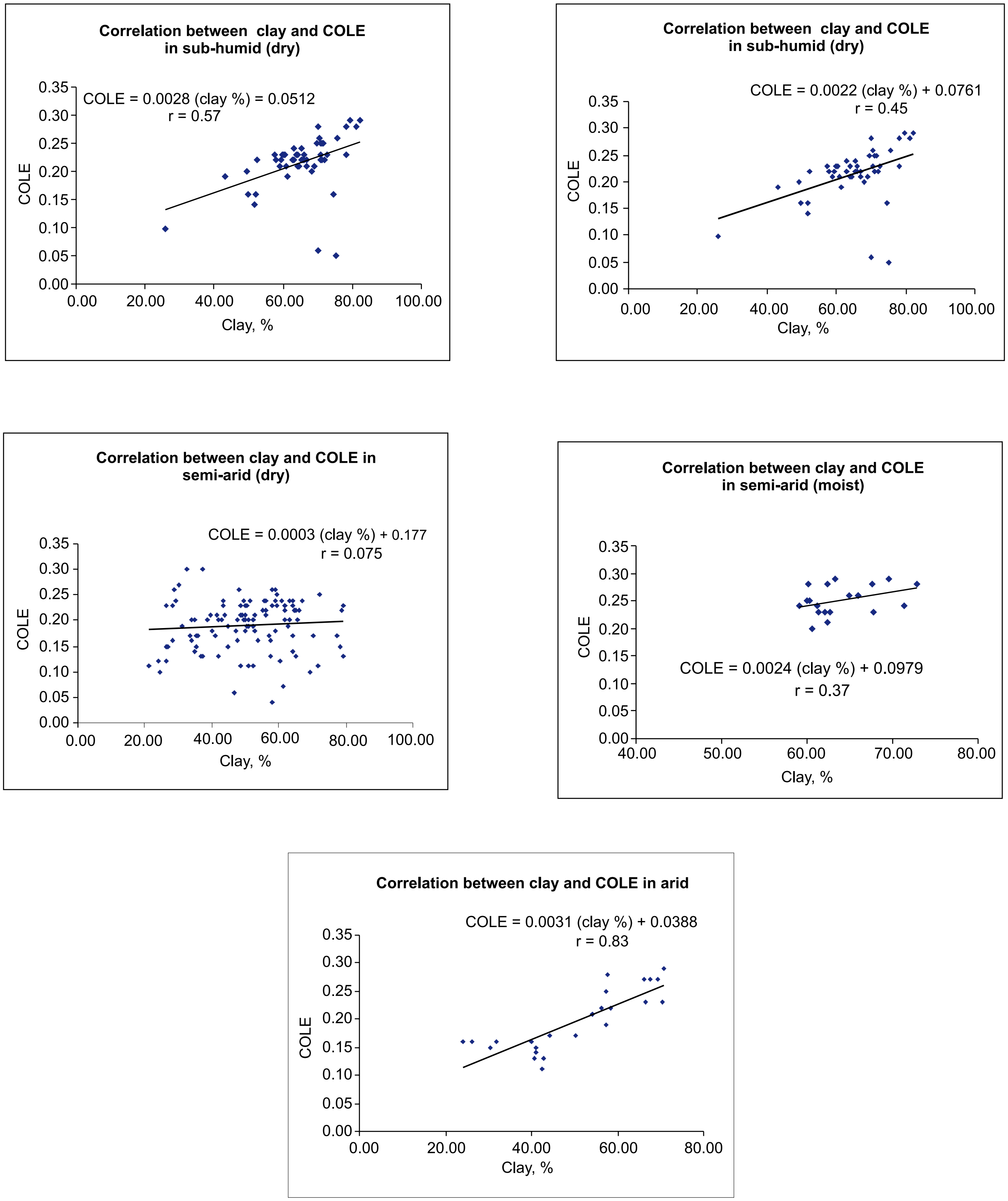


Figure 3.18. Correlation between clay and COLE in different bioclimatic systems.

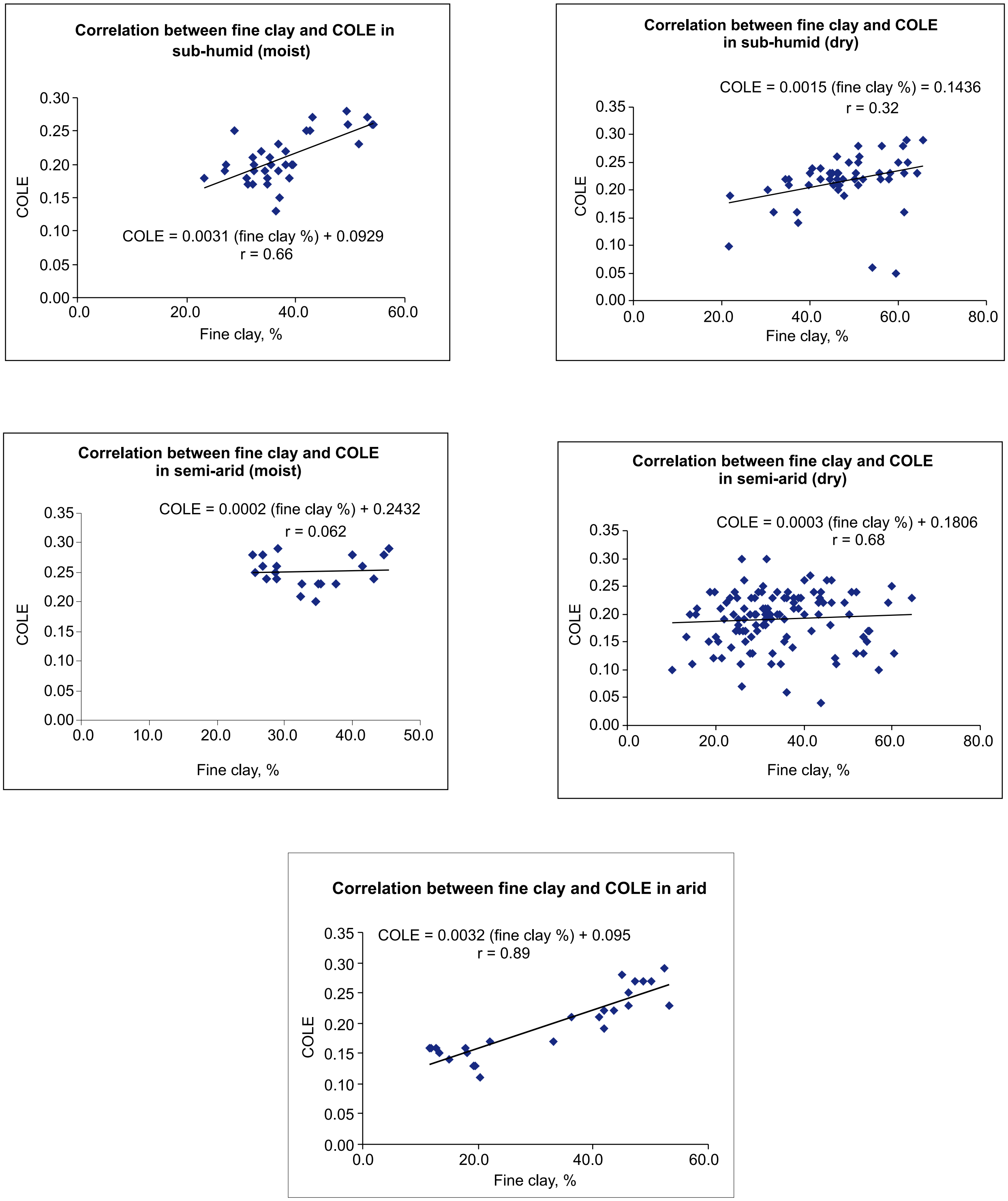


Figure 3.19. Correlation between fine clay and COLE for Vertisols in different bioclimatic zones.

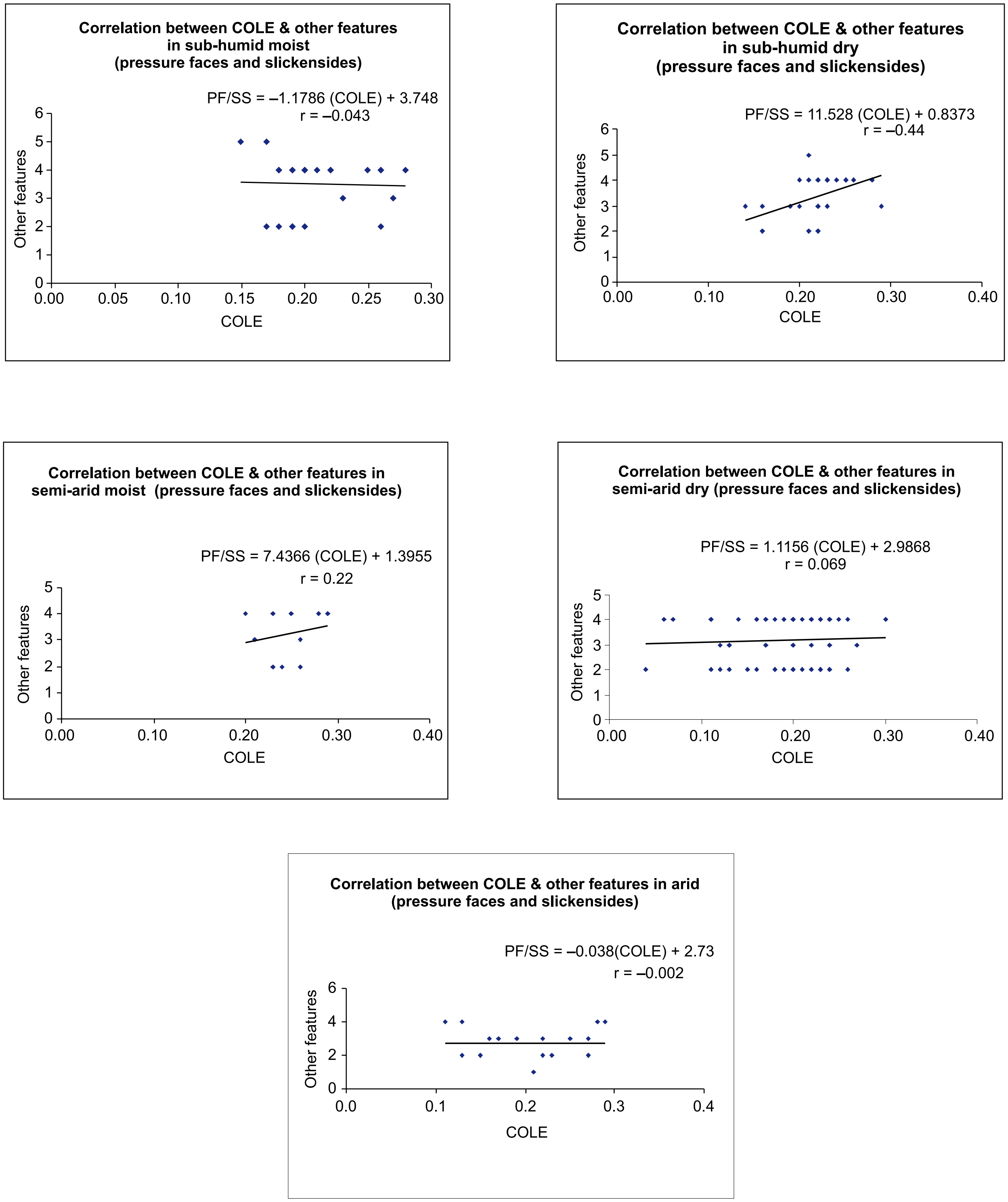


Figure 3.20. Correlation between COLE and other features in different bioclimatic zones.

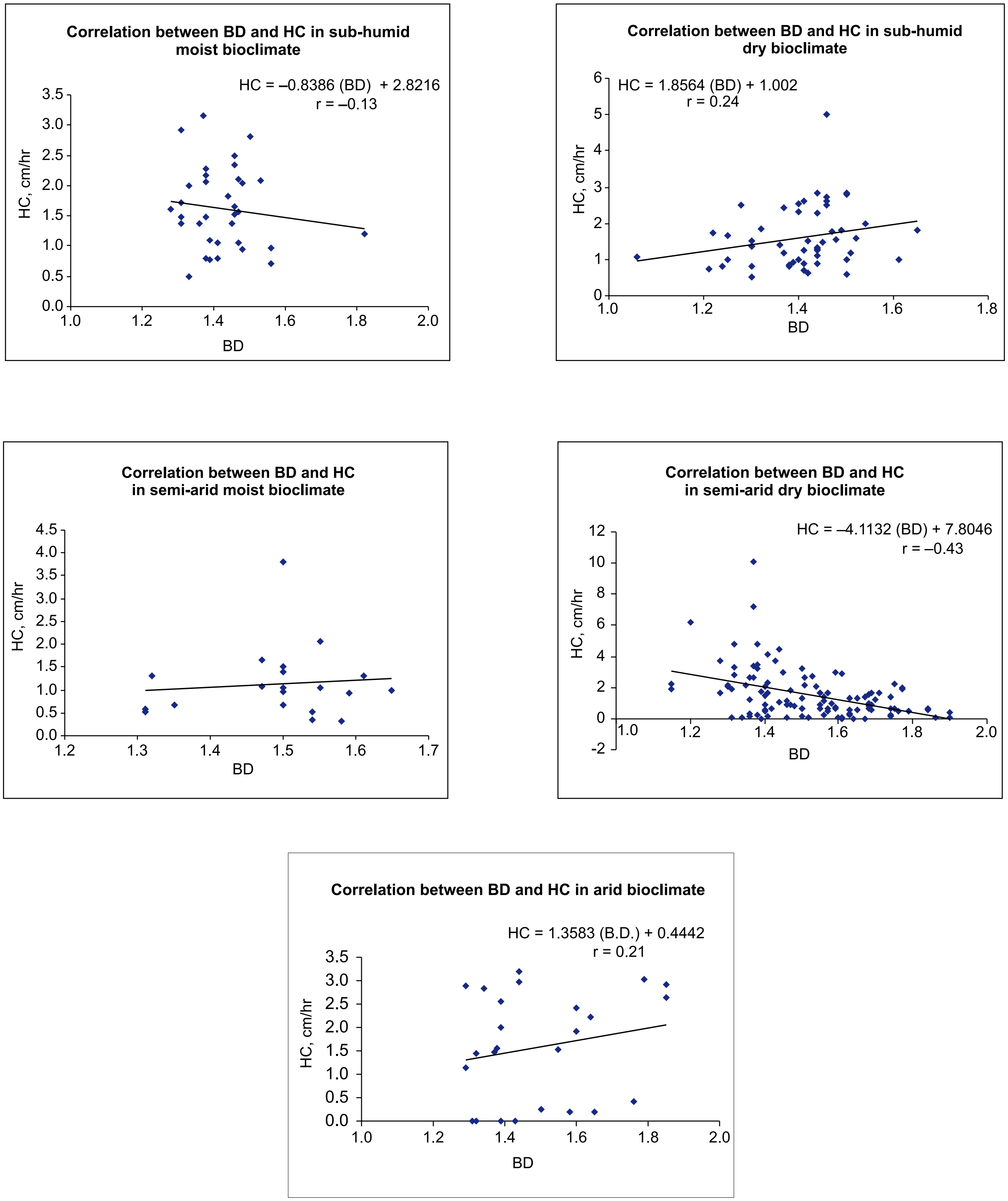


Figure 3.21. Correlation between BD and HC in different bioclimatic regions.

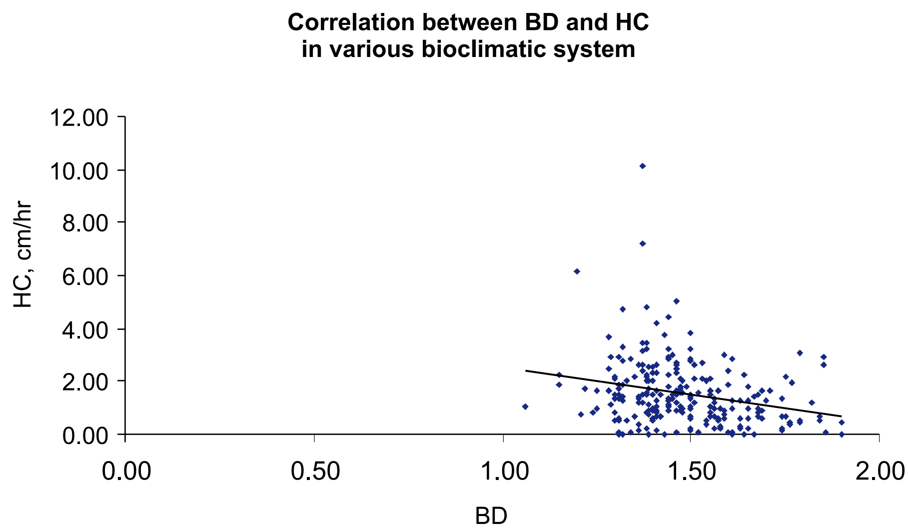


Figure 3.22. Overall correlation between BD and HC for all the soils in different bioclimatic systems.

dissolution of pedogenic carbonate. It may be argued that if there is a decrease in pH, pedogenic carbonates which are finer as well as more recently evolved, would be solubilized first. Therefore, the first three relatively wetter bioclimates show increase in HC with decrease in SIC. Conversely, in semi-arid (dry) and arid bioclimates the pedogenic carbonates are much higher than in their wetter counterparts (Pal et al. 2000; Srivastava et al. 2002). However, the contribution of non-pedogenic carbonates towards SIC is higher (by the available methods of determination of $CaCO_3$ equivalent), which is reflected in the increasing trend of HC with increase in SIC. It is interesting to note that the soils of drier bioclimatic regions contain coarser fragments in the form of $CaCO_3$ nodules (Table 3.4). The $CaCO_3$ nodules decrease BD (Fig. 3.12). This observation indirectly supports increasing values of HC in drier climates (Fig. 3.27).

3.5 Exchangeable Sodium Percentage (ESP)

3.5.1 Relationship between SOC and ESP

In all the bioclimates, there is an increasing trend of SOC with decrease in ESP (Fig. 3.29). The r value is the highest (0.396) in semi-arid (moist) bioclimate. The increase in SOC decreases soil pH, which helps to release Ca^{2+} in the system by dissolving $CaCO_3$. This results in decreased ESP (Please see sections 3.43 and 3.44 of this report) (Pal et al. 2000; Bhattacharyya and Pal 2003). The data of 52 pedons from the five bioclimatic zones reaffirmed the data obtained by the above authors (Fig. 3.30).

3.5.2 Relationship between SIC and ESP

The ESP values show an increasing trend with increase in SIC values in all the bioclimatic zones (Fig. 3.32). The r value in semi-arid (moist) bioclimate is the highest. The sub-humid (dry) and semi-arid (dry) bioclimates show poor r values. It is well known that an increase in SIC increases the ESP of a soil system (Pal et al. 2000). However, the discrepancies arising from poor r values in Figures 3.31b

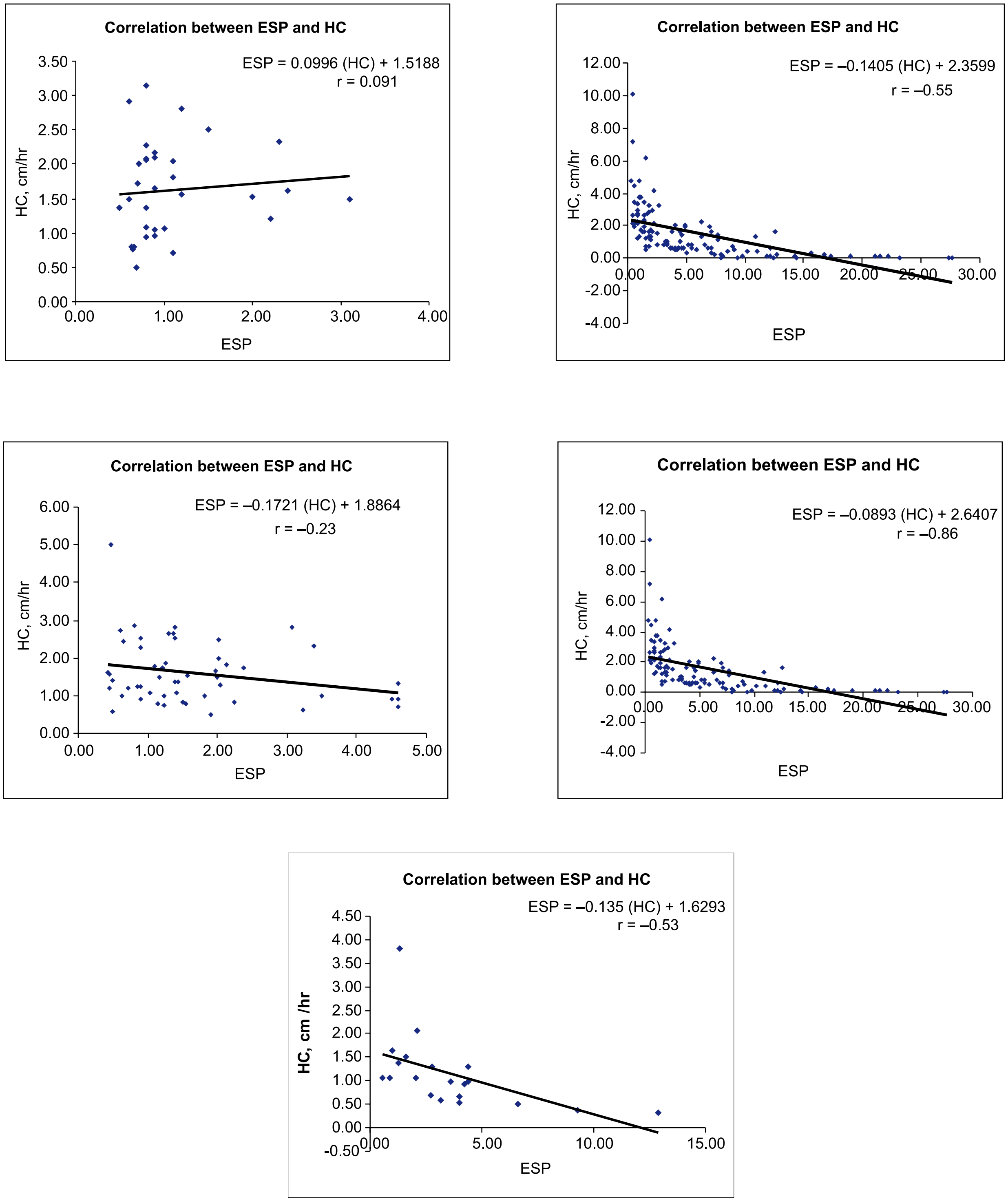


Figure 3.23. Correlation between ESP and HC of Vertisols in different bioclimatic regions.

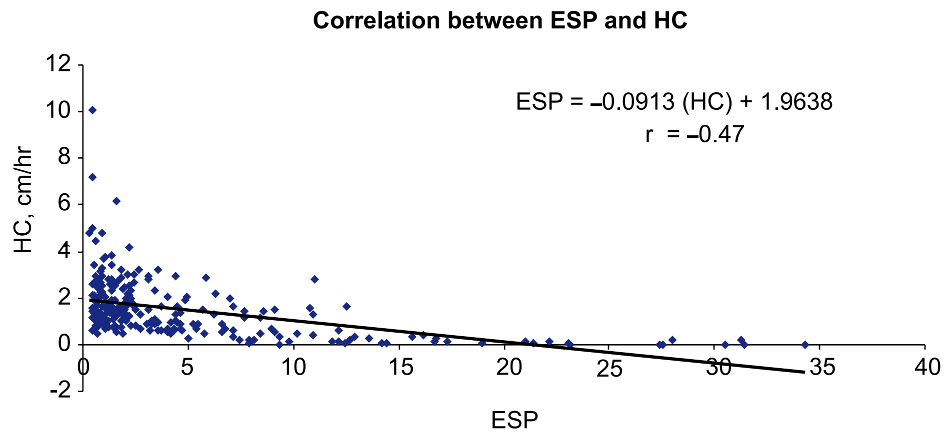


Figure 3.24. Overall correlation between HC and ESP for all soils in different bioclimatic systems.

and 3.31d may be due to the relative contribution of pedogenic carbonates towards SIC, as pedogenic carbonates are directly proportional to the ESP.

The overall trend also shows an increase in ESP with increase in SIC. This is because Ca^{2+} in the exchange complex is preferentially released to precipitate as $CaCO_3$ thereby increasing the relative concentration of Na^+ in the exchange complex. The r value is highest in semi-arid (moist) bioclimate may be because all the four profiles of Asra and Bhatumbra series show an increase in ESP values with SIC in almost all horizons.

3.6 Clay Carbonate

3.6.1 Relationship between SOC and Clay Carbonates

Plant residues and roots contribute to soil organic matter. These materials on decomposition release organic acids, which may solubilize inorganic calcium carbonate. Further, root exudates and organisms also effect solubilization of carbonates. These processes may reduce the amount of $CaCO_3$ in the soil.

Earlier, the relationship between SOC and SIC were discussed. SIC represents overall $CaCO_3$ content in the whole soils ($\leq$2 mm). Since clay is the most reactive part in soils, it appears prudent to see how clay CO_3 is related to SOC in these soils.

An inverse relationship was found between SOC and clay CO_3. It is true for soils under sub-humid (moist), semi-arid (dry) and arid bioclimates, wherein the correlation coefficient is negative (Fig. 3.34). However, this relation does not hold good in the soils under sub-humid (dry) and semi-arid (moist) ecosystems (Fig. 3.34). When correlation was computed between clay CO_3 and SOC for the whole SAT area, an inverse correlation was obtained (Fig. 3.33).

3.6.2 Relationship between SIC and Clay Carbonates

Soil inorganic carbon in SAT areas are both non-pedogenic and pedogenic in nature and it has a direct relationship with aridity (Pal et al. 2000). Therefore, with the decrease in rainfall under natural system, clay CO_3^{2-} is expected to have a positive relationship with SIC. The major contribution for clay CO_3^{2-} in soil is supposed to be from pedogenic carbonates.

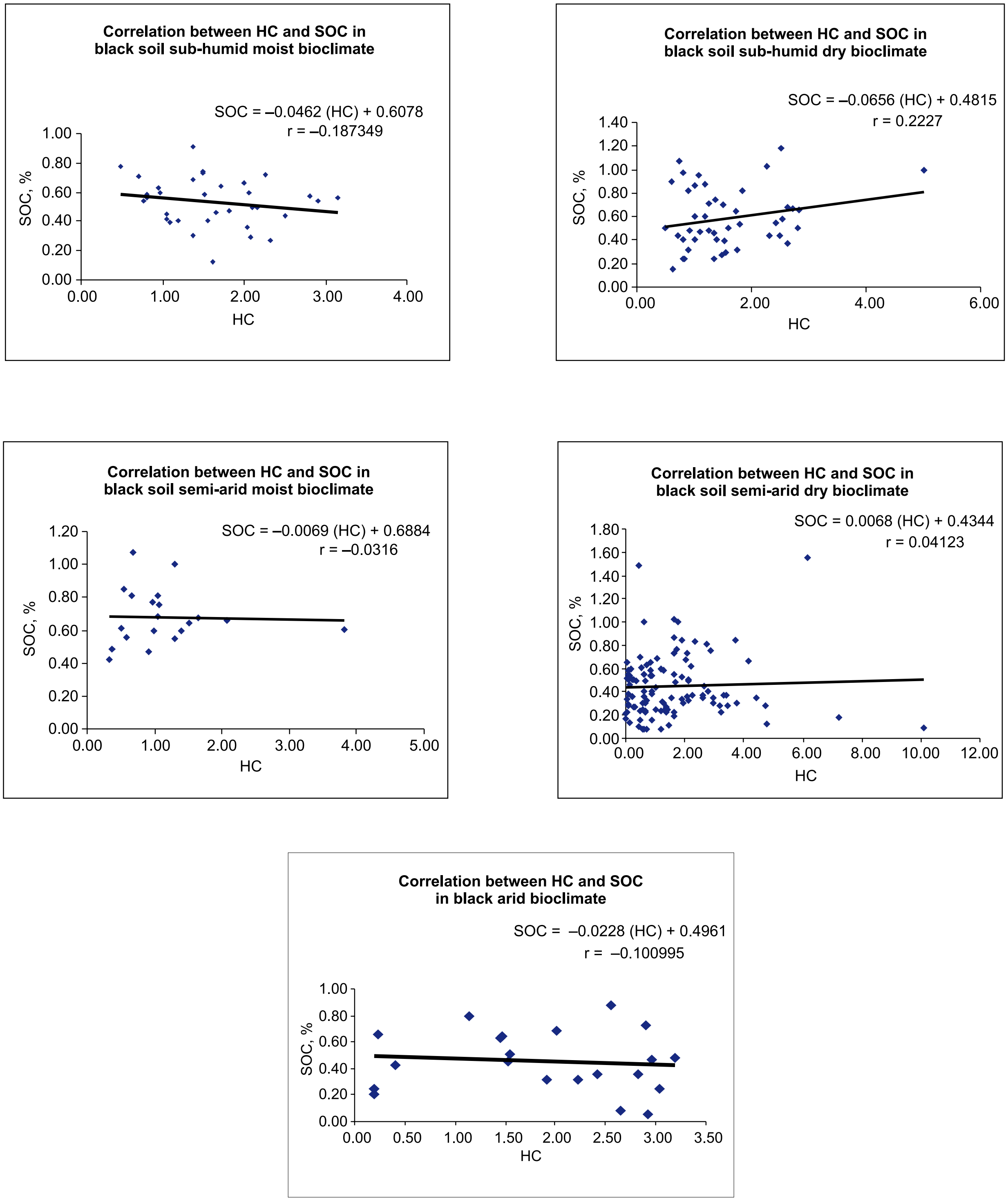


Figure 3.25. Correlation between HC and SOC of Vertisols in different bioclimatic regions.

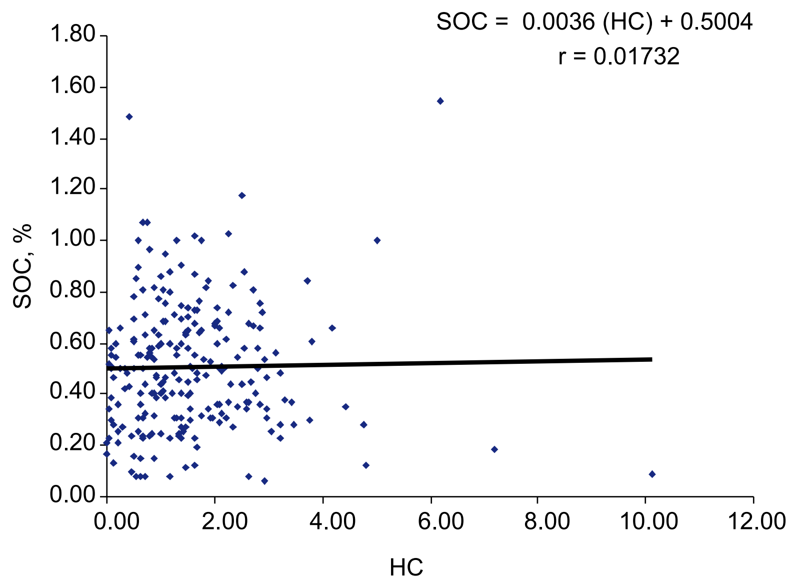


Figure 3.26. Correlation between HC and SOC in various bioclimatic systems in black soils.

Though a positive correlation between clay carbonates and SIC is expected, only under semi-arid (moist) ecosystem this relationship is found to be true (Fig. 3.35). Under other systems a negative correlation between SIC and clay CO_3^{2-} exists. This is also true when all systems are taken together (Fig. 3.36).

3.6.3 Relationship between water dispersible clay (WDC) and clay carbonates

It is known that pH has a decisive role in the dispersion of clay. In Vertisols, the pH in most cases increases with depth and become strongly alkaline in the subsurfaces. When the bicarbonates precipitate as $CaCO_3$ due to high evaporative demand under semi-arid condition, this results in the increase of ESP (Pal et al. 2000). Thus, a positive correlation between water dispersible clay (WDC) and clay carbonates is expected. This relationship holds good for soils in the sub-humid (dry) and semi-arid (moist) bioclimatic regions (Fig. 3.37), but not in other systems (Fig. 3.38).

3.7 pH

3.7.1 Relation between SOC and pH

Vertisols generally have low organic matter due to low prevailing rainfall or aridity, which results in higher degree of ions in organic matter. Absence of luxuriant vegetation further decreases level of organic matter in these soils. Increase in aridity increases the pH due to precipitation of $CaCO_3$ and increases the ESP. Therefore, it is expected that an increase in rainfall or decrease in aridity retards the formation of $CaCO_3$ and also decreases soil pH.

The relationship between pH and SOC is inverse in the Vertisols of all the bioclimatic zones except soils under arid climate (Fig. 3.39). A significant negative correlation (at 1% level) between SOC and pH (r= 0.556) was observed for the soils under sub-humid (dry) climate. An inverse correlation was also observed when a relation was drawn for all the soils studied (Fig. 3.40).

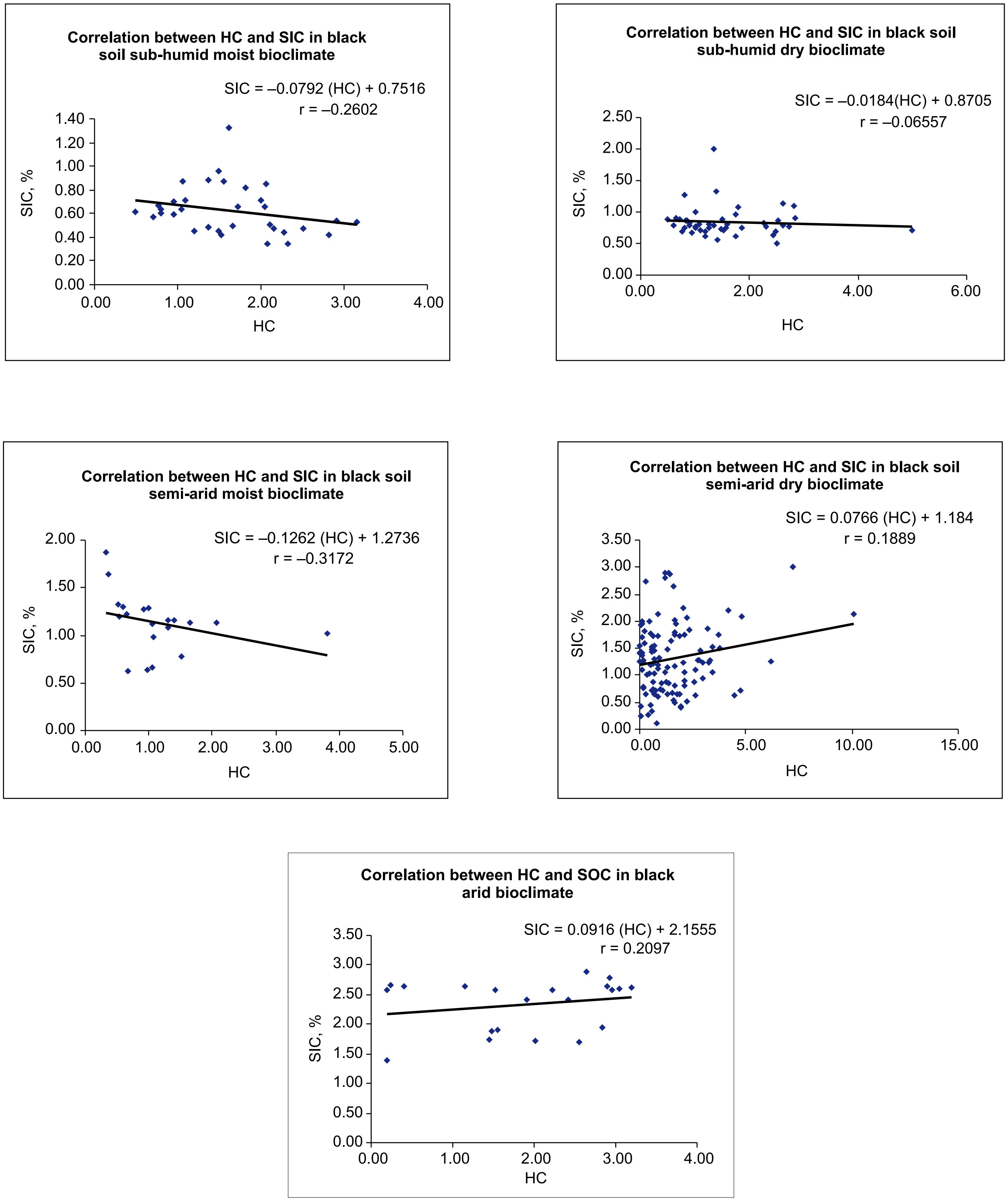


Figure 3.27. Correlation between HC and SIC in different bioclimatic regions.

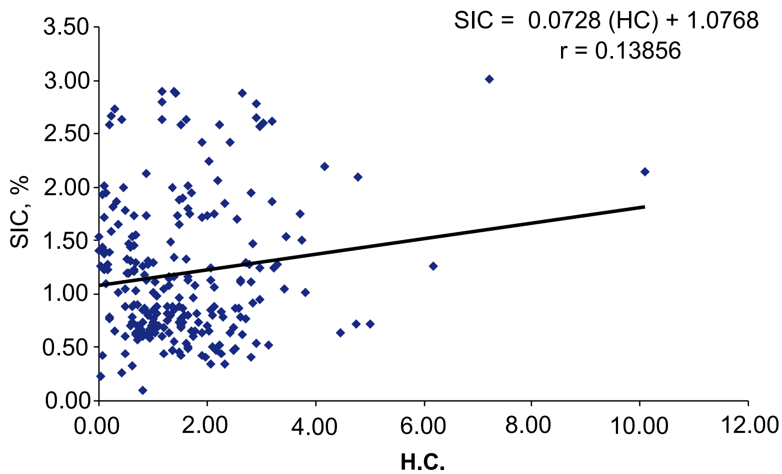


Figure 3.28. Relationship between HC and SIC in various bioclimatic systems in black soil.

3.7.2 Relationship between SIC and pH

The soils in the SAT area have both pedogenic and non-pedogenic calcium carbonates (Pal et al. 2000). The formation of pedogenic calcium carbonate can be attributed solely to arid and semi-arid climate that induces the process of depletion of Ca^{+2} ions from the soil solution in the form of $CaCO_3$, resulting an increase in the relative proportion of magnesium and sodium causing higher ESP and SAR values. Therefore, formation of calcium carbonate is also a basic process for development of sodicity (Pal et al. 2000) and increase in soil pH. Vertisols under SAT may have a positive correlation between SIC and pH. The correlation between SIC and pH is positive in Vertisols of all bioclimatic systems, except those in the semi-arid (dry) ecoregion (Fig. 3.41). However, a slight negative relation was observed for soils in the semi-arid region. A positive trend line was also observed (r= 0.3755) in the soils under SAT, confirming that with the increase in SIC there is an increase in pH due to development of sodicity (Fig. 3.42).

3.8 Soil Separates

3.8.1 Relationship between SOC and soil separates (silt + clay)

The significance of nature and content of clay as substrate has been stressed as the most important factor influencing organic carbon dynamics (Arrouays et al. 1995). Soils containing minerals with higher surface area are most suitable substrate for sequestering organic carbon. Though the soils in the SAT area are expected to be high in surface area due to dominant proportion of smectites, the Vertisols under SAT are low in organic matter. This is because the accumulation of organic carbon depends on the rate of decomposition due to higher temperature of the tropics. The Vertisols have high amount of silt and clay and very low amount of sand. Finer substrate increases the surface area and therefore Vertisols with high amount of 2:1 minerals, particularly of smectites, are expected to retain more organic carbon. Therefore, a positive correlation between soil separates and organic carbon is expected particularly in Vertisols. The study shows that the surface soil (0–15 cm) under sub-humid (moist) and arid climate has a positive correlation with SOC and clay + silt fraction (Fig.

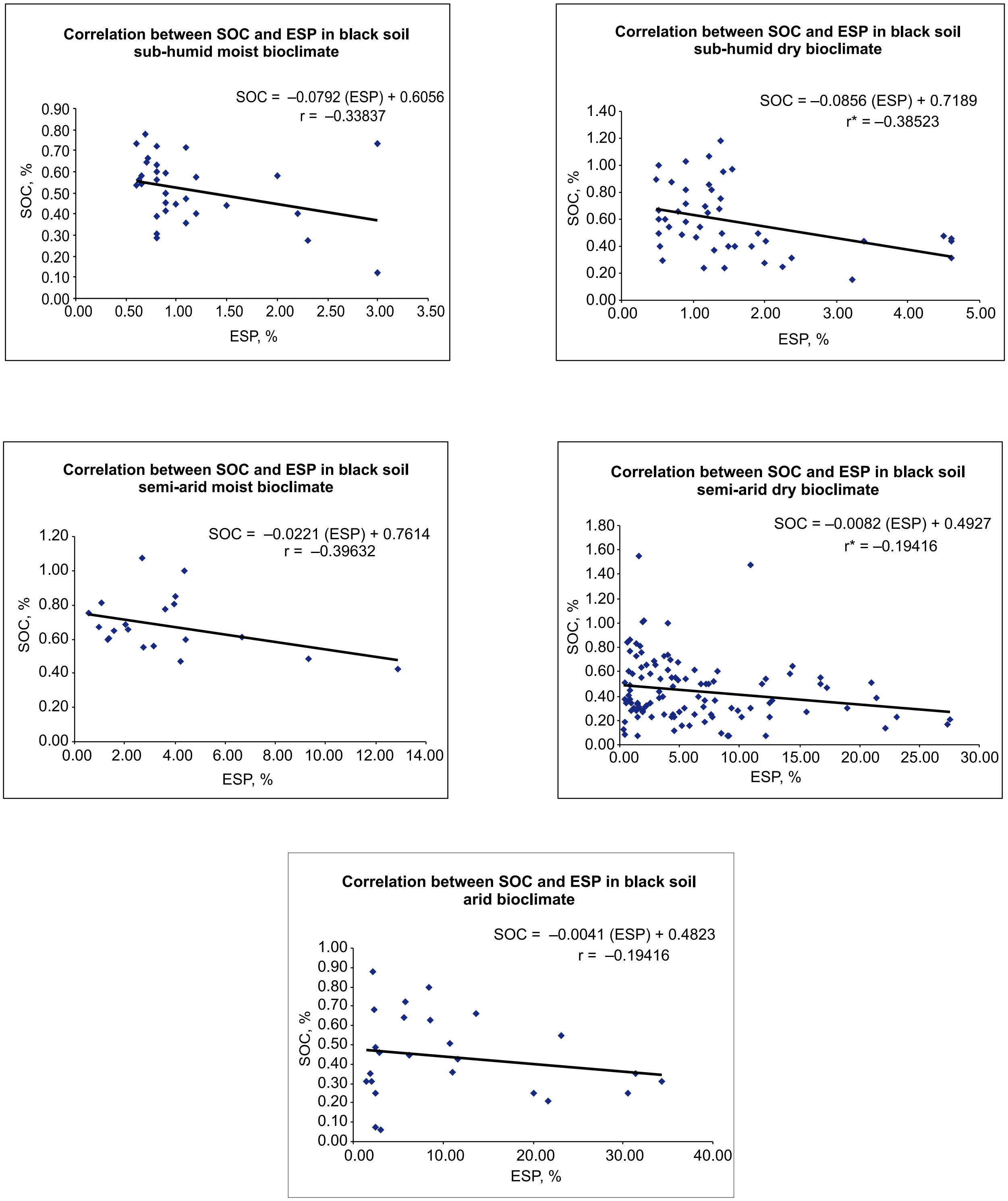


Figure 3.29. Correlation between SOC and ESP in Vertisols of different bioclimatic regions.

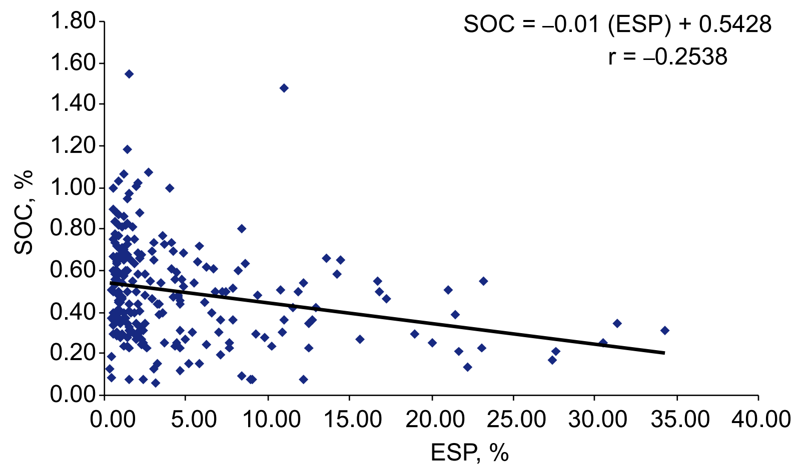


Figure 3.30. Relationship between SOC and ESP in various bioclimatic systems in black soils.

3.43). The general hypothesis of positive correlation also holds good when all the surface soils cutting across bioclimates are taken together (Fig. 3.44).

3.8.2 Relationship between SOC and Fine clay

A positive correlation exists between the amount of fine clay and SOC in surface soils (Fig. 3.45) except for the soils in the semi-arid (dry) climate. The Vertisols under SAT areas have more than 50% clay, of which fine clay generally comprises more than 70%. The fine clay fractions are dominated by smectites that have higher surface areas compared to other minerals in clay fractions. Therefore, the positive correlation between fine clay and SOC is expected. This positive relation is also seen in the soils under sub-humid (moist), semi-arid (moist) and arid bioclimates (Fig. 3.45). A positive relationship ($r = 0.01$) (not significant) between SOC and fine clay obtained for all soils together (Fig. 3.46).

3.8.3 Relationship between SIC and Silt + Clay

Due to linkages between finer particles of soils and organic matter as clay-humus complexes, a relationship between the two is expected. But such a relationship between clay and SIC is not reported. However, the amount of finer particles dominated by shrink-swell minerals and sodium in the exchange complex may control the water movement in a Vertisol profile. Therefore, in arid climate, the high ESP in the clay exchange site increases the precipitation of carbonates and hence in arid climate a positive correlation between clay + silt and SIC is expected. However, this correlation is true only in the surface soils in the semi-arid (dry) ecosystem (Fig. 3.47) and when all soils are taken together (Fig. 3.48).

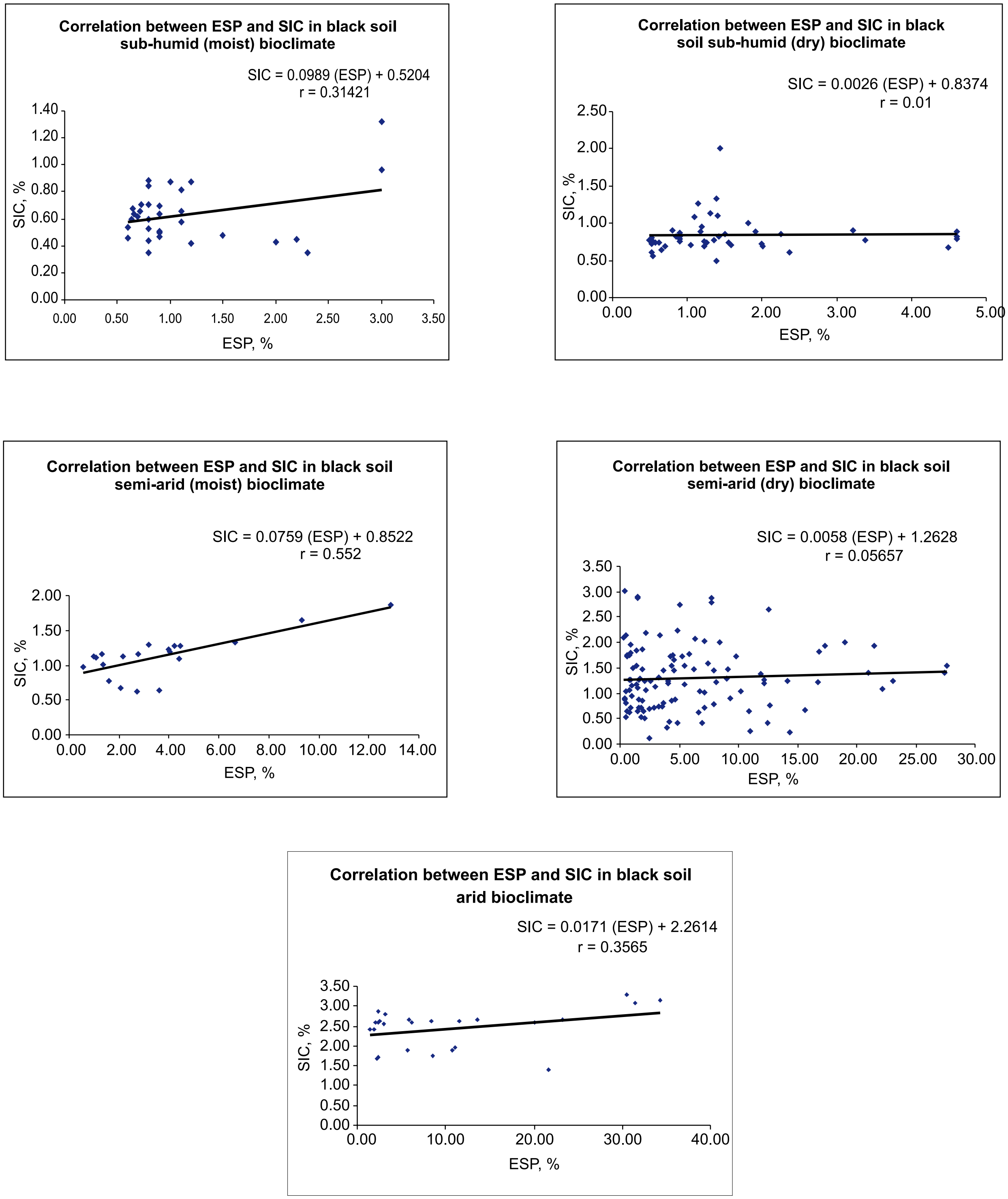


Figure 3.31. Correlation between SIC and ESP in different bioclimatic regions.

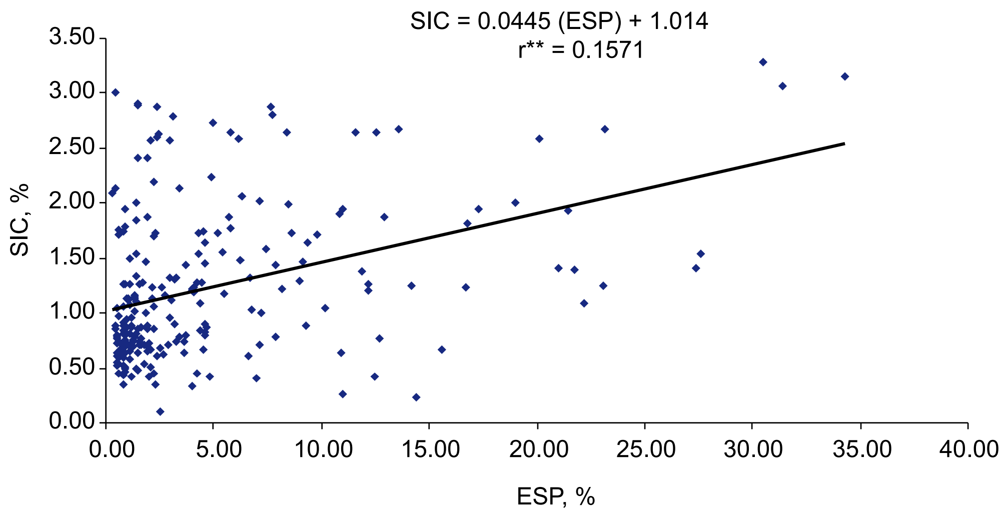


Figure 3.32. Relationship between SIC and ESP in various bioclimatic systems in black soils.

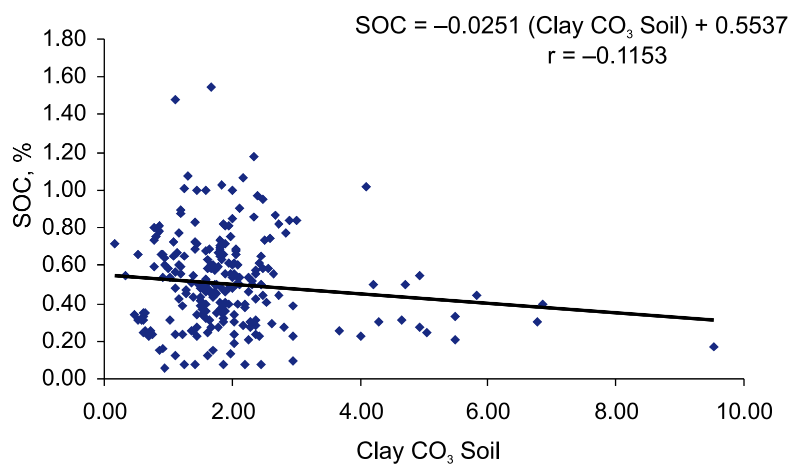


Figure 3.33. Relationship between SOC and clay carbonates in various bioclimatic systems in black soils.

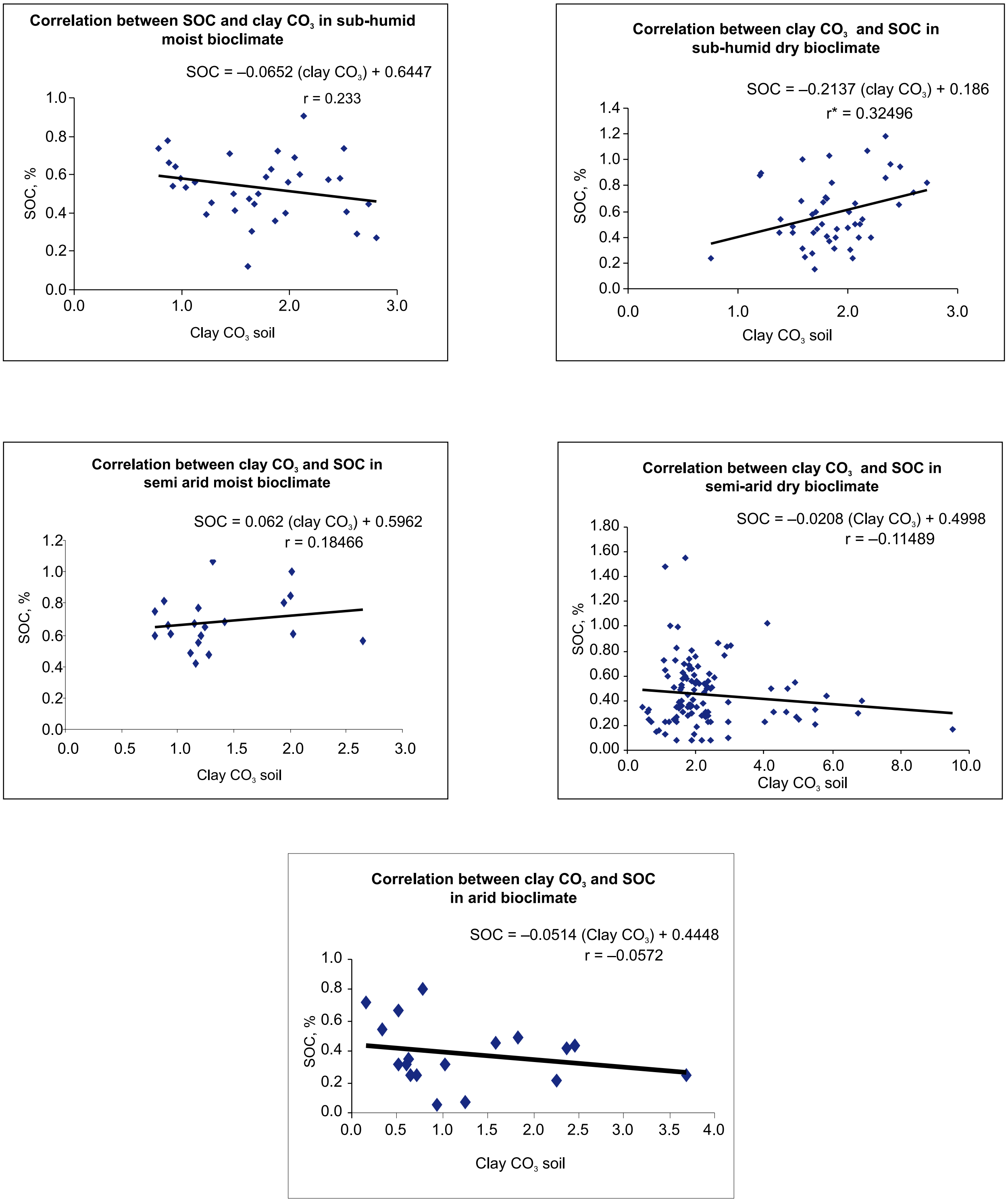


Fig. 3.34. Correlation between SOC and clay carbonates of black soils in different bioclimatic regions.

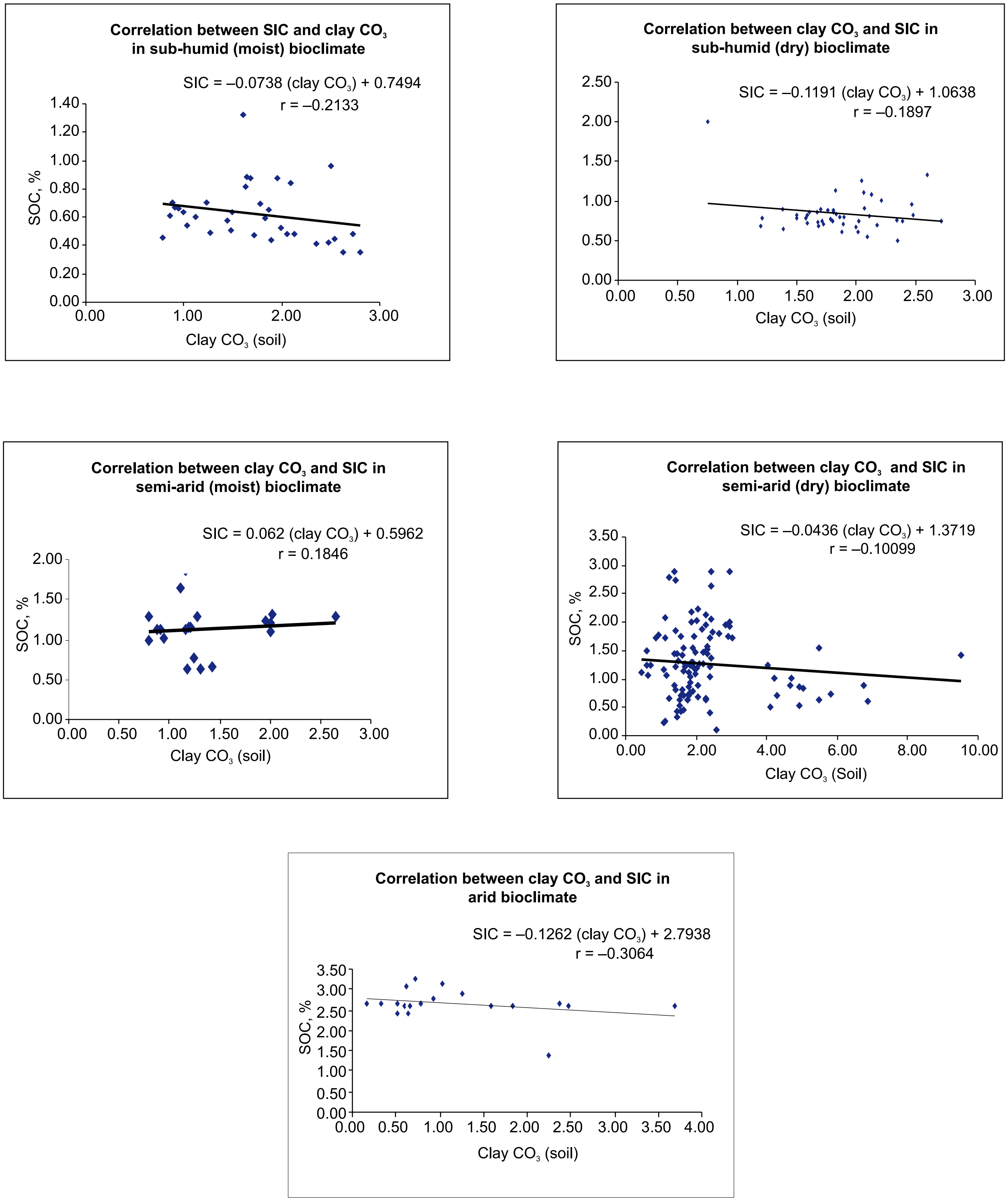


Figure 3.35. Correlation between SIC and clay carbonates in different bioclimatic regions.

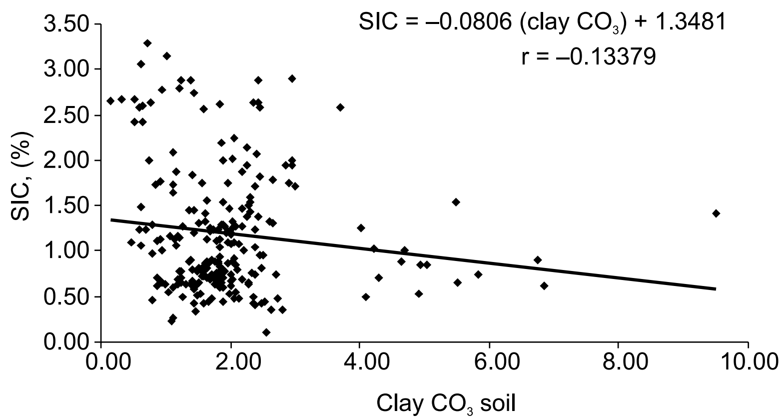


Figure 3.36. Relationship between SIC and clay carbonates in various bioclimatic systems in black soils.

3.9 Land Use Systems

3.9.1 SOC in various Land Use Systems

Soil organic carbon in the 0–30 cm depth is the highest under forest system, followed by soils under permanent fallow (having grassland), horticultural system, agricultural system and the lowest in wasteland (Fig. 3.49). Within the forest system, Dadarghugri soils (P24) formed from basalts under teak plantation show much higher SOC than Karkeli soils (P25), which are formed from sandstone (Tate and Theng 1980; Bhattacharyya 1984) and under sal plantation (Jagdish Prasad and Gaikawad 1991). The variation in SOC is due to the variation in texture (Neufeldt et al. 2002; Bhadwal and Singh 2002) and mineralogy (Bhattacharyya and Ghosh 1994; Parfitt et al. 2002) of soils. Boripani soils (P15) are also formed from basalts but the SOC contents are lower. This may be because the forests are degraded and the rainfall is lower than Dadarghugri region.

Soils under permanent fallow system (P41) have the next highest SOC value of 1.42%. This is due to earthworm casts in the top 4 cm of the surface that is covered with grassland vegetation. This covers about 70-80% by volume. The soils of P41 have appreciably higher COLE values, indicating substrates with higher surface area. The system under citrus crop (P1 and P3) shows higher SOC (0.80%) compared to agricultural system in general (0.70%). Naitam (2001) and Naitam and Bhattacharyya (2003) have shown that in general there was higher humic acid recovery in soils under horticultural system than agricultural system. However, there are some exceptions in Dadarghugri soils (P23), which contain very high SOC (Fig. 3.49). This might be due to the recent conversion of this spot into cultivation. This area was under forest, like the site of P24. Other exceptions are Pangidi soils (P49), containing relatively high SOC since these have been deforested for cultivation during the past 7–8 years. Teligi soils (P43), which have been cultivated for rainfed paddy for several years also contain relatively high SOC. The wasteland system has the lowest SOC (0.47%) as it has sparse vegetation of grasses and *Prosopis sp.*

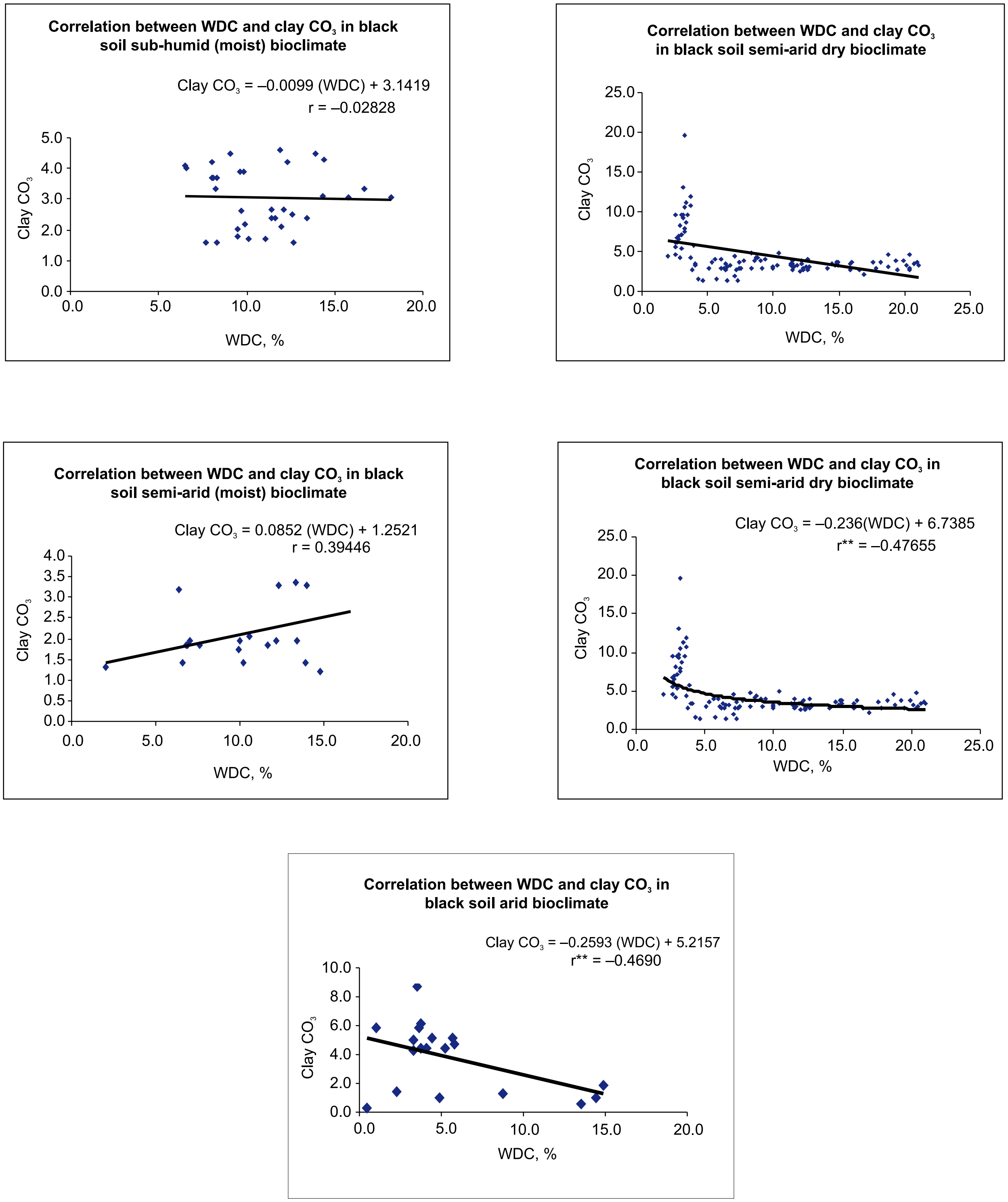


Figure 3.37. Correlation between WDC and clay carbonates in different bioclimatic regions.

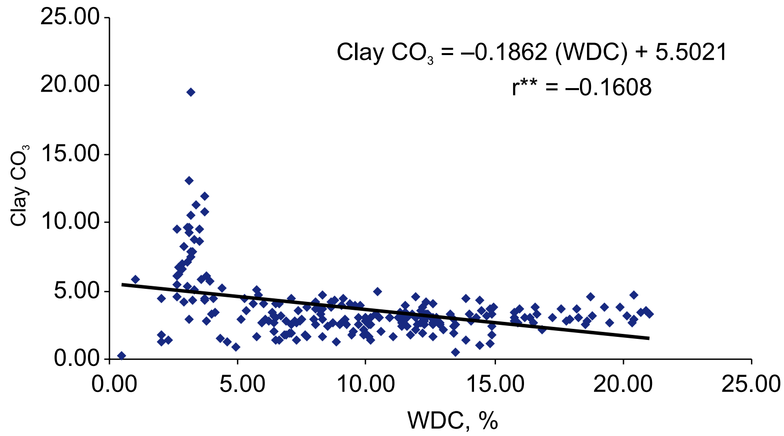


Figure 3.38. Relationship between WDC and clay carbonates in various bioclimatic systems in black soils.

3.9.2 SIC in various Land Use Systems

In the 0–30 cm soil layer, agricultural system and horticultural systems show the highest SIC (Fig. 3.50) with some exceptions: SIC is found to increase in the sub-humid to arid bioclimatic zones. Nipani soils (P48) show higher values of SIC because in addition to basaltic alluvium, the formation of these soils is also influenced by the presence of Cuddapah limestone observed during field study (Wadia 1989).

The SIC content of wasteland system (0.78%) is slightly lower but comparable to those under agricultural and horticultural systems. The wastelands under study are situated in the semi-arid environment with scanty vegetation and these conditions enforce development of SIC (Pal et al. 2000). The permanent fallow system on red soils do not have SIC in the 0–30 cm soil layer.

3.10 Variation of SOC in Agricultural Systems under Different Bioclimates

3.10.1 Black Soils

The soils in the semi-arid (moist) bioclimate have maximum SOC (0.825%) in the 0–30 cm layer of black soils (Fig. 3.51). This is due to green manuring (P12), addition of FYM and keeping the lands fallow during *kharif*, which must have increased SOC content. Growing green-manure crops improves the structure of the soils (Cotching et al. 2002) and reduces the pH and ESP and increases the hydraulic conductivity of the soils (Bhattacharyya et al. 2000). The semi-arid (moist) bioclimate has slightly higher SOC (0.82%) than sub-humid (moist) bioclimatic system. The SOC contents under these bioclimates are comparable except the SOC under soybean-wheat system, which is considerably lower (0.54%). In the sub-humid (moist) bioclimate, the agricultural systems have similar SOC content. The relatively low values of SOC under sub-humid (moist) bioclimate than under bioclimates with lower rainfall may be due to influence of the agricultural systems practised. For example, Panjri soils (P4) having sole cotton system yields lower values of SOC. This is because it has been shown that cotton intercropped with a legume yields more SOC than sole cotton (Naitam

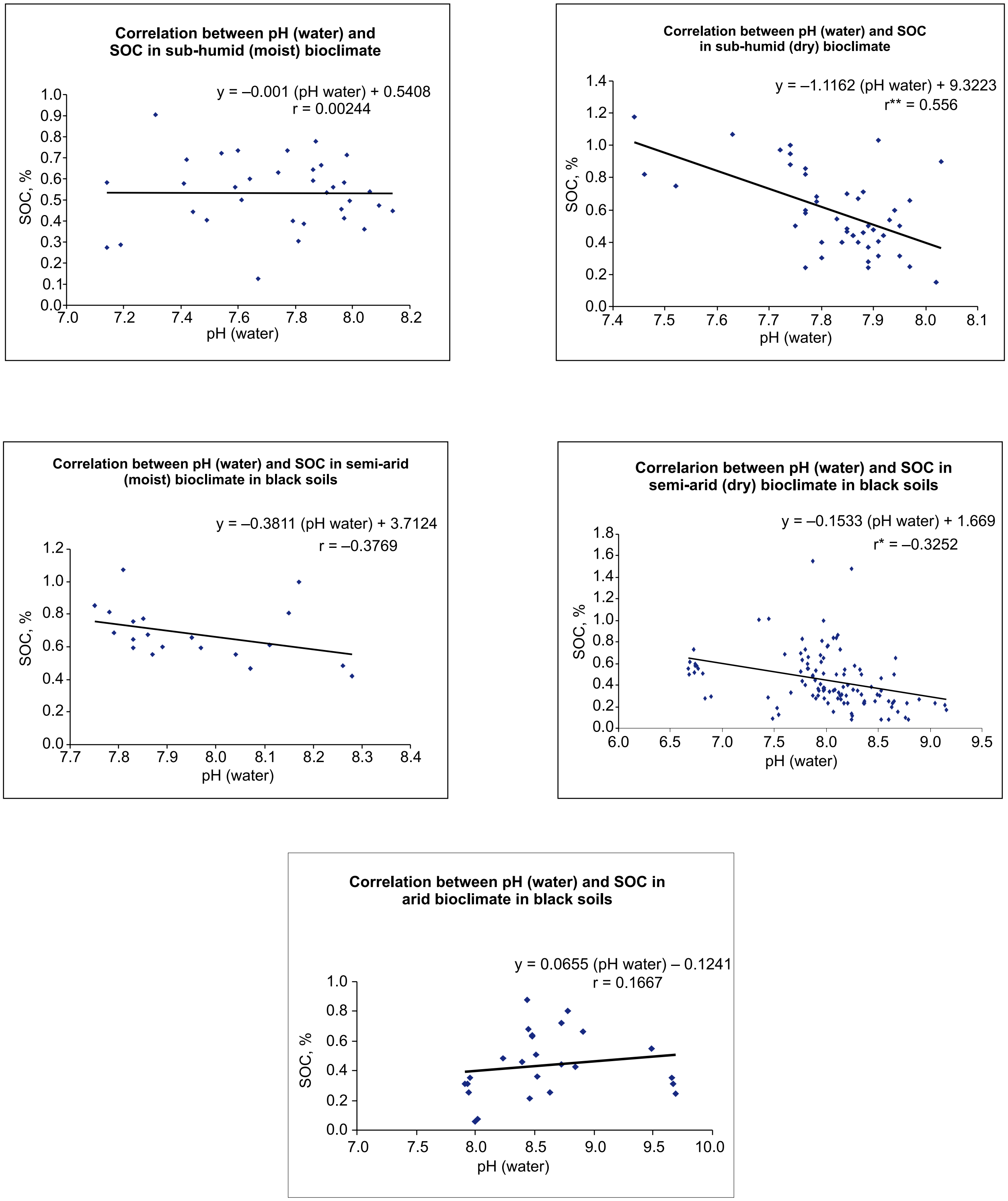


Figure 3.39. Correlation between pH water and SOC in different bioclimatic zones.

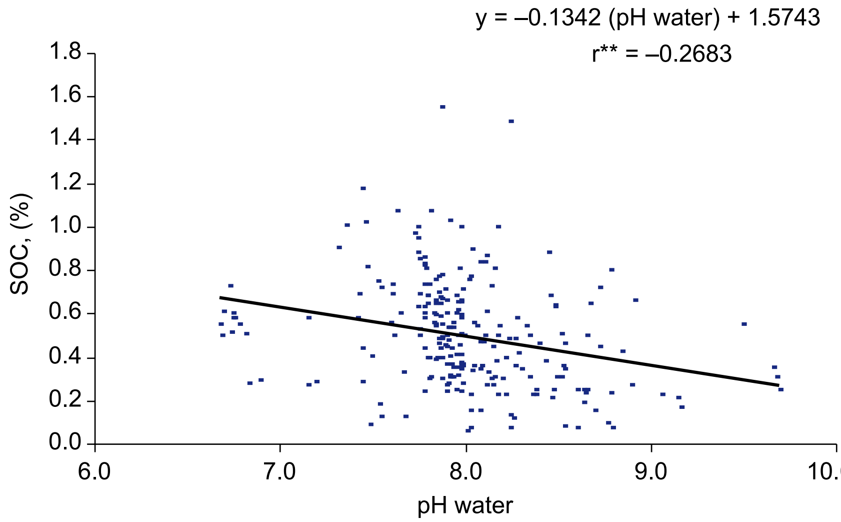


Figure 3.40. Correlation between pH water and SOC in various bioclimatic systems in black soils.

2001; Naitam and Bhattacharyya 2003). Moreover, in general, it has been observed that Kheri (P27 and P28) and Nabibagh (P5 and P6) soils with mainly soybean-wheat system show lower content of SOC than cotton + pigeonpea or sorghum + pigeonpea or soybean + pigeonpea systems with one fallow season. This may be because soybean yields higher SOC with a narrow C: N ratio. Besides, the wheat crop in the *rabi* season makes the system (soybean-wheat) more exhaustive in terms of nutrient uptake without any gap. On the other hand, cotton+ pigeonpea systems are longer-duration crops and also produce more biomass than wheat crop and effectively increase SOC content.

The average SOC value of semi-arid (dry) bioclimate for black soils is 0.63%. Higher content of SOC are found in P43, P44, P36 (paddy-paddy), P46 (fallow-sorghum + safflower) and P47 (sugarcane/sorghum-wheat/gram) and P29 (cotton/groundnut-wheat). Except P46 all sites are irrigated and under high management. Although P46 (Konheri 1) soils are not under HM, they being preceded by a fallow *kharif* season led to a higher SOC (0.84%) in 0–30 cm soil layer. The highest value of SOC is in Teligi soils (P43), which is under a paddy-paddy system. The Teligi soils under low management (P43) have higher SOC (1.03%) than Teligi soils under high management (P44) (0.80%). The lowest value is in Konheri soils (P45) (0.30%), which also have relatively lower clay compared to other soils. The content in SOC agricultural systems in arid bioclimate is the lowest (0.59%). The higher values in Nimone soils (P51, P52) are due to sugarcane cultivation, which produces larger biomass and provides surface cover for a longer duration. Sokhda soils (P30) with cotton–pearl millet under a two-year rotation have the lowest value of SOC (0.363%). Soils under sole cotton generally contain low SOC (Naitam 2001). Inclusion of pearl millet in rotation does not seem to influence the SOC value of these soils.

3.10.2 Red Soils

The content of SOC in agricultural systems is the highest in sub-humid (moist) (1.35%), followed by semi-arid (dry) (0.84%), and the lowest in semi-arid (moist) (0.74%) bioclimate (Fig. 3.52). In sub-humid (moist) bioclimate, most of the SOC is contributed by Dadarghugri soils (P23) (2.12%), which are adjacent to forest ecosystem and developed from basalt. Whereas the Karkeli soils (P26), which are developed from deforested sandstone and adjacent to forest lands, have SOC value of

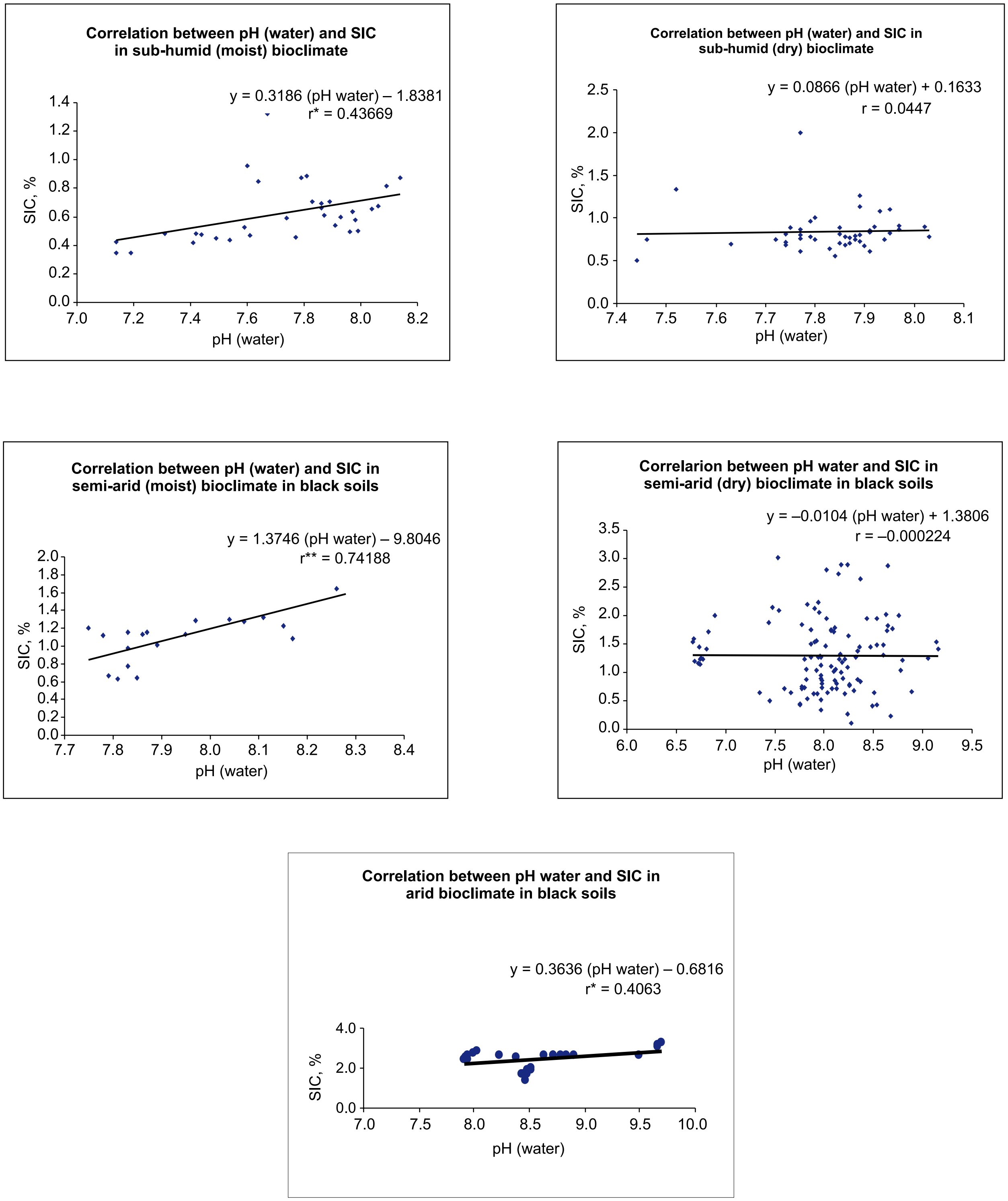


Figure 3.41. Correlation between pH water and SIC in different bioclimatic zones.

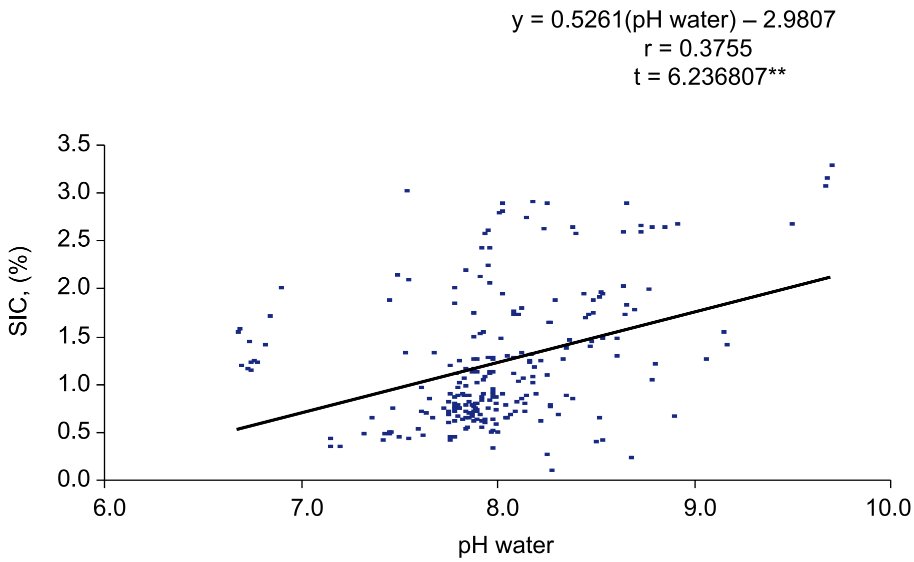


Figure. 3.42. Correlation between pH water and SIC in various bioclimatic systems in black soils.

0.60%. This may be because the Dadarghugri soils have higher COLE, higher clay CEC and higher specific surface area as compared to Karkeli soils (P26) for greater sorption of organic matter (Kaiser and Guggenberger 2003). The SOC content in agricultural systems in semi-arid (dry) is found to be slightly higher than in semi-arid (moist). This may be because of higher base saturation, clay CEC and specific surface area compared to Vijaypura soils (P16, P17, P18) in semi-arid (moist) bioclimate. Moreover, except Palathurai series (P22) all other series in semi-arid (dry) are cultivated to crops, which have good cover and produce higher biomass (sorghum-castor; castor+ pigeonpea) compared to Vijaypura soils, which have finger millet as the sole crop.

3.11 SIC Content in Soils under Agricultural Systems in Different Bioclimates

3.11.1 Black Soils

SIC content in soils under agricultural systems is highest in arid bioclimate (2.3%), followed closely by soils in sub-humid (dry) (1.1%), semi-arid (moist) (1.0%) and semi-arid (dry) (0.9%). The lowest SIC content was found in soils under sub-humid (moist) bioclimate (0.5%) in first 30 cm depth of soils (Fig. 3.53). It is known that there is an increase in precipitation of $CaCO_3$ with increase in aridity (Pal et al. 2000; Srivastava et al. 2002). The soils under semi-arid (dry) bioclimate show lower SIC than those in sub-humid (moist and dry) bioclimates. In general, there is an increase in $CaCO_3$ down the depth of soil and the 0–30 cm soil does not truly represent the nature and properties of $CaCO_3$. Moreover, P32, P35, P36, P39, P47, P19 soils are being continuously irrigated and this may have resulted in movement of clay carbonates to lower layers, except in P19, which is better drained due to the presence of gypsum. Therefore, the SIC values are lower in soils under semi-arid (dry) due to manifestations of irrigation and some management practices such as broad-bed ridge and furrow system which facilitate drainage in P39. The higher value of SIC in soils (P48) in sub-humid (dry) is due to formation and accumulation of $CaCO_3$ and the presence of Cuddapah limestone in the area.

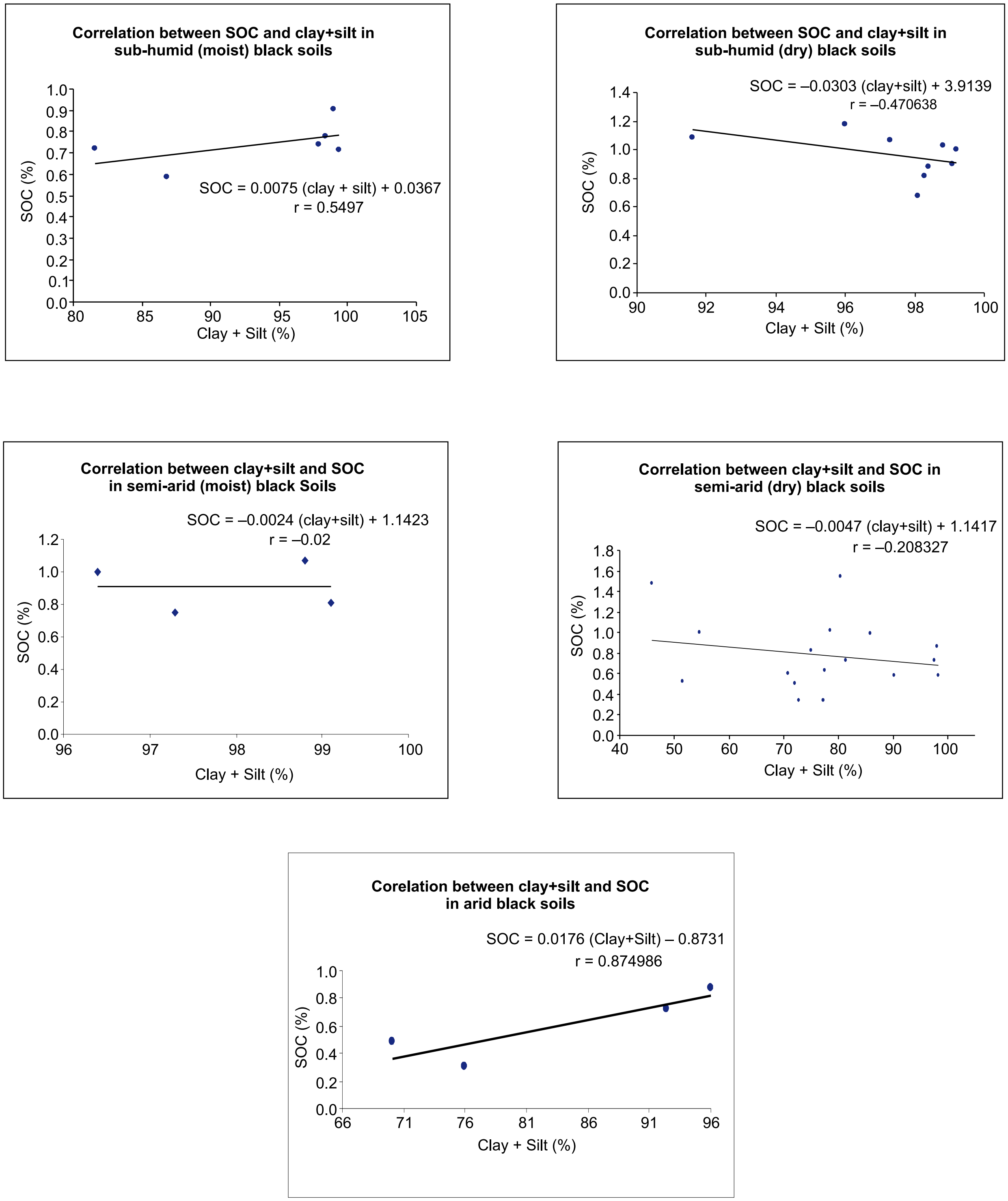


Figure 3.43. Correlation between SOC and clay + silt in different bioclimatic systems in black soils.

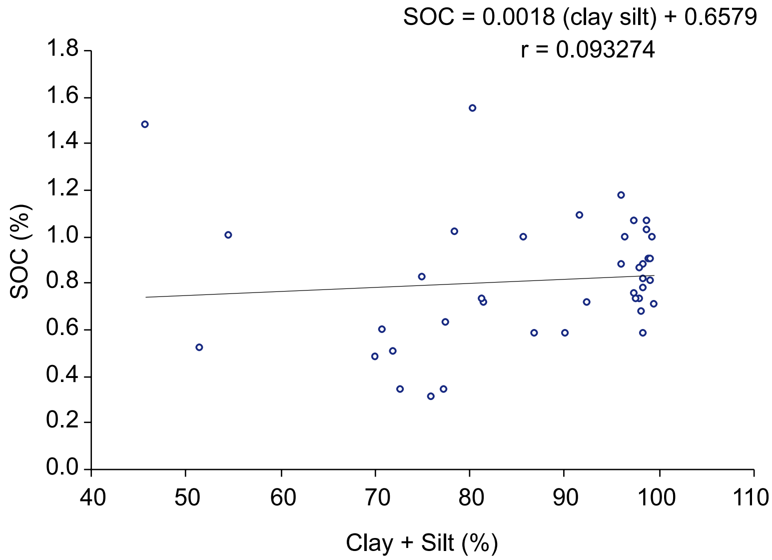


Figure 3.44. Correlation between SOC and clay + silt in various bioclimatic systems in black soils.

3.11.2 Red Soils

The red soils have considerable amounts of SIC in the 0–30 cm soil in various agricultural systems under various bioclimates, except in Palathurai soils (P22) under semi-arid (dry) bioclimate (Fig. 3.54). However, other soils in semi-arid (dry) show accumulation of SIC at lower depths. The sub-humid (moist) and semi-arid (moist) bioclimates do not contain SIC even at lower depths in the profile.

3.12 SOC in Dominant Cropping Systems

The SOC values in the 0-30 cm depth in various agricultural systems shows higher values for cereal-based systems (0.79%) followed by soybean-based systems (0.70%) and cotton-based systems (0.68%) (Fig.3.55). It has been generally observed that cereal-based systems contribute to higher accumulation and stabilization of organic matter (West and Post 2002; Ludwig et al. 2003) especially in paddy-paddy system. The paddy-paddy system contributed relatively higher SOC than paddy-wheat in our study also. Sorghum/pigeonpea + green gram system of Jajapur (P35) and sorghum/sunflower/ cotton system of Kovilpatti (P19) showed very low values of SOC under rainfed conditions. The sorghum+ pigeonpea/ black gram–chickpea system of Bhatumbra (P42) showed higher values of SOC under irrigated condition. The higher values of SOC in Bhatumbra (P42) may also be due to better management and crop rotation (West and Post 2002) (Fig. 3.56). The red soils formed from granites and gneiss, viz. Hayatnagar soils (P37, P38) having a sorghum-castor crop rotation after every two years, show higher SOC than Palathurai soils (P22). The Dadarghugri soils (P23) show very high SOC (2.12%) with a maize/mustard cropping system under a very low management. The SOC level is maintained at a higher level even after deforestation and cropping for more than 15 years because of the very low level of management and less exhaustive type of cultivation practised by farmers (Fig. 3.57).

In the soybean-based cropping systems, soybean+ pigeonpea intercropping showed slightly higher SOC than soybean-wheat system. The latter groups are under irrigated and highly exhaustive system,

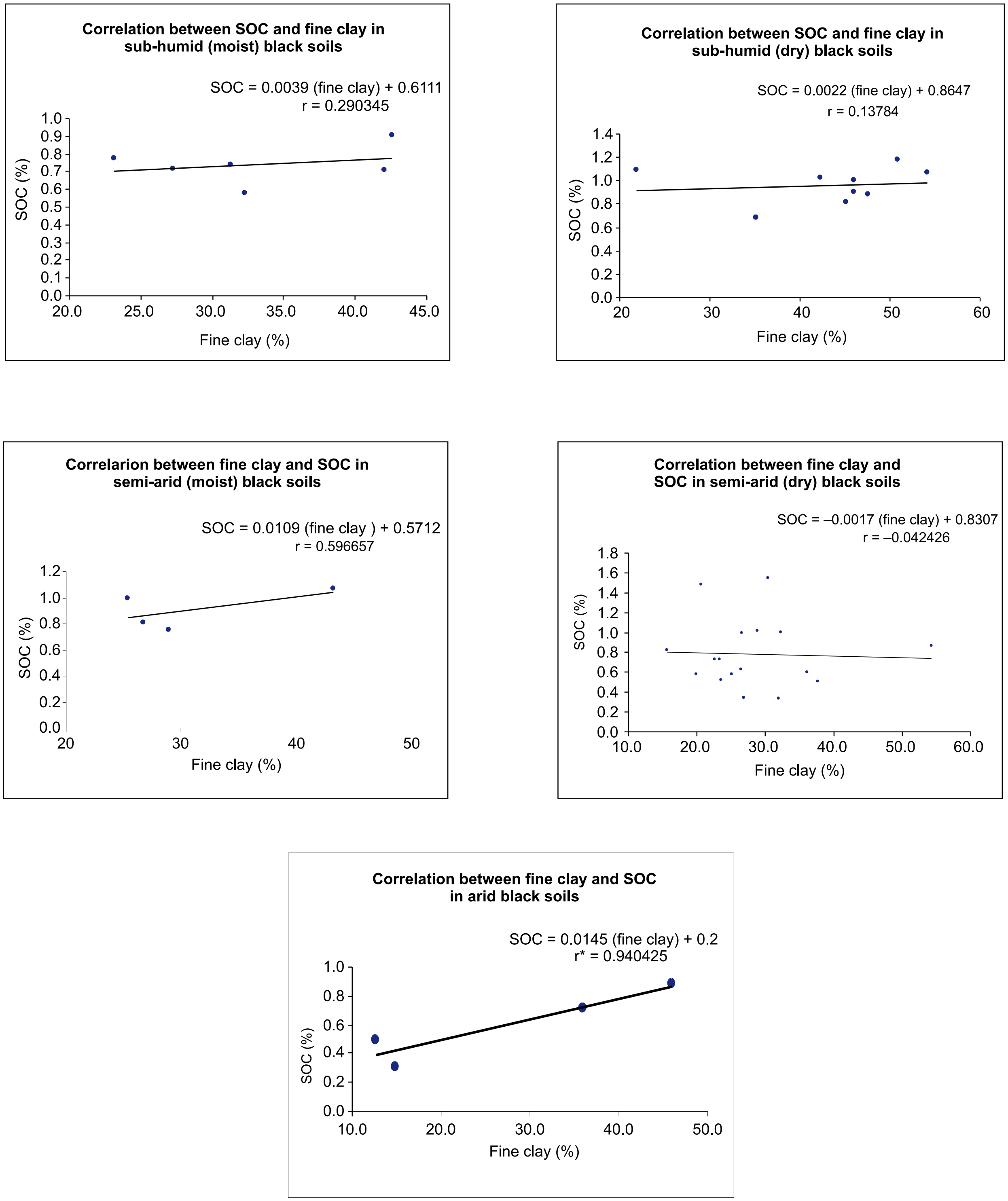


Figure 3.45. Correlation between SOC and fine clay in different bioclimatic systems in black soils.

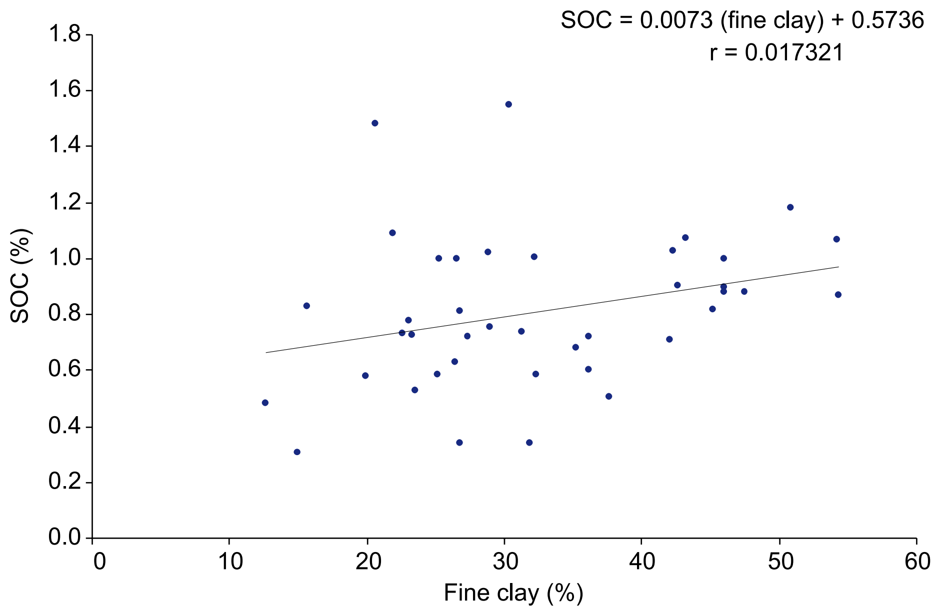


Figure 3.46. Correlation between SOC and fine clay in various bioclimatic systems in black soils.

whereas the former groups are under rainfed cropping system (Cotching et al.rr 2002). Soybean-gram and soybean-gram/wheat showed slightly higher SOC than soybean-wheat. Pangidi soils (P50) having sole soybean showed the highest SOC (0.90%) in soybean-based system because these lands only have been recently deforested for cultivation.

Cotton-based cropping systems have the lowest SOC in the 0–30 cm depth of soil (0.68%). However, cotton+ pigeonpea intercropping showed higher SOC than soybean+ pigeonpea intercropping in soybean-based system. Cotton+ pigeonpea intercropping showed higher SOC than sole cotton (Naitam 2001; Naitam and Bhattacharyya 2003). The soils growing cotton rotated with pearl millet or linseed recorded lower SOC values than those growing only cotton.

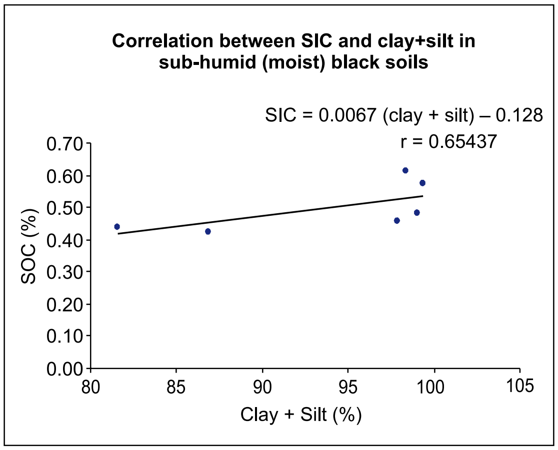
The SOC content in teak and sal forests is shown in Figure 3.58. Comparatively, teak in red soils permits higher SOC content than that in black soils. Climatic factors, viz. more rainfall and cool winters in red soils (P24), may be responsible for slow decomposition of SOM (Bhattacharyya et al. 2000). Figure 3.59 shows typical landscape and soils under forest.

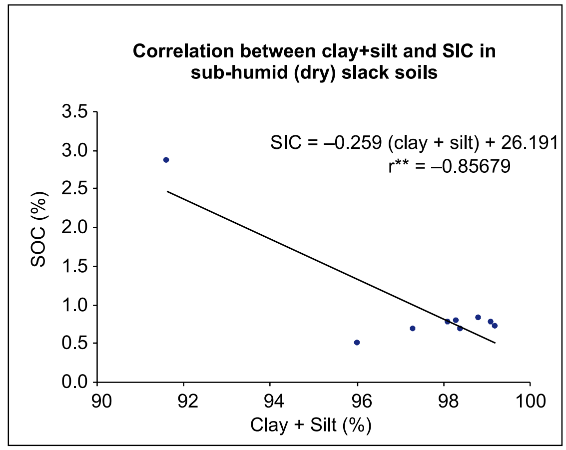
3.13 SIC in Dominant Cropping Systems

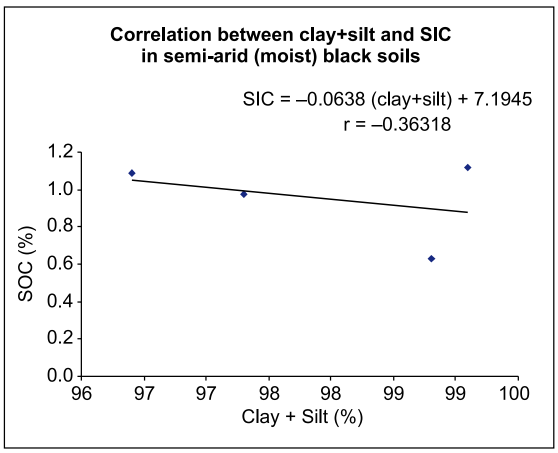
The SIC in the 0–30 cm depth of soil is the highest in cotton-based systems (1.53%), followed by soybean-based systems (0.66%) and the lowest in cereal-based systems (0.29%) (Fig. 3.60). This trend is opposite to that observed for SOC content (Fig. 3.56) under these systems.

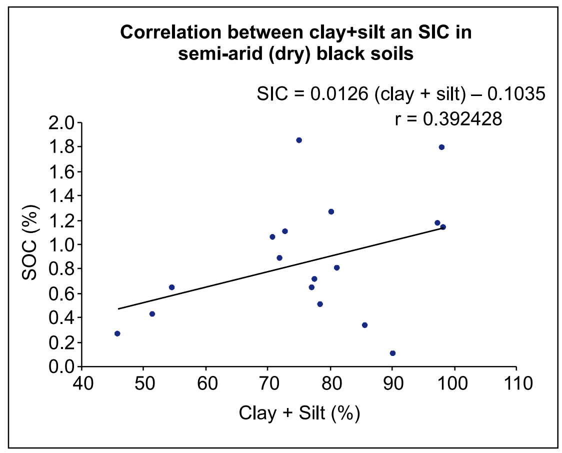
In cotton-based systems, the SIC increased with decreasing rainfall from sub-humid (moist) to arid bioclimatic zones, with the exception of sub-humid (dry) system. However, Nipani soils (P48) are rich in non-pedogenic $CaCO_3$ and contain higher SIC. The soils of Sokhda (P30 and P31) showed higher values of SIC with cotton–pearl millet and cotton-bajra/linseed systems, respectively. These soils also showed lower values of SOC in the 0–30 cm soil layers.

Soybean-based systems also showed a trend similar to that of cotton-based systems in terms of variation in SIC under different bioclimates, with the exception of semi-arid (dry), which showed









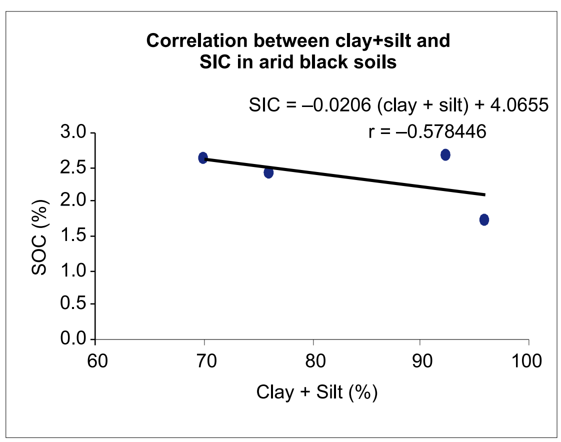


Figure 3.47. Correlation between SIC and clay + silt in different bioclimatic systems in black soils.

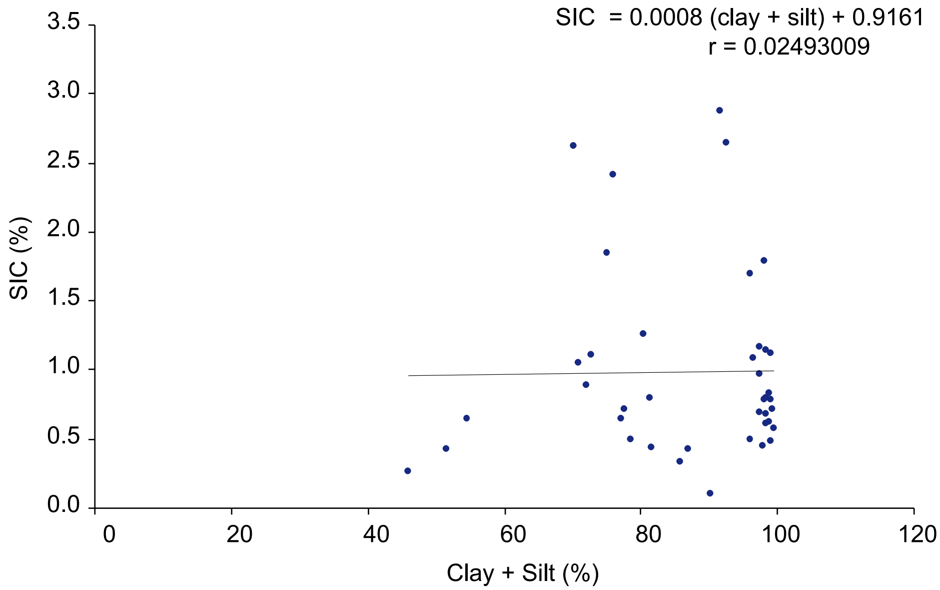


Figure 3.48. Correlation between SIC and (clay + silt) in various bioclimatic systems in black soils.

lower values than those in the higher rainfall regions. The soils under cereal-based systems showed irregular variation in SIC under different bioclimates.

3.14 Variation of SOC with Type of Management

Dominant Crop as Cotton (Agricultural System)

3.14.1 Asra soils (P10, P11, P12) Amravati, Maharashtra

P10 and P11 represent rainfed mixed/intercropping systems with single *kharif* crop or occasional double crop (soybean-chickpea) depending upon the availability of soil moisture for the *rabi* crop. Legumes, viz. green gram, soybean, chickpea or pigeonpea are inherent components of the agricultural system. FYM is frequently applied to supplement moderate application of chemical fertilizers. These irrigated-crop management practices maintained high SOC levels. The site for P12 does not represent any fixed cropping system. A two-year rotation of cotton + pigeonpea-sorghum-chickpea is regularly interrupted by green manuring with sun hemp or sesbania. Being a non-exploitative system, the SOC was higher and SIC was lower at this site (Fig. 3.61).

3.14.2 Paral soils (P13 and P14) of Akola, Maharashtra

Both the profiles represent rainfed, single (*kharif*) season cotton + pigeonpea strip cropping system. However, a third intercrop of either sorghum (P13) or green gram (P14) is also practised. The input levels, viz. FYM, fertilizers and seed rate, were higher in P14 than in P13. Despite lower inputs, the SOC levels were comparable in P13 and P14 (Fig. 3.62).

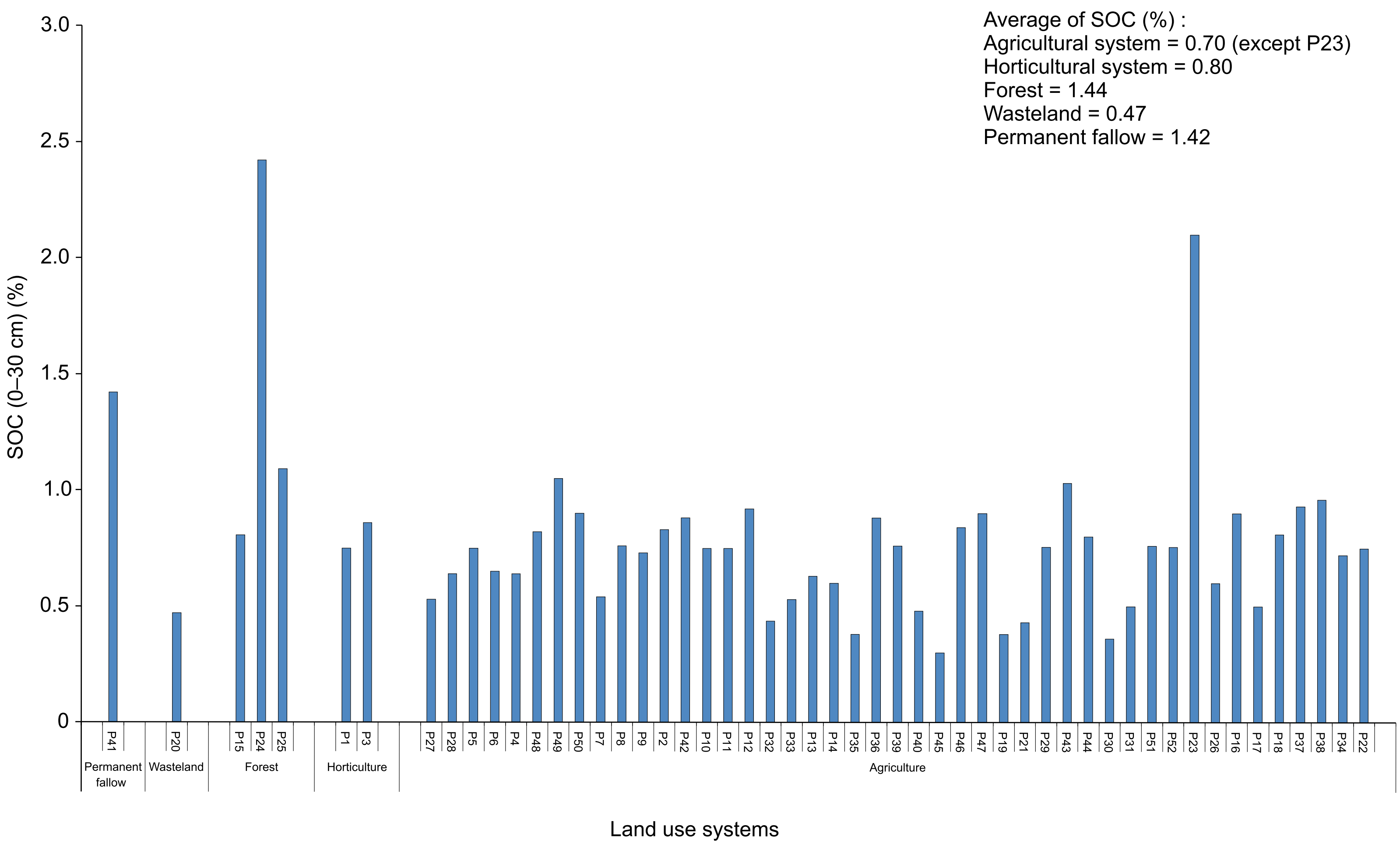


Figure 3.49. SOC (0–30 cm) in various land use systems.

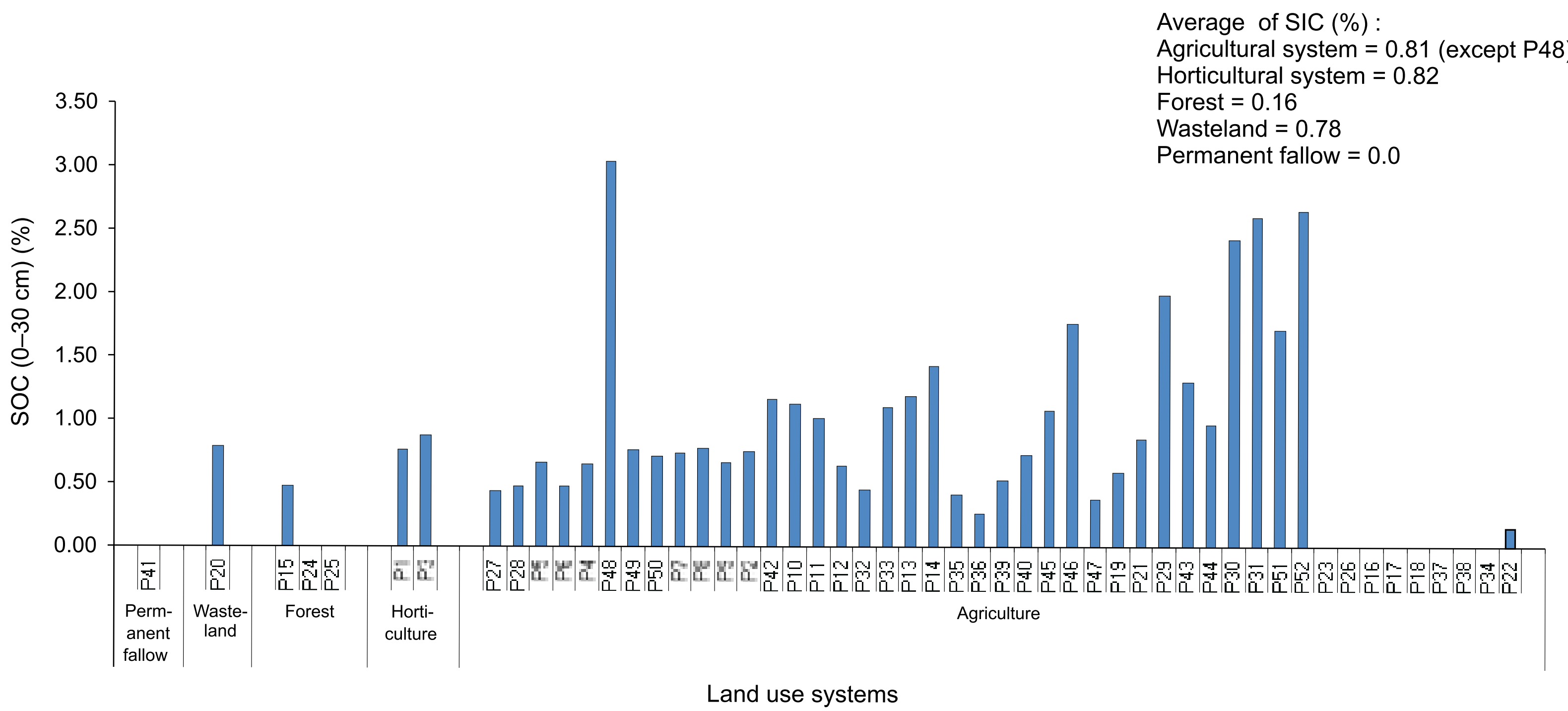


Figure 3.50. SIC (0–30 cm) in various land use systems.

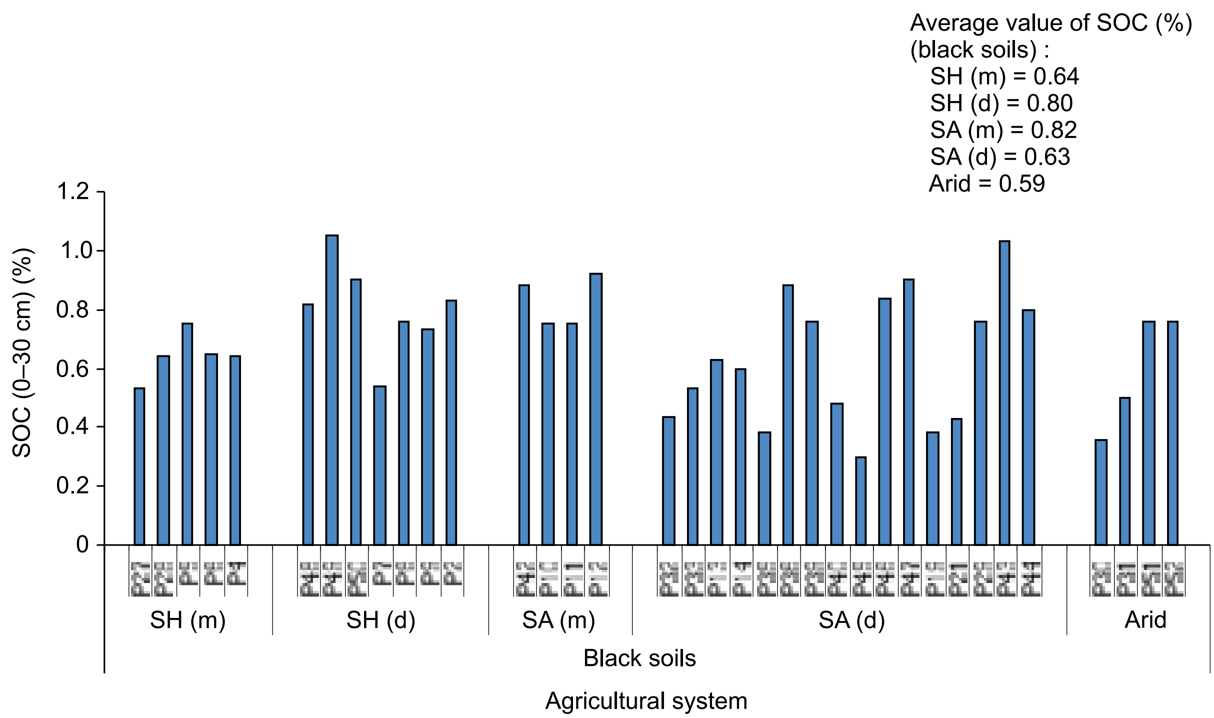


Figure 3.51. SOC in black soils (0–30 cm) under agricultural systems.

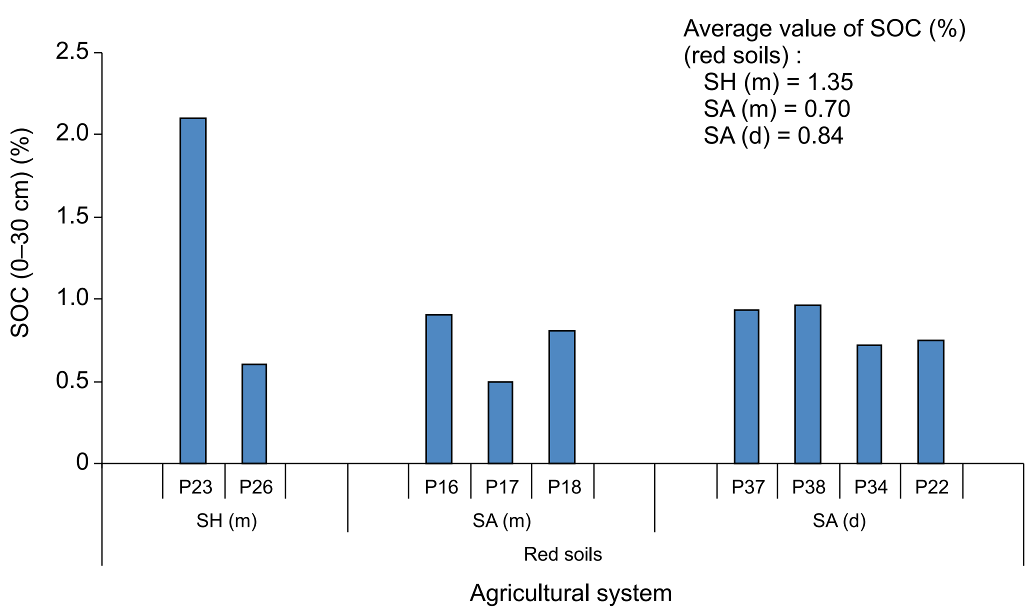


Figure 3.52. SOC in red soils (0–30 cm) under agricultural systems.

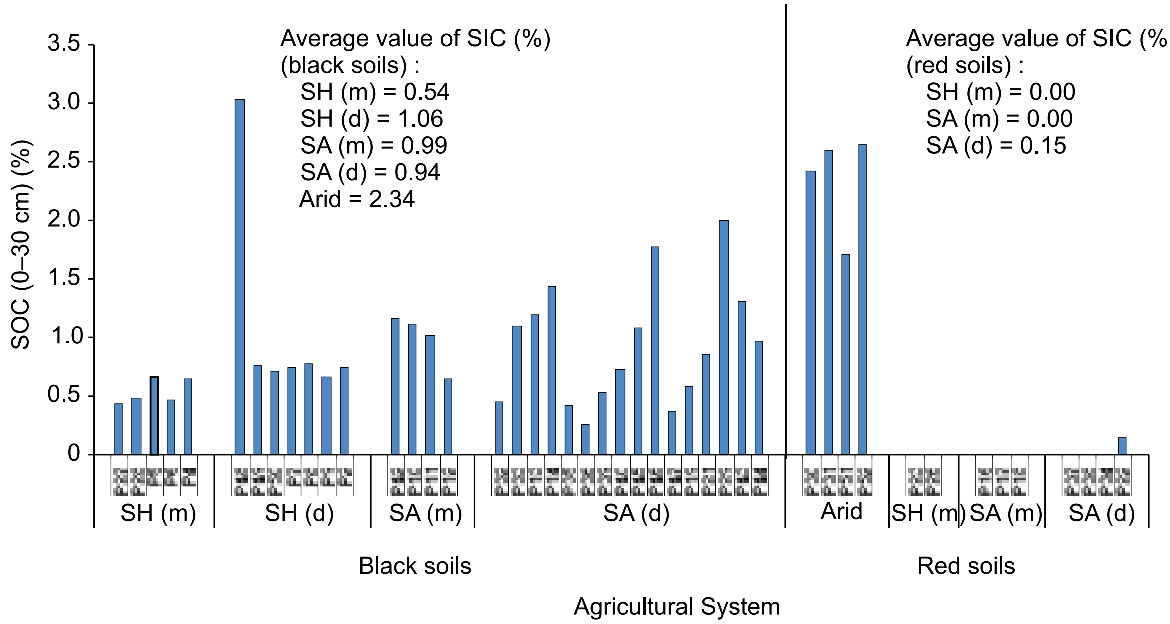


Figure 3.53. SIC in black and red soils (0–30 cm) in agricultural systems.

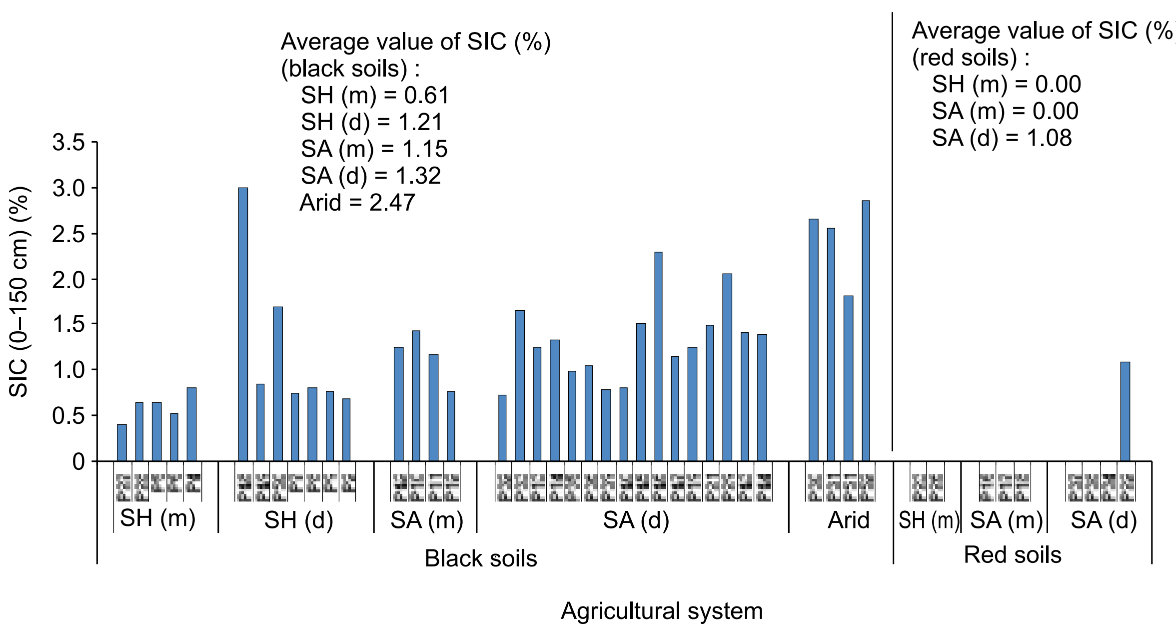


Figure 3.54. SIC in black and red soils (0–150 cm) in agricultural systems.

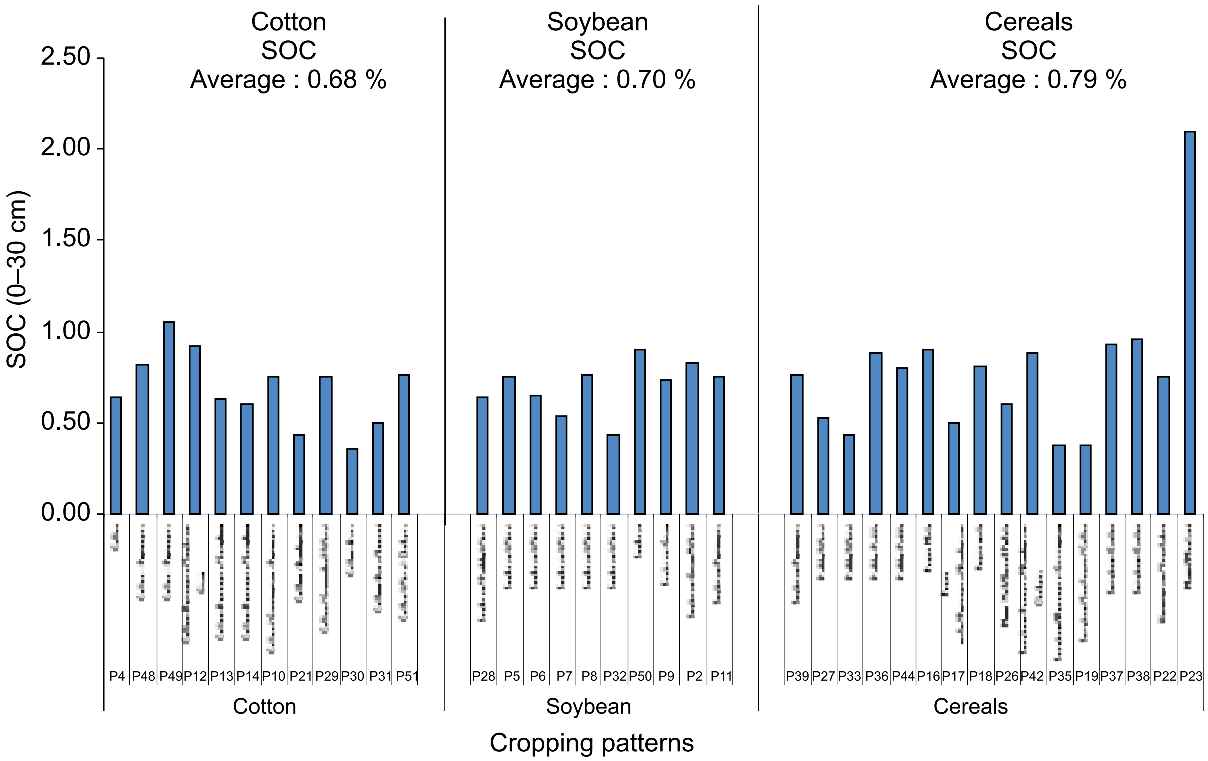


Figure 3.55. SOC (0–30 cm) under three dominant cropping systems.

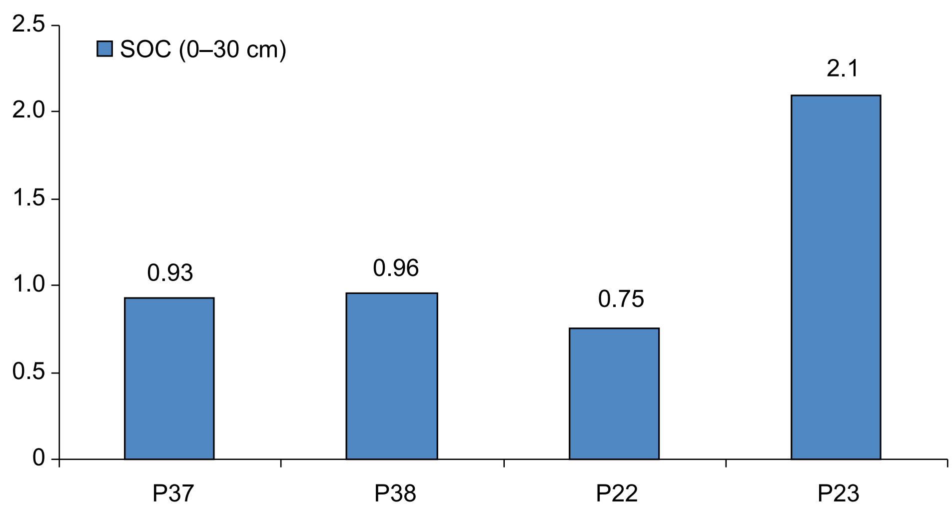


Figure 3.56. SOC under sorghum cropping systems in SAT, India.

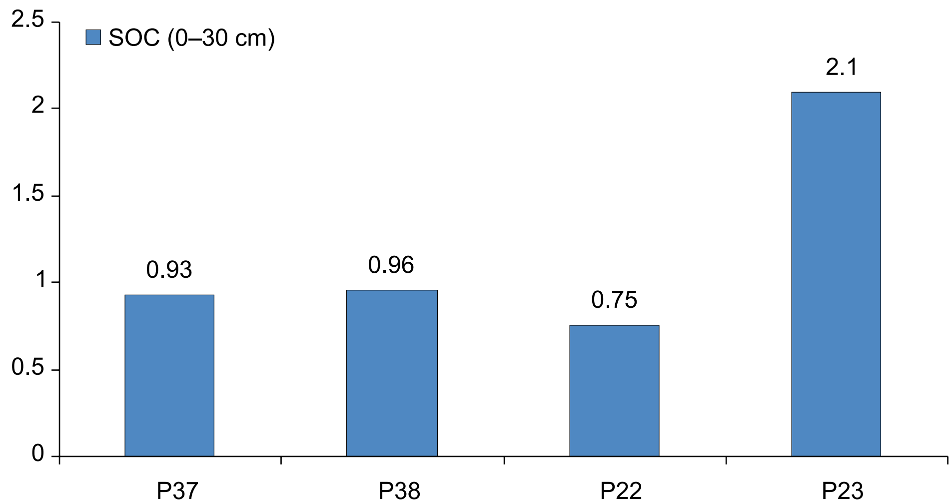


Figure 3.57. SOC in red soils under sorghum and maize systems in SAT, India.

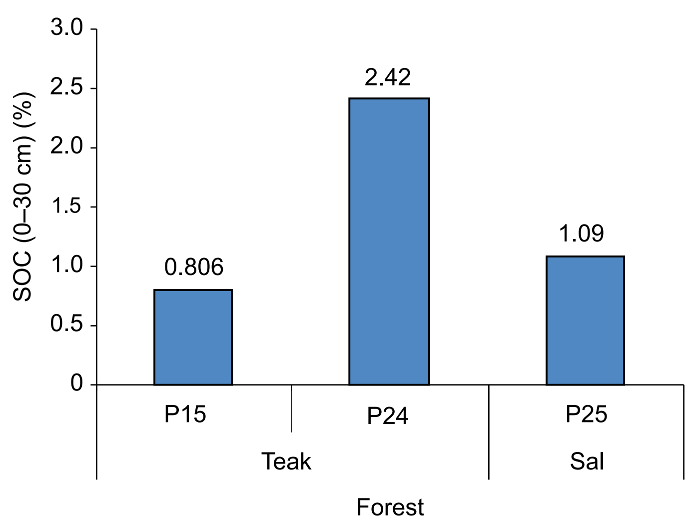


Figure 3.58. Distribution of SOC (0–30 cm) under forest systems.

Figure 3.59. Profile and landscape view of soils in Dindori district, Dadarghugri series, Madhya Pradesh.

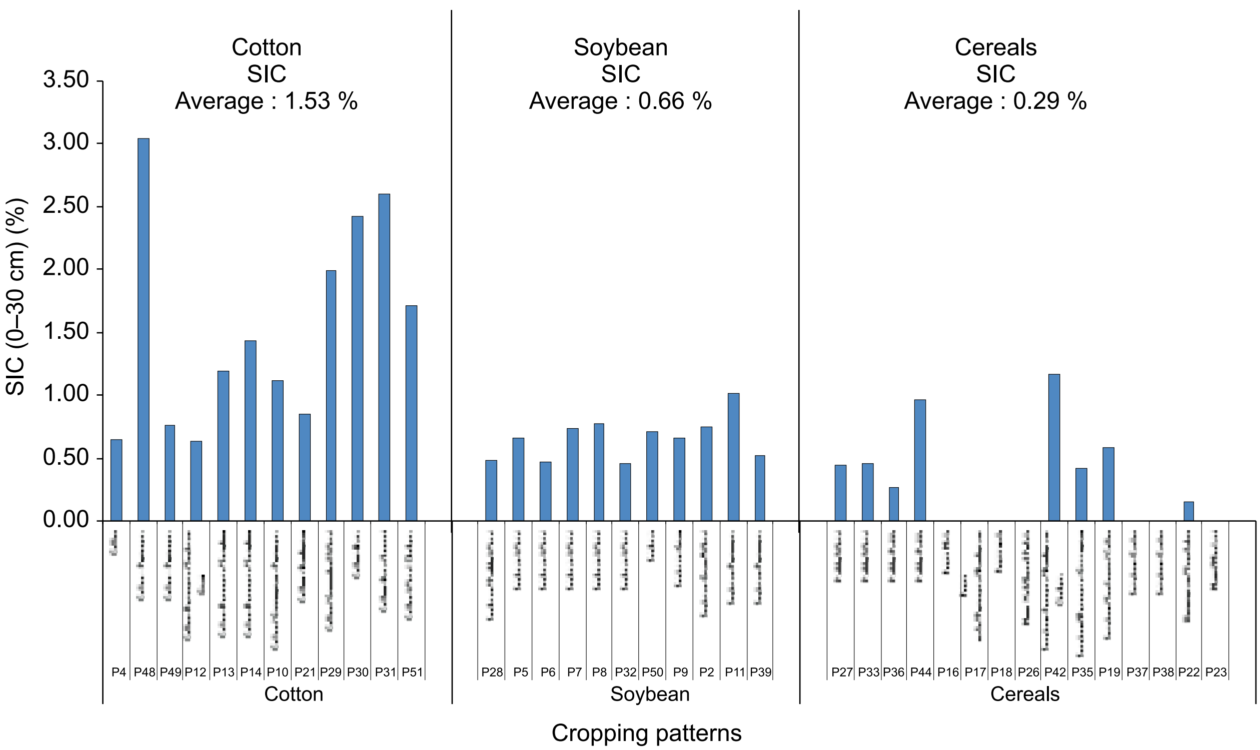


Fig. 3.60. SIC (0–30 cm) in three dominant cropping patterns.

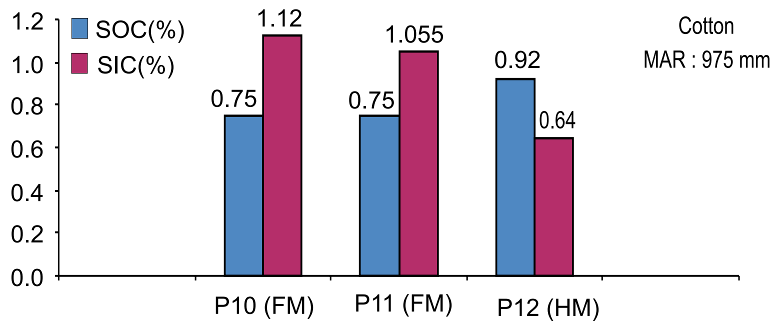


Figure 3.61. Effects of management on SOC and SIC content in Asra series, Amravati, Maharashtra (0–30 cm depth).

3.14.3 Kovilpatti soils (P19 and P21) of Tuticorin, Tamil Nadu

Both P19 and P21 have rainfed production systems involving two-year rotations with cropping during SW monsoon from September–March with long summer fallows (March–August) (Fig 3.63).

P19 represents a typical cotton-sorghum (traditional two-year) rotation using moderate NPK (40:20:20) and no organic supplements. P21 is under alternate row intercropping of cotton+ black gram-maize (sorghum). Liberal doses of organics 10–12 tonnes/ha of FYM manure are added in addition to N: P @ 90:110 kg/ha. Black gram residues are incorporated. High organic inputs with fertilizers increased biomass and organic C content in P21 (Table 3.12 and Fig. 3.63).

Table 3.12. Yield of selected crops at P19 and P21 sites.

	Yield range (kg/ha)	
Crops	P19 (Org)	P21 (HM)
Cotton	75–200 kg/ha	400–500 kg/ha
Mung	-	500 kg/ha
Sorghum	700–1000 kg/ha	2200–2500 kg/ha
Maize	-	3500–4000 kg/ha

3.14.4 Sokhda soils (P30 and P31) Rajkot, Gujarat

Both P30 and P31 represent rainfed production systems. P30 represents a two-year rotation of cotton+ green gram (as green manure) with pearl millet. About 30 cartloads of FYM are added every year at this site. Green manuring and heavy doses of FYM helped to bring down SIC (Fig. 3.64). P31 soil is cropped as a less exhaustive system, involving a two-year rotation of cotton-sesamum (or at times pearl millet) (Table 3.13). FYM application is approximately 5 tons/ha every year, supplemented with adequate applications of N, P and K.

Table 3.13. Yield of selected crops at the site of P30 and P31.

Crops	Yield range (kg/ha)	
	P30	P31
Cotton	12–40 q/ha	12–40 q/ha
Pearl millet	15–20 q/ha	15–20 q/ha
Sesamum	-	5–6 q/ha

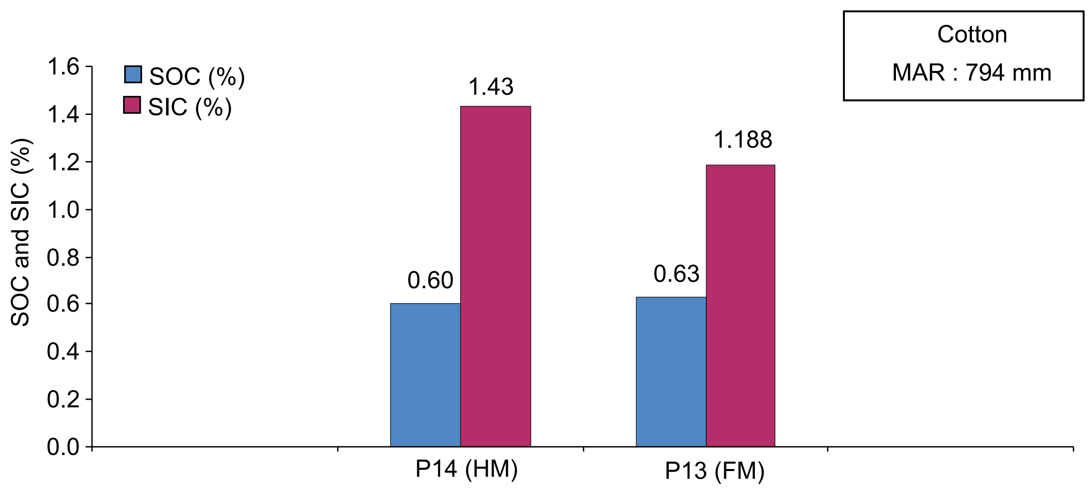


Figure 3.62. Effects of management on SOC and SIC content (0–30 cm depth) in Paral soil series, Akola, Maharashtra.

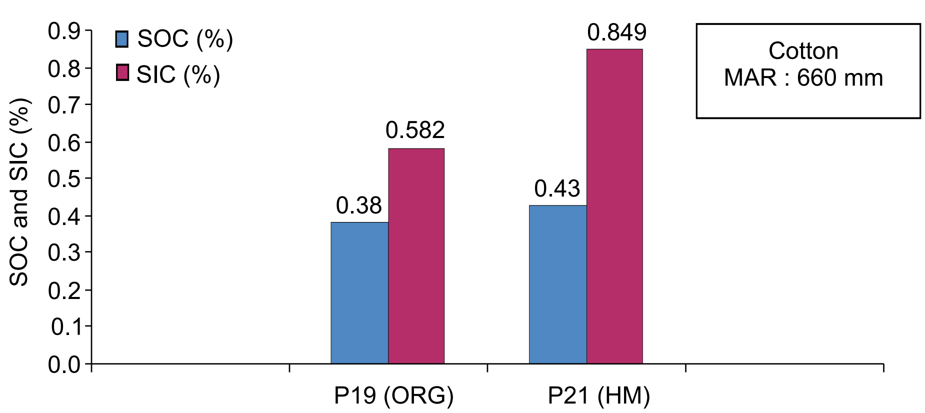


Figure 3.63. Effects of management on SOC and SIC (0–30 cm depth) contents in Kovilpatti soils, Tamil Nadu.

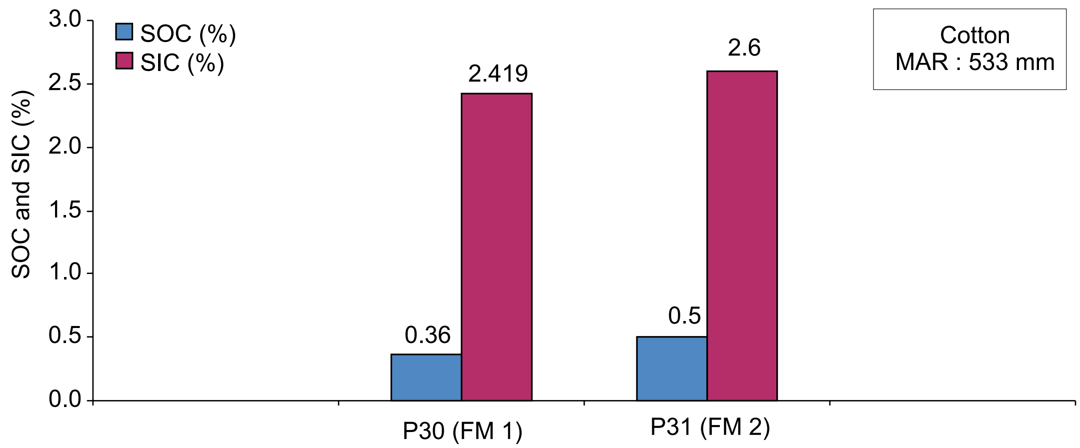


Figure 3.64. Effects of management on SOC and SIC contents in Sokhda soils, (0–30 cm depth) Gujarat.

3.14.5 Nimone soils (P51 and P52) Rahuri, Maharashtra

P51 has a double-cropped cotton-pigeonpea system involving regular rotation with sorghum (fodder) and Sesbania (green manure). Besides recommended doses of fertilizers, FYM is also applied on a regular basis. The cropping system in P52 is more exploitative: sugarcane (*ratoon*)- wheat/sorghum with high doses of N and P fertilizers without addition of FYM. Higher water requirement (2500–3000 mm/ha) of sugarcane compared with cotton-chickpea (1000–1200 mm/ha) would demand more number of irrigations (average 30 per year) in P52. Frequent irrigation with canal/well water and absence of organic inputs raised SIC levels (Fig 3.65).

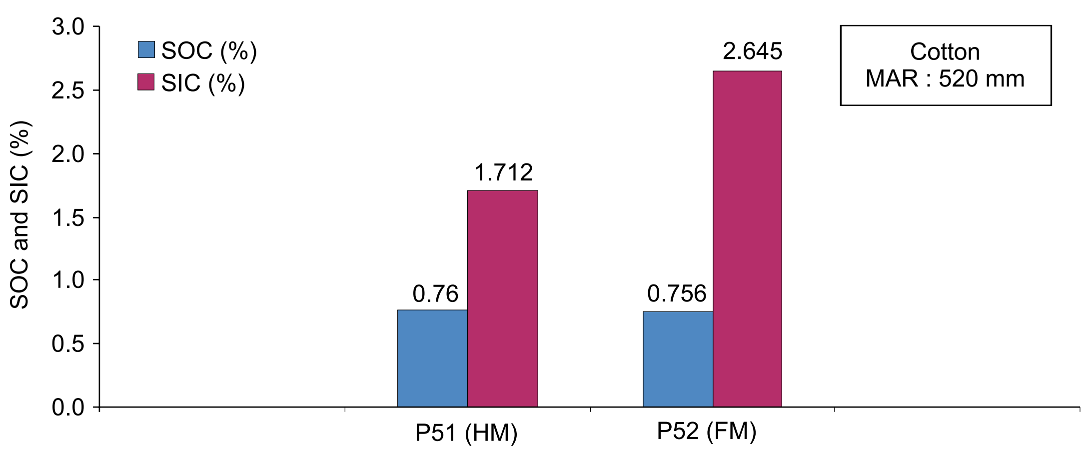


Figure 3.65. Effects of management on SOC and SIC content in Rahuri soils (0–30 cm depth), Ahmednagar, Maharashtra.

Soybean-based systems

Dominant Crop as Soybean (Agricultural System)

3.14.6 Nabibagh soils (P5 and P6), Bhopal, Madhya Pradesh

Under irrigated soybean-wheat cropping system, P5 (HM) comprising annual application of 3–4 t/ha of FYM, increased seed rate and balanced fertilizer application produced more yield of soybean and wheat compared to P6 (FM), besides increasing SOC levels. The presence of bicarbonate salts in well water used for irrigation could be the reason for higher concentration of $CaCO_3$ (SIC) in P5 (Fig. 3.66).

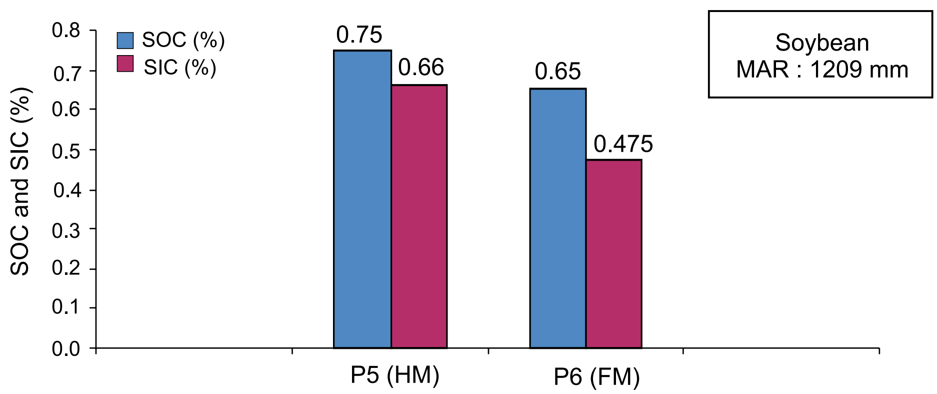


Figure 3.66. Effect of management on SOC and SIC contents in Nabibagh soils (0–30 cm depth), Bhopal, Madhya Pradesh.

3.14.7 Sarol soils (P7, P8, P9) of Indore, Madhya Pradesh

The site under high inputs and well irrigation represents intensive soybean-wheat double-cropping system conditions. Recommended seed rate, balanced fertilizer and chemical methods of weed control ensured higher yields of component crops in P7 (HM) compared to P8 (FM). However, the SOC levels did not show an increase. Deep (mechanical) ploughing might have influenced SOC. Comparatively, the farmers' management (P8) was less intensive with soybean as the main crop, followed by wheat or fallow. This crop-livestock integrated farmers' system, with regular FYM application and non-exploitative yield levels (800–900 kg/ha soybean and 2000–2200 kg/ha wheat) favored SOC build-up. These results show that farmers' management may be also beneficial for increasing the SOC levels. The site for P9 represents an agri-horticultural system involving soybean-chickpea under mango orchard. As in P7, no FYM was being applied but unlike P7, stubbles were regularly incorporated. These practices coupled with a lower soil temperature (shade) favored SOC build-up compared to P7 (Fig 3.67).

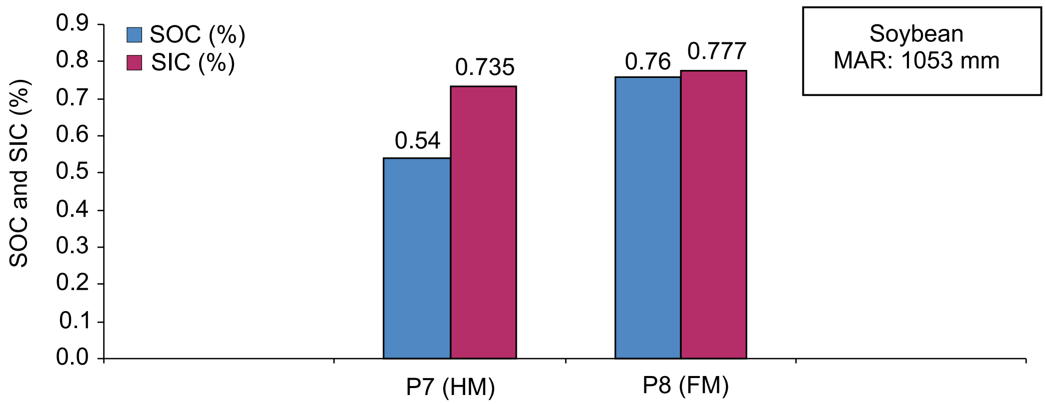


Figure 3.67. Effect of management on SOC and SIC contents in Sarol (0-30 cm depth), Indore, Madhya Pradesh.

3.14.8 Kasireddipalli soils (P39, P40) Medak, Andhra Pradesh

P39 (HM) represents an improved production system comprising (*kharif*) soybean+ pigeonpea (4:1) intercropping. Fertilizer dose of 40 kg P_2O_5/ha is regularly supplemented with *Glyricidia* (green manure). Better conservation of soil moisture is achieved through broad bed (1.05 m) and furrow system (0.50) (BBF) (Table 3.14).

Table 3.14. Yield of selected crops at the sites of P30 and P40.

	Yield range (kg/ha)	
Crops	P39	P40
Soybean	470–2070 kg/ha	--
Pigeonpea	590–1450 kg/ha	--
Chickpea	--	1160–1550 kg/ha
Sorghum	--	820–1740 kg/ha

P40 represents the traditional (*kharif*) fallow-(*rabi*) chickpea and (*kharif*) fallow-(*rabi*) sorghum (two-year rotation) production system. About 10 tons of FYM is added every alternate year, which helped to maintain SOC almost at the same level as in P39 (Fig. 3.68).

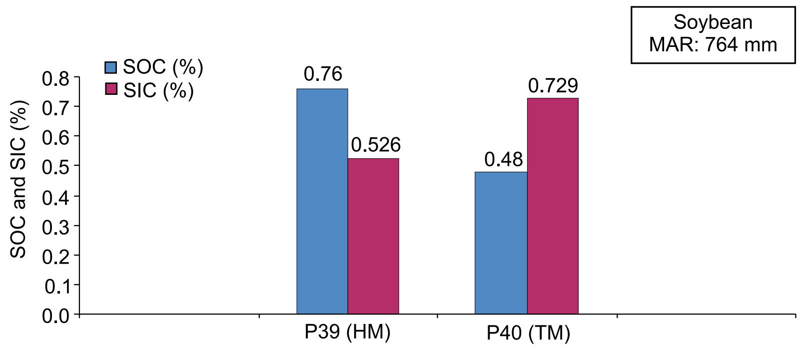


Figure 3.68. Effect of management on SOC and SIC contents in Kasireddipalli (0–30 cm depth), Medak, Andhra Pradesh.

Cereal-based systems

Dominant Crop as Cereals (Agricultural System)

3.14.9 Jhalipura soils (P32 and P33), Rajasthan

Both the profiles represent intensive double-cropping systems under irrigation. P32 is under soybean-wheat with annual addition of 6–8 cartloads of FYM/ha along with annual applications of 150 kg N and 120 kg P_2O_5/ha with no residue management and soil conservation measures (Fig. 3.69).

P33 is under paddy-wheat crop rotation with annual additions of 230–260 kg N and 140 kg P_2O_5/ha, but no FYM (Table 3.15). Wheat and rice stubbles are burnt. The wheat stubbles (after combined harvest) are incorporated before paddy is transplanted. Lower soil temperature could be the reason for higher SOC in P33.

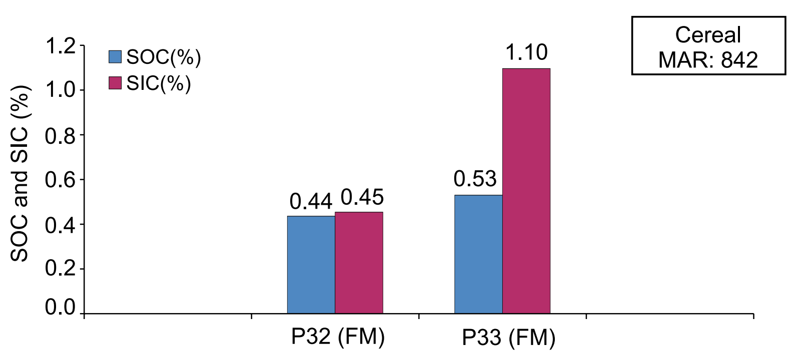


Figure 3.69. Effect of management in SOC and SIC contents in Jhalipura (0–30 cm depth), Rajasthan.

Table 3.15. Yield of selected crops at the site of P32 and P33.

	Yield range (kg/ha)	
Crops	P32	P33
Wheat	3000–4500	4300–5000
Paddy	-	4000–5000
Soybean	1200–1500	--

3.14.10 Hayatnagar soils (P37 and P38), Andhra Pradesh

Both P37 and P38 represent rainfed (*kharif*-based) production systems involving a two- year sorghum-castor rotation. The recommended doses of fertilizers are used in P38 and P37. In case of P37, however, supplemental nutrition through the incorporation of *Glyricidia* toppings resulted in higher yield (Table 3.16 and Fig. 3.70).

Table 3.16. Yield of selected crops at the site of P37 and P38.

	Yield range (kg/ha)	
Crops	P37 (HM)	P38 (LM)
Castor	975–1263	800–1000
Sorghum	1220–1450	--

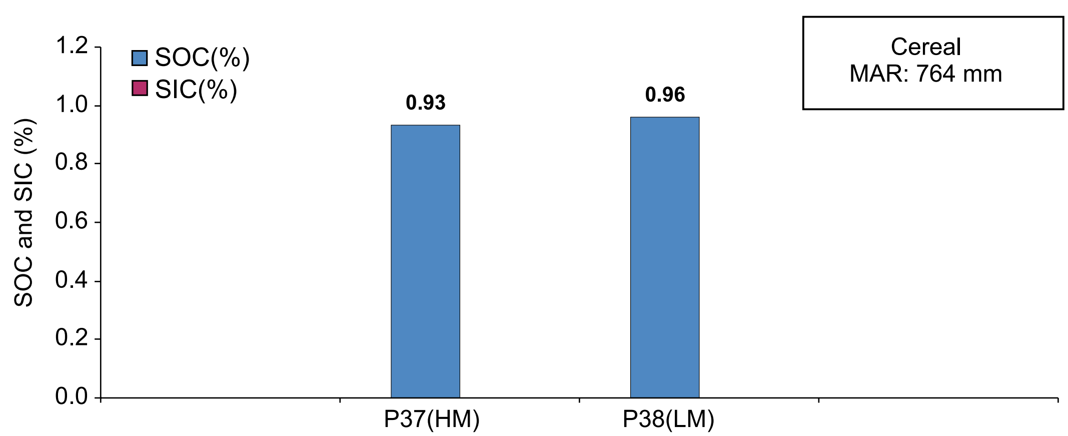


Figure 3.70. Effect of management on SOC and SIC contents in Hayatnagar (0–30 cm depth), Andhra Pradesh.

3.14.11 Teligi soils (P44 and P43) of Siruguppa, Bellary, Karnataka

Both the sites (P44 and P43) are under monocropping of paddy with canal irrigation. P43 represents a low-input sustainable agricultural system, showing a yield of 20–32 q/ha. Conversely, the high-input system P44 indicates higher yield levels ranging from 60 to 70 q/ha. The former system nevertheless favored the build up of SOC (Fig. 3.71).

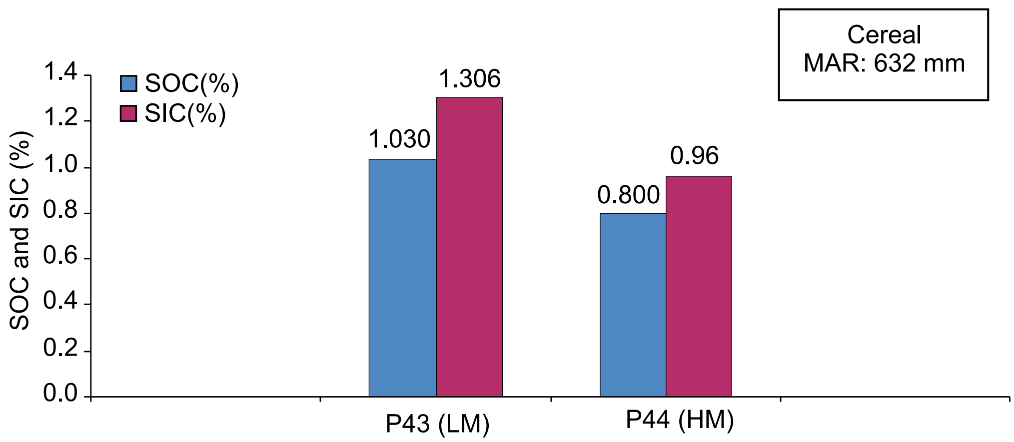


Figure 3.71. Effect of management on SOC and SIC contents in Teligi, Bellary (0–30 cm depth), Karnataka.

Forest Systems

3.14.12 Boripani (Nagpur, Maharashtra) and Dadarghugri (Dindori, Madhya Pradesh) soils (P15 and P24)

No management effect was conspicuous in this system. P15 represents a natural mixed vegetation dominated by teak, whereas P24 represents a systematically planted teak plantation under an afforestation program and hence has a closed canopy which might have resulted in better organic carbon sequestration (Fig. 3.72).

Horticultural System

3.14.13 Linga soils (P1 and P2), Katol, Maharashtra

Improved orchard management (Table 3.17) with higher yields of orange reduced the level of SOC as compared to nearby orchard with low level of management (Fig. 3.73). Besides, grasses among the orange trees in the low-management system might have further contributed to the SOC levels in the low-management (original) site (P3).

Table 3.17. Experiment on Integrated Nutrient Management on Citrus at Katol, Nagpur (Linga soils, P1)*

Treat-ments	Fertilizers ($N : P_2O_5 : K_2O$) (g)	Manures (kg)	Others (kg)	Yield (No. of fruits/tree) 1998	1999		2000		2001		2002	
				M	A	M	A	M	A	M	A	M
T1	1200 : 400 : 400	25	--	Nil	32	421	315	--	522	--	1290	--
T2	900 : 300 : 300	50	--	Nil	30	378	355	--	364	--	1107	--
T3	--	50	--	Nil	36	311	291	--	402	--	1040	--
T4	--	50	10 (neem cake)	Nil	21	323	344	--	430	--	1118	--
T5	--	50	Sowing of sun hemp around the base of tree during summer and rainy season	Nil	20	295	310	--	407	--	1112	--
T6	900 : 300 : 300	50	PSB	Nil	29	383	360	--	325	--	1097	--
T7	--	50	PSB (2.5 kg/ha)	Nil	20	300	301	--	324	--	945	--

M : Mrigbahar; A = Ambebahar
* Year of Planting: 1993; Year of start (fruits): 1998
Design: RBD; Replication: Three; Tree Unit / Treatment: Two; Spacing: 6 x 6 m

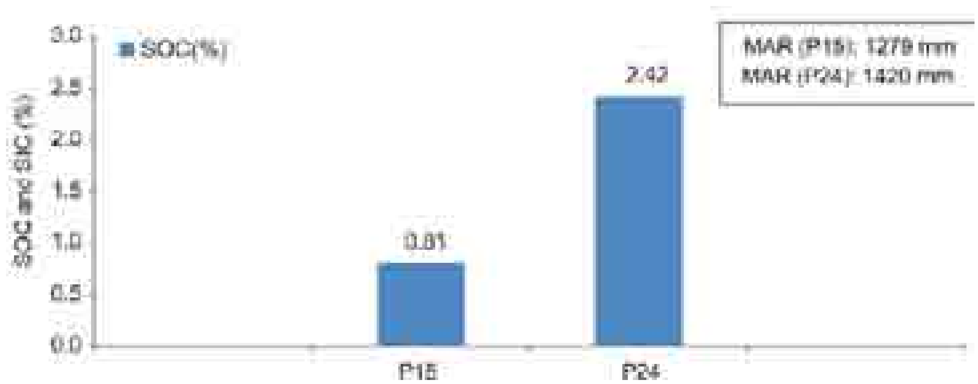


Figure 3.72. Effect of management on SOC content (0–30 cm depth) in Boripani (Maharashtra) and Dadarghugri (Madhya Pradesh).

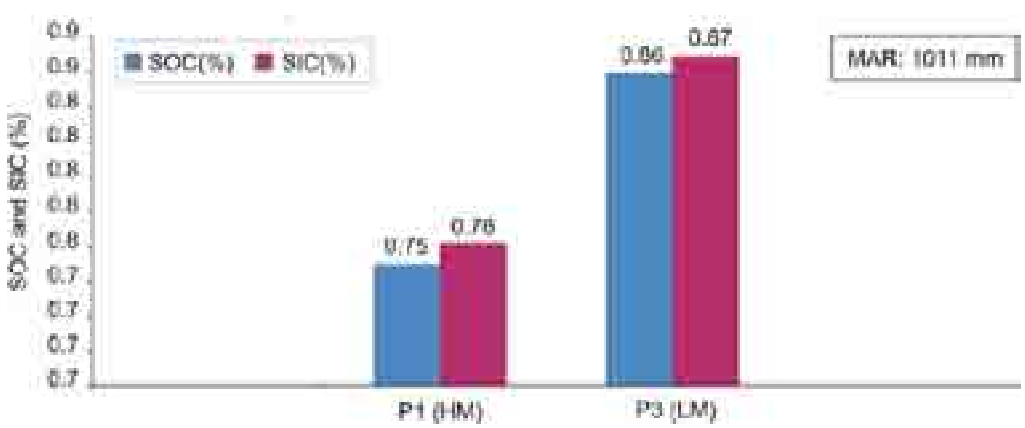


Figure 3.73. Effect of management on SOC and SIC content (0-30 cm depth) in Linga soil, Katol, Maharashtra.

Chapter 4: Summary and Conclusions

4.1 Summary

4.1.1 Physical properties and their influence in sequestration of SOC and SIC

The physical and chemical soil parameters such as sand, silt, clay, bulk density (BD), coefficient of linear extensibility (COLE), hydraulic conductivity (HC), exchangeable sodium percentage (ESP), clay carbonate, soil reaction (pH) were correlated with SOC and SIC in black and red soils. The contents of SOC and SIC were also compared in different land-use systems, bioclimates and dominant-cropping systems, such as those based on cotton, soybean and cereals. Variations in SOC and SIC with management levels were also examined.

The total clay, in general, and fine clay, in particular, was positively correlated with SOC content. There was generally a negative correlation between SOC content and BD in the 0–30 cm soil layer except in soils under semi-arid (dry) climate. The correlation between SIC and BD, on the other hand, showed a positive correlation. There was a negative correlation between coarse fragments and BD in black soils. This observation assumes importance since most of the coarse fragments in black soils contain $CaCO_3$ and this is in sharp contrast to the positive correlation between SIC ($CaCO_3$) and BD values. It appears that $CaCO_3$ present in powdery lime form and as calcium concretion (coarse fragments) have contrasting effects on BD. The physical nature of $CaCO_3$ in soils, therefore, is more important rather than the total amount of SIC.

Fine clay and smectite content in black soils show a positive correlation with COLE values (Shirsath et al. 2000; Bhuse et al. 2001). An attempt was made to find a relation between COLE values and coded numericals of vertic properties such as pressure faces and slickensides. The study showed that except for soils in the sub-humid (moist) and arid bioclimates, a positive correlation was formed between COLE and vertic properties in the Vertisols of SAT India.

A negative correlation of BD and ESP with HC is observed. Similar observations were made when HC and SOC values were correlated. The sub-humid (dry) and semi-arid (dry) bioclimates, however, show an increasing trend of SOC with HC. This relation seems to be more realistic in view of the fact that the higher amount of SOC usually helps in dissolution of native $CaCO_{3,}$ which leads to decrease in soil pH and ESP, and increase in HC of the soils. The HC and SIC indicate a negative correlation in soils under relatively wet bioclimate (MAR from 1100–850 mm). However, in dry bioclimates (semi-arid (dry) and arid with MAR <850 mm), the HC increases with increase in SIC. This was explained earlier. Higher amount of $CaCO_3$ concretions in the drier part of SAT India leads to better drainage in soils. Many such areas have been also found to contain a soil modifier, namely zeolites which have a positive influence on HC (Bhattacharyya et al. 2003).

4.1.2 Chemical properties and their influence in sequestration of SOC and SIC

In all the bioclimates, an increase in ESP decreased SOC content. A diametrically opposite relationship, however, was found between ESP and SIC. An inverse relationship was found between SOC and clay carbonate. This is in line with a generally observed inverse relationship between SOC and SIC of soils, in general, and black soils, in particular (Bhattacharyya et al. 2000). The relationship between SIC and clay carbonates shows a general negative correlation because considerable amount of clay carbonate may simply be a result of physical communition of non-pedogenic $CaCO_3$ in soils, especially in higher MAR (>850 mm).

The correlation between pH and SOC is negative in almost all the Vertisols. Conversely, an increase in pH always indicates more $CaCO_3$ in the soil.

The relationship between SOC content and the active components of soil, namely clay and silt, shows a positive correlation supporting influence of clay and silt as seats of charge to sequester more organic carbon. Interestingly, substrate quantity (clay and silt) does not follow a linear relationship with SIC content because the $CaCO_3$ precipitation is an independent chemical reaction.

4.1.3 Influence of land-use systems on SOC and SIC sequestrations

Five land-use systems were selected for the present study. The highest concentration of organic carbon (1.44%) was under forest system, followed by permanent fallow (1.42%), horticultural system (0.80%), agricultural system (0.70%) and wasteland (0.47%). The sequestration of inorganic carbon, on the other hand, was found to be the highest in horticultural system and agricultural system (0.80%), followed by wasteland (0.70%) and forest system (0.16%).

4.1.4 Influence of different bioclimates on SOC and SIC

It was pointed out that rainfall has an overriding influence over other climatic parameters in sequestering organic carbon in soils. However, a closer look at the average values of SOC of black soils in first 30 cm depth show concentrations of 0.83, 0.80, 0.60, 0.63 and 0.59% for semi-arid (moist), semi-arid (dry), sub-humid (moist), sub-humid (dry) and arid bioclimatic systems, respectively. For the red soils, the average SOC follows the trend sub-humid (moist) (1.35%) > semi-arid (dry) (0.84%) > semi-arid (moist) (0.74%).

The influence of bioclimate, however, is more conspicuous in black soils as indicated by higher SIC under drier climate. The average value of SIC in first 150 cm depth of soils shows the following trends: arid (2.50%) > semi-arid (dry) (1.30%) > sub-humid (dry) (1.20%) semi-arid (moist) (1.10%) > sub-humid (moist) (0.60%). $CaCO_3$ was not detected in red soils, for soils under semi-arid (dry) bioclimatic systems.

4.1.5 Influence of cropping systems on SOC and SIC sequestration

A close look at different cropping systems led us to focus on three major systems, namely cotton, soybean and cereals.

4.1.5.1 Influence of cotton as dominant crop in the sequestration of SOC and SIC

An average value of 0.685% SOC in first 30 cm depth of soil seems a quasi-equilibrium concentration (Saikh et al. 1998a,b, Naitam and Bhattacharyya 2003) of SOC in black soils used for cotton cultivation. In sub-humid (dry) bioclimate, average value of SOC is 0.93%. This is followed by semi-arid (moist) (0.83%), sub-humid (moist) (0.64%), semi-arid (dry) (0.60%) and arid (0.54%) bioclimatic systems. Irrespective of bioclimatic systems, introduction of pigeonpea, with or without other leguminous crops, improved SOC status in soils (Fig 4.1). Monocropping of cotton and cotton–pearl millet rotation appear to have exhausted SOC.

Figure 4.2 shows the distribution of SIC in first 30 cm depth of soil. The average value of SIC in cotton system is 1.53% with the trend in different bioclimatic systems as follows: arid (2.24%) > semi-arid (dry) (1.37%) > semi-arid (moist) (0.88%) > sub-humid (dry) (1.84%) > sub-humid (moist) (0.64%). A closer look at the SIC values in the wetter bioclimatic system shows that pigeonpea in the crop rotation has a positive influence in reducing the level of SIC.

4.1.5.2. Influence of soybean as dominant cropping system on SOC and SIC sequestration

Soybean registers marginally high average quasi-equilibrium value of SOC in black soils. When SOC content values were compared in different bioclimatic systems, the following trend was observed: sub-humid (dry), semi-arid (moist) (0.75%) > sub-humid (moist) (0.68%) > semi-arid (dry) (0.60%).

Unlike under sole cotton system (Fig. 4.1), which stabilizes SOC concentration at 0.64%, monocropping with soybean stabilizes SOC at much higher value of 0.90% (at the site of P50). It is worthwhile to mention that the site of P50 has recently been deforested and is being cultivated for soybean (Fig. 4.3). The data show that soybean-wheat crop rotation stabilizes SOC concentration between 0.54 to 0.76% (Fig. 4.4).

Interestingly, SIC values in first 30 cm depth of soils average 0.66% (Fig. 4.6). The general trend in different bioclimates is as follows: semi-arid (moist) (1.02%) > sub-humid (dry) (0.73%) > sub-humid (moist) (0.54%) > semi-arid (dry) (0.49%).

4.1.5.3 Influence of cereals cropping systems on SOC and SIC sequestrating

On an average, cereals dominated by paddy, wheat and sorghum stabilize SOC at 0.789% in the first 30 cm depth of soil. Cereals represent three bioclimatic systems, namely, semi-arid (moist), sub-humid (moist) and semi-arid (dry). The SOC values in these three bioclimatic systems are 0.88, 0.53 and 0.52%, respectively.

On the basis of dominant crop among cereals, following observations are made:

a) Paddy-wheat cropping system: Normally this system is followed in sub-humid (moist) and semi-arid (dry) bioclimatic systems. The SOC values stabilize at 0.44–.53%.

b) Sorghum-pigeonpea system: This system under semi-arid (moist) bioclimate registers a value of 0.88% SOC. Similarly, sorghum-pigeonpea system in semi-arid (dry) bioclimate registers a much lower value of SOC (0.30%) at the site of P35 (Jajapur). This may be due to low management levels. The land-use data collected from the field (Bhatumbra series, Bidar, Karnataka) shows that these areas are under intensive agriculture and canal irrigated, which might have resulted in higher SOC.

c) Paddy-Paddy: Paddy-paddy system stabilizes SOC values at 0.80 to 0.88% (Fig 4.5) Among cereals, paddy-paddy system seems to be more beneficial for higher amount of SOC sequestration. In general, the level of SIC in cereals is less (0.29%) than in cotton (1.53%) and soybean (0.66%) systems (Fig 4.6). Unlike SOC, the distribution of SIC does not follow any definite trend either in terms of bioclimatic systems or in different cropping systems.

4.1.6 Influence of management on SOC and SIC sequestration

4.1.6.1 Influence of type of management on sequestration of SOC and SIC with cotton as dominant cropping system

In contrast to the generally held view that black cotton soils are low in SOC, our study indicates that black cotton soils in semi-arid bioclimatic system stabilize in terms of SOC between 0.60 and 0.92%.

Expectedly, Sokhda soils representing arid bioclimate registered low SOC values (0.36 to 0.50%) under both the farmers' management systems. Interestingly, Nimone soils, although occurring in arid bioclimatic system, stabilizes at a higher level of SOC (0.76%). This shows that in spite of low rainfall and high ESP, Nimone soils respond to high level of management. Judging by the similarity in soil substrate, it seems probable that even in arid climate, the soils with high ESP and CaCO3 can respond to better management practices, indicating that these soils are resilient (Bhattacharyya et al. 2003).

4.1.6.2 Influence of management on sequestration of SOC and SIC with soybean as dominant cropping system

Soybean system, in general, maintains a higher level of SOC, which ranges from 0.50 to 0.76%. The higher (than cotton) SOC values in Nabibagh soils are partly due to application of FYM as well as relatively high rainfall (MAR 1209 mm). When soybean is grown under semi-arid bioclimate represented by Kasireddipalli soils, it is found that the soybean system stabilizes SOC at high concentration under high level of management involving pigeonpea in the crop rotation, high dose of phosphorous, green manuring and BBF system (P39). In general, higher level of management maintains the SIC content in the range 0.60 to 0.70%.

4.1.6.3 Influence of management on SOC and SIC sequestration with cereals as dominant cropping system

Among cereals, paddy system maintains higher SOC even in semi-arid bioclimatic system. When crop rotation under same soil is compared, paddy-wheat system shows higher SOC than soybean-wheat crop rotation. Interestingly, red soils under sorghum-castor crop rotation register higher SOC level (0.93 to 0.96%).

4.1.7 SOC in forest system

SOC level under forest system is usually considered as control value. For the present study, the control has been selected in black soils under teak forest; SOC content varies from 0.81 to 2.42%. This large variation is mainly due to differences in management (P51, Boripani) as well and soil profile depth (Naitam and Bhattacharyya 2003). It is suggested that 2.42% SOC may be considered as control level of organic carbon equilibrated over centuries at the site of P24 in Dindori, Madhya Pradesh.

4.1.8 SOC and SIC in horticultural system

Black soils under horticultural system maintain a moderate level of SOC, ranging from 0.78 to 0.86% in the first 30 cm soil layer. Interestingly, soils at low-management site maintain higher SOC (0.87%) level than at site under high management (0.76%).

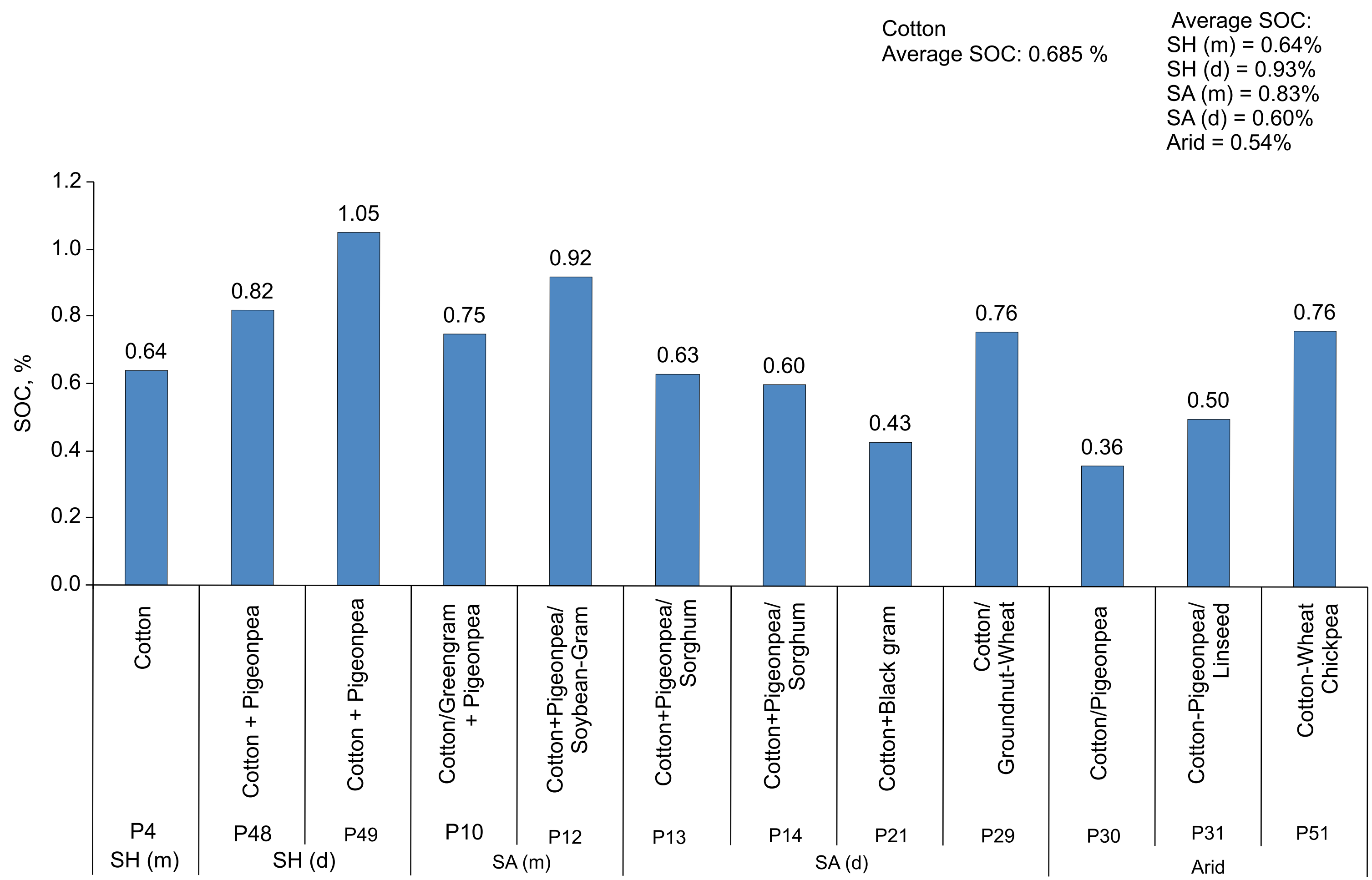


Figure 4.1. Distribution of SOC in black soils (0–30 cm depth) with cotton as dominant crop.

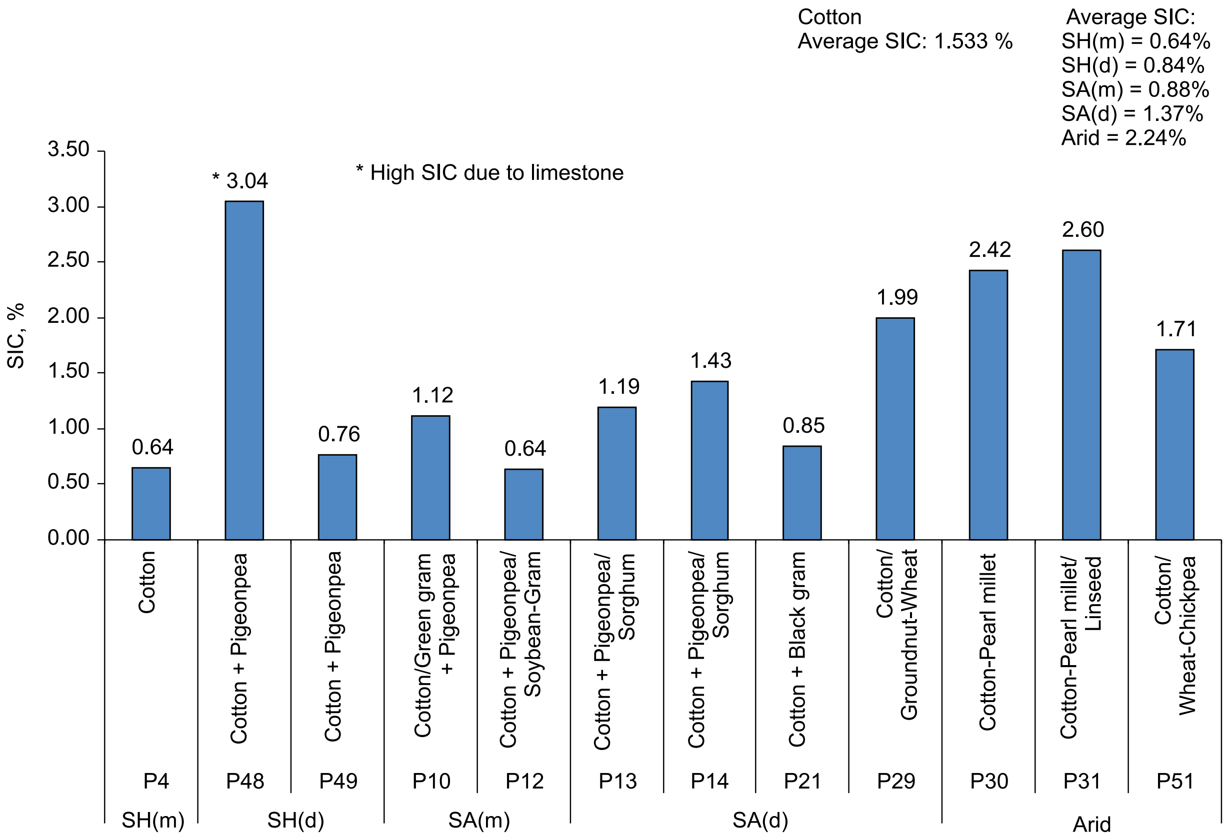


Figure 4.2. Distribution of SIC in black soils (0–30 cm depth) with cotton as dominant crop.

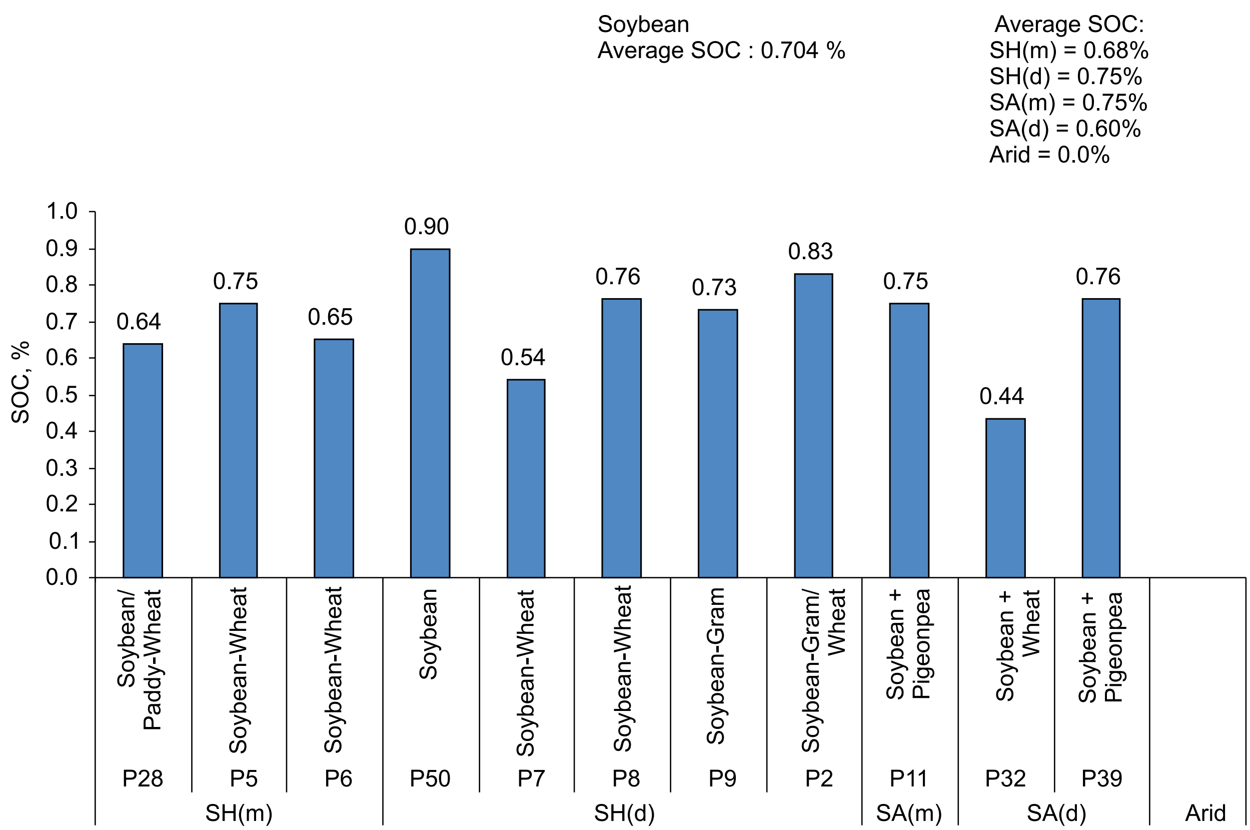


Figure 4.3. Distribution of SOC in black soils (0–30 cm depth) with soybean as dominant crop.

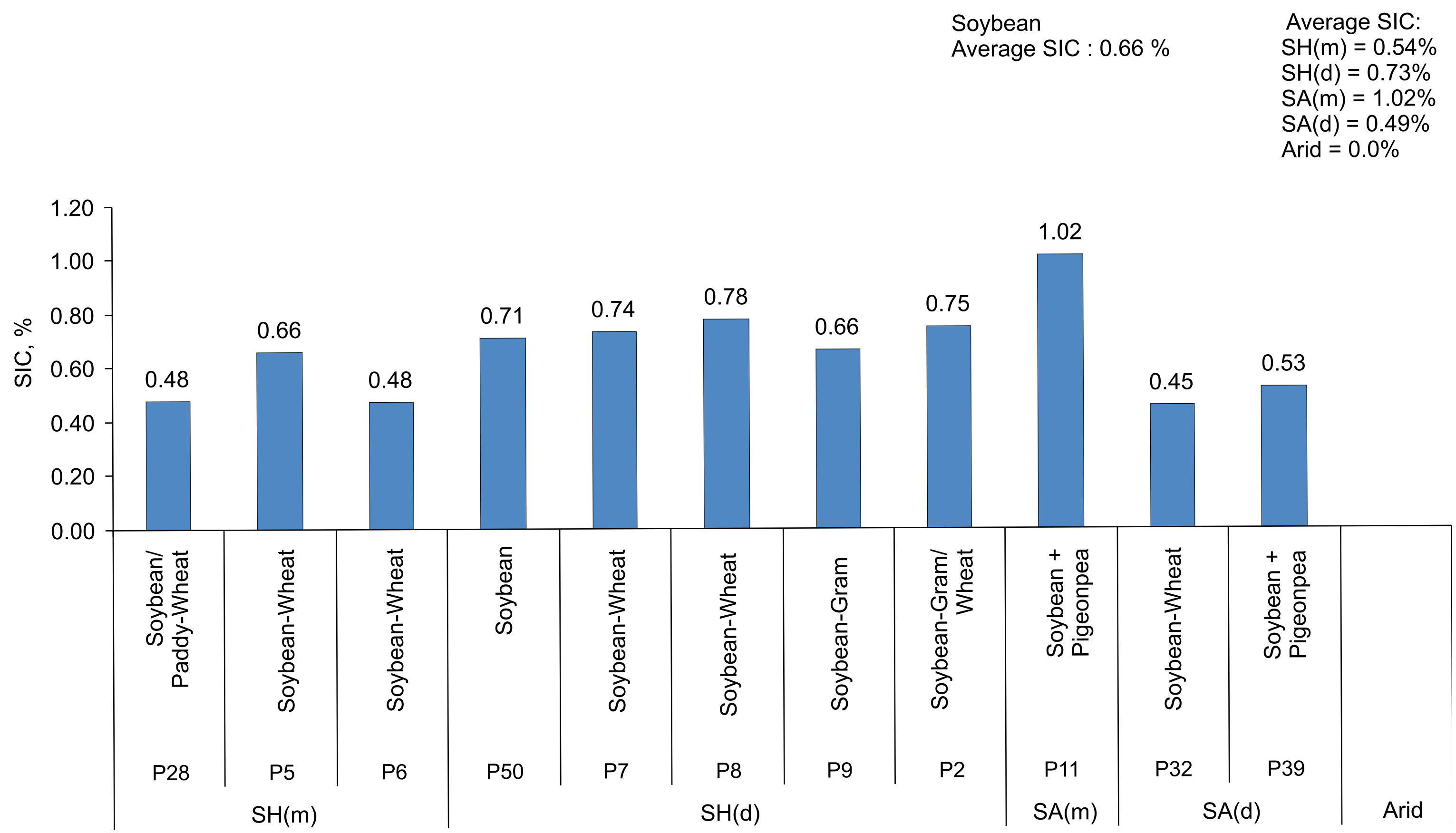


Figure 4.4. Distribution of SIC (0–30 cm depth) in black soils with soybean as dominant crop.

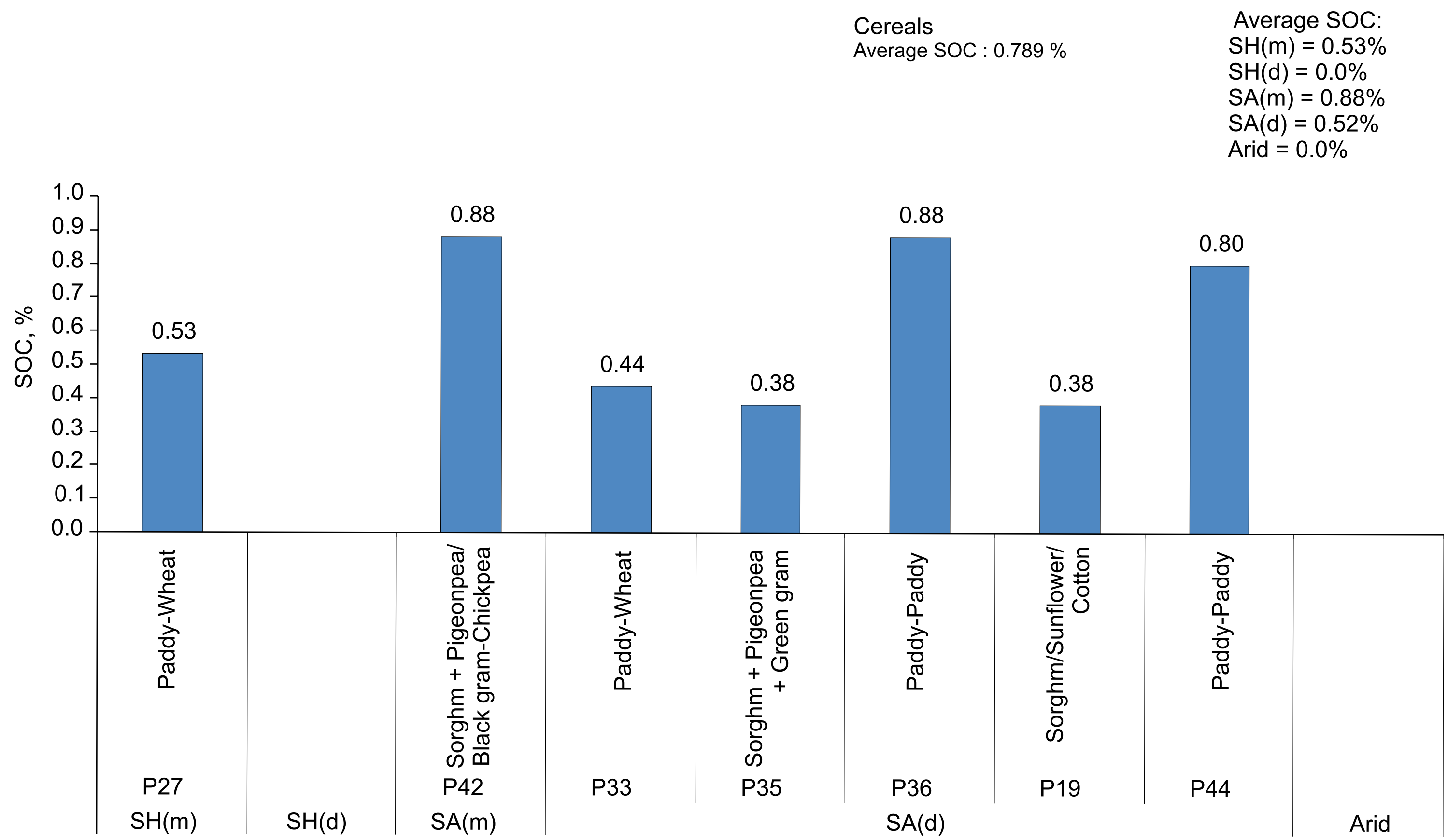


Figure 4.5. Distribution of SOC in black soils (0–30 cm depth) with cereals as dominant crops.

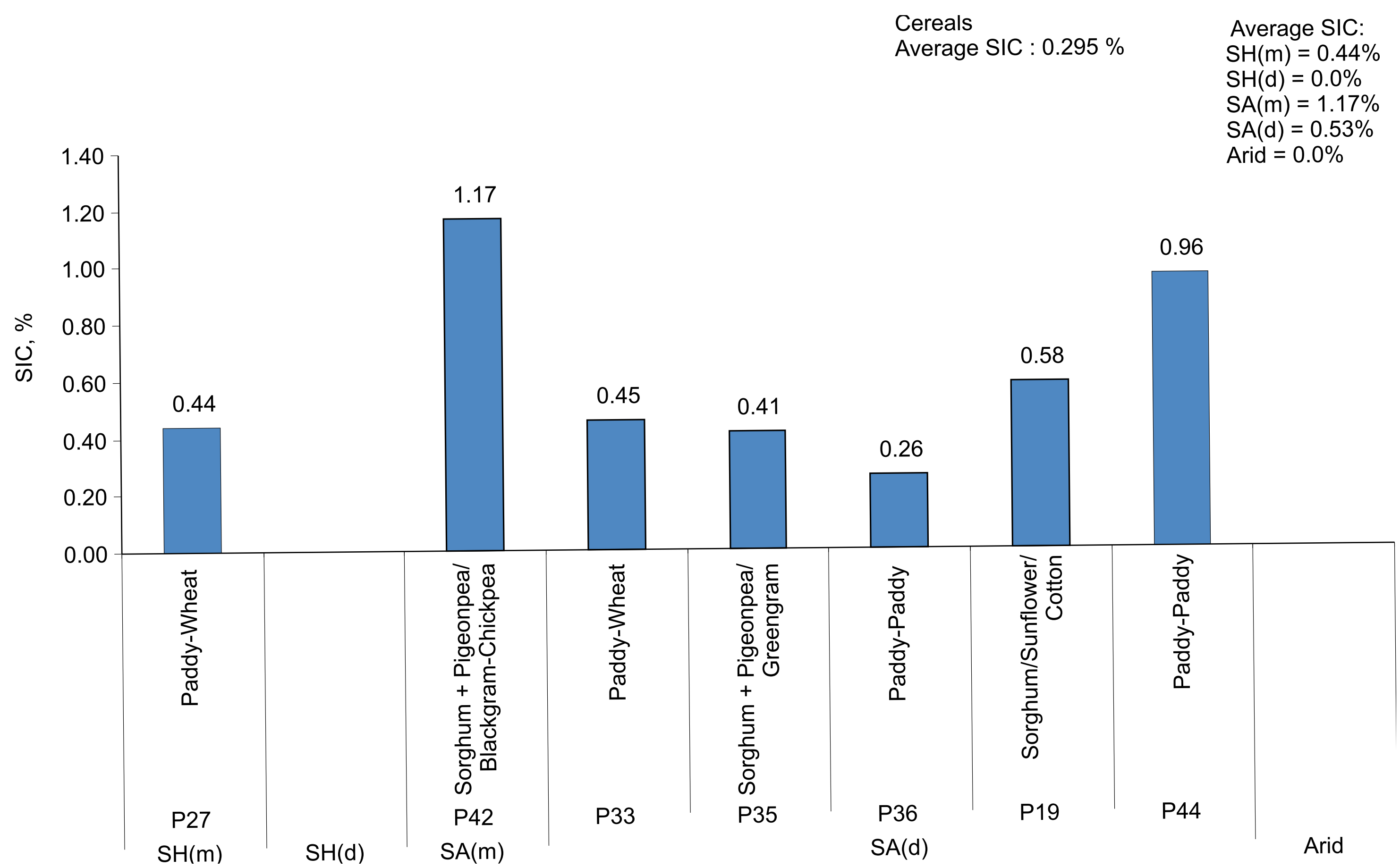


Figure 4.6. Distribution of SIC in black soils (0–30 cm depth) with cereals as dominant crops.

4.2 Conclusions

Results in Tables 4.1 to 4.5 can be used for the identification of systems for organic carbon sequestration. The systems identified for C sequestration are briefly described.

Agricultural systems with cotton/sugarcane as dominant crop

1. Asra soils (P12) with a two-year rotation of cotton+ pigeonpea-sorghum-chickpea and green manuring (sun hemp/*Sesbania*) contained 0.92% SOC in the surface layer.

2. Paral soils (P13) with cotton+ pigeonpea and sorghum as third intercrop had 0.63% SOC. Nimone soils (P51) with cotton+ pigeonpea, sorghum fodder and *Sesbania* (green manure) as regular rotation with FYM and normal fertilizer applications contained 0.76% SOC in the surface layer. Nimone soils (P52) with sugarcane-wheat/sorghum, N: P high dose, FYM – nil, irrigation 30 per year, water requirement 2500–3000 mm/ha had 0.76% SOC in the surface layer.

Agricultural systems with soybean as dominant crop

1 Nabibagh soils (P5) with soybean-wheat cropping system, high seed rate, balanced fertilizer, 3–4 tonnes/ha (annual) FYM contained 0.75% SOC in the surface soil layer.

2 Sarol soils (P8) with soybean-wheat fallow cropping system, regular dose of FYM, 800–900 kg/ha yield (soybean) and 2000–2200 kg/ha (wheat) had a concentration of 0.76% SOC.

3 Kasireddipalli soils (P39) with soybean+ pigeonpea (4:1), 40 kgP_2O_5/ha, *Glyricidia* as green manure, BBF (1.05/0.5m) technique, 270–470 kg/ha soybean yield, 590–1450 kg/ha pigeonpea had 0.76% SOC.

Agricultural systems with cereal as dominant crops

1. Hayatnagar red soils (P37) with sorghum-castor (two-year rotation), recommended dose of fertilizer, sorghum/*Glyricidia* stubbles as manure, 975–1263 kg/ha castor yield, 1220–1450 kg/ha sorghum yield has 0.93% SOC in the surface layer.

2. Hayatnagar red soils (P38) with sorghum-castor (two-year rotation), recommended dose of fertilizer, 800–1000 kg/ha castor yield sequesters 0.96% SOC.

3. Teligi soils (P43) with paddy (monocrop), canal irrigation, has a SOC content of 1.03% in the surface.

4. Teligi soils (P44) with paddy (monocrop), high level of input and paddy yield has a concentration of 0.80% SOC. Dadarghugri soils (P24) with afforested plantation, teak as single-tree species and close canopy sequesters 2.42% SOC.

Horticultural system: Citrus

1. In Linga soils (P1) with horticultural system (citrus) under high level of management, SOC concentration is 0.75%.

2. In Linga soils (P3) with horticultural system (citrus) under low level of management, SOC concentration is 0.86%.

Table 4.1. Identifying systems for carbon sequestration

Agricultural system:Cotton/Sugarcane

Sl.No.	Soil series	Rainfall (mm)	Pedon No.	Management level	Yield (kg/ha)				Carbon sequestration SOC %	SIC %
1.	**Asra**	975	P10	• Occasional double cropping	--				0.75	1.12
			P11	• Legumes always part of rotation	--				0.75	1.05
			P12	• **2-year rotation of Cotton+ pigeonea-sorghum-chickpea** • **Green manuring (sun hemp/*Sesbania*)**	--				**0.92**	**0.64**
2.	**Paral**	794	**P13**	• **Cotton+ pigeonpea** • **Sorghum as third intercrop**	--				**0.63**	**1.19**
			P14	• Cotton+ pigeonpea • Green gram as third intercrop FYM, fertilizers, seed rate higher	--				0.60	1.43
3	Kovilpatti	660	P19	• 2-year rotation of cotton-sorghum • N: P: K = 40:20:20 • No FYM	Cotton 75–200	Sorghum 700–1000	Moong --	Maize --	0.38	0.58
			P21	• Alternate row intercropping of cotton+ black gram/maize/sorghum • Manures: FYM @ 10-12 t/ha + sheep manure @ 10–12 t/ha • N: P = 90:110 • Black gram residues incorporated	400–500	2200–2500	500	3500–4000	0.43	0.85
4	Sokhda	533	P30	• Cotton+ green gram–pearl millet • FYM: 30 cartloads/ha • Green gram as manure	Cotton 1200–4000	Pearl millet 1500–2000	Seasamum --		0.36	2.42
			P31	• 2-year rotation of cotton-sesamum • 5 t/ha every five years • N: P: K: adequate	1200–4000	1500–2000	500–600		0.50	2.60
5.	**Nimone**	520	**P51**	• **Cotton+ pigeonpea** • **Sorghum fodder and *Sesbania* green manure as regular rotation** • **FYM and fertilizer: normal dose** • **Water requirement – 1000-1200 mm/ha**	--				**0.76**	1.71
			P52	• **Sugarcane-wheat/sorghum** • **N: P: high dose** • **FYM: nil** • **Irrigation: 30 per year** • **Water requirement: 2500–3000mm/ha**	--				**0.76**	2.64

Highlighted management levels indicate better systems for organic carbon sequestration

Table 4.2. Identifying systems for carbon sequestration

Agricultural system: Soybean

Sl.No.	Soil series	Rainfall (mm)	Pedon no.	Management level	Yield (kg/ha)				Carbon sequestration	
									SOC %	SIC %
1.	Nabibagh	1209	P5	• **Soybean-wheat** • **Seed rate: high** • **Fertilizer: balanced** • **FYM: (3–4 t/ha (annual)**	--				**0.75**	0.65
			P6	• Soybean-wheat • Seed rate: low • Fertilizer: low	--				0.65	0.50
2	**Sarol**	1053	P7	• Soybean-wheat • Seed rate: recommended • Fertilizers: balanced • Weed control: chemical • Mechanized cultivation	--				0.54	0.74
			P8	• **Soybean-wheat/fallow** • **FYM: regular**	**Soybean** **800–900**	**Wheat** **2000–2200**			**0.76**	0.78
			P9	• Soybean-chickpea (maize orchard) • FYM: nil (stubbles incorporated)	--				--	--
3	**Kasireddypalli**	764	P39	• **Soybean+ pigeonpea (4:1)** • **Fertilizers: 40 kg P_2O_5/ha** • **Manure: *Glyricidia* as green manure** • **BBF (1.05/0.5m)**	**Soybean** **470–270**	**Pigeonpea** **590–1450**	chickpea --	Sorghum --	**0.76**	**0.53**
			P40	• Kharif fallow-Rabi chickpea/ Kharif fallow–Rabi sugarcane (2-year rotation) • Manure 10 t/ha alternate year	--	--	1160–1550	820–1740	0.48	0.73

Highlighted management levels indicate better systems for organic carbon sequestration.

Table 4.3. Identifying systems for carbon sequestration

Agricultural system: Cereals

Sl.no.	Soil series	Rainfall (mm)	Pedon No.	Management level	Yield (kg/ha)			Carbon sequestration SOC %	SIC %
1.	Jhalipura	842	P32	• Soybean-wheat • FYM: 6–8 cartloads/ha/year • Fertilizer: N: 150kg/ P_2O_5 120 kg • Residue management: nil	Wheat	Paddy	Soybean	0.44	0.45
					3000–4500	--	1200–1500		
			P33	• Paddy-wheat • FYM: nil • Fertilizers: N: 230–260 kg P_2O_5 : 140 kg • Others - Burning wheat/paddy stubbles	4300–5000	4000–5000	--	0.53	1.09
2	Hayatnagar	764	**P37**	**• Sorghum-castor (2-year rotation) • Fertilizers: Recommended dose • Manure: Sorghum/*Glyricidia* stubbles**	Castor	Sorghum		**0.93**	--
					975–1263	**1220–1450**			
			P38	**• Sorghum-castor (2 year rotation) • Fertilizer – Recommended dose**	**800–1000**	--		**0.96**	--
3	Teligi	632	**P43**	**• Monocrop (paddy) • Canal irrigation**	**Paddy**			**1.03**	1.31
					2000–3200				
			P44	**• Monocrop (paddy) • Input: High**	**6000–7000**			**0.80**	0.96

Highlighted management levels indicate better systems for organic carbon sequestration

Table 4.4. Identifying systems for carbon sequestration						
						Forest system: Teak
					Carbon sequestration	
Sl.no.	Soil series	Rainfall (mm)	Pedon No.	Management level	SOC %	SIC %
1	Boripani	1279	P15	• Natural Mixed vegetation • Dominant species: Teak • Poorly maintained forest	0.81	--
2	Dadarghugri	1420	P24	• **Afforested plantation** • **Teak as single plantation** • **Canopy close**	**2.42**	--

Table 4.5. Identifying systems for carbon sequestration						
						Horticultural system: Citrus
					Carbon sequestration	
Sl.No.	Soil series	Rainfall (mm)	Pedon No.	Management level	SOC %	SIC %
1	Linga	1011	P1	• **Level: High**	**0.75**	0.76
			P3	• **Level: low**	**0.86**	0.87

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Appendix-1

PHYSICAL PROPERTIES
OF
SELECTED SOILS
IN
28 BENCHMARK SPOTS

BLACK SOILS

(Sub-humid moist)

(MAR: > 1100 mm)

- **Benchmark Spots: 2, 3, 7, 13**
- **No. of Pedons: 6 (P4, P5, P6, P15, P27, P28)**

Series: PANJRI BM Spot: 2 (Black soil)

Profile No: P4 *System: Agriculture (Cotton)* (HM)

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1127 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: Panjri, CICR farm, Nagpur, Maharashtra		Sampling Date: 30.11.2000

Physical properties of Profile No. 4 (Panjri, CICR Farm, Nagpur)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3070	Ap	0–13	0.6	44.0	55.4	42.0	75.8
3071	Bw1	13–38	0.4	42.1	57.5	49.5	86.0
3072	Bss1	38–60	0.3	31.7	68.0	53.0	77.8
3073	Bss2	60–89	0.3	32.5	67.2	54.3	80.8
3074	Bss3	89–131	0.3	43.7	56.0	49.2	87.8
3075	Bss4	131–150	0.2	31.2	68.6	54.0	78.7

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–13	1.6	0.3	0.7	9.7
13–38	1.6	0.3	1.0	14.3
38–60	1.4	0.3	1.8	11.4
60–89	1.5	0.3	1.1	12.6
89–131	1.4	0.3	1.1	9.9
131–150	1.5	0.3	1.4	13.4

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: NABIBAGH BM Spot: 3 (Black soil)

Profile No: P5 *System: Agriculture (Soybean-Wheat)* (HM)

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1209 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location : Nabibagh, Bhopal, Madhya Pradesh		Sampling Date: 5.12.2000

Physical properties of Profile No. 5 (Nabibagh, Bhopal)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3084	Ap	0–15	1.6	47.7	50.7	23.1	45.5
3085	Bw1	15–42	1.5	43.5	55.0	32.4	58.9
3086	Bw2	42–69	1.4	43.2	55.4	36.8	66.4
3087	Bss1	69–107	1.1	45.7	53.2	38.7	72.7
3088	Bss2	107–135	1.1	43.8	55.1	35.2	63.9
3089	Bss3	135–150	2.3	40.6	57.1	39.5	69.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–15	1.3	0.2	0.5	10.1
15–42	1.3	0.2	2.0	12.6
42–69	1.3	0.2	1.7	11.1
69–107	1.4	0.2	0.8	12.0
107–135	1.4	0.2	0.8	9.5
135–150	1.4	0.2	0.8	7.7

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: NABIBAGH **BM Spot: 3 (Black soil)**

Profile No: P6 ***System: Agriculture (Soybean-Wheat*) (FM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1209 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location : Islamnagar, Bhopal, Madhya Pradesh		Sampling Date: 5.12.2000

Physical properties of Profile No. 6 (Nabibagh, Bhopal)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3090	Ap	0–23	2.1	49.0	48.9	31.3	64.0
3091	Bw1	23–42	1.8	46.9	51.4	34.4	67.0
3092	Bss1	42–81	1.8	42.5	55.7	38.2	68.6
3093	Bss2	81–122	1.8	45.2	53.0	35.5	67.0
3094	Bss3	122–150	1.6	42.5	55.9	38.2	68.3

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–23	1.3	0.2	1.5	8.3
23–42	1.3	0.2	2.9	9.5
42–81	1.5	0.2	2.1	12.1
81–122	1.5	0.2	1.7	11.6
122–150	1.4	0.2	1.1	11.4

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: BORIPANI **BM Spot: 7 (Black soil)**

Profile No: P15 ***System: Forest (Teak)***

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1279 mm	Classification: Very fine, smectitic, hyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: Boripani-Sirajpur, Umred, Nagpur, Maharashtra		Sampling Date: 24.01.2001

Physical properties of Profile No. 15 (Boripani, Umred, Nagpur)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3142	A1	0–16	1.0	29.0	70.0	42.6	60.8
3143	Bw1	16–44	1.1	31.4	67.5	43.0	63.7
3144	Bw2	44–57	1.2	24.0	74.8	51.6	69.0
3145	Ck1	57–94	35.1	16.7	48.2	36.4	75.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–16	1.4	0.3	1.4	15.8
16–44	1.3	0.3	1.4	18.2
44–57	1.4	0.2	1.5	16.7
57–94	1.3	0.1	1.6	8.2

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KHERI **BM Spot: 13 (Black soil)**

Profile No: P27 ***System: Agriculture (Paddy-Wheat)*** **(HM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1448 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: NRC for Weed Science Farm, Jabalpur, Madhya Pradesh.		Sampling Date: 17.10.2001

Physical Properties of Profile No. 27 (Kheri, Jabalpur)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3253	Ap	0–20	13.2	33.0	53.8	32.3	60.0
3254	Bw1	20–42	4.0	31.0	65.0	32.2	49.5
3255	Bw2	42–63	3.9	33.8	62.2	39.2	63.0
3256	Bss1	63–84	3.8	35.2	61.0	36.7	60.2
3257	Bss2	84–115	3.5	36.2	60.3	34.9	57.8
3258	Bss3	115–160	12.1	31.6	56.3	37.0	65.7

Depth (cm)	BD[1] ($Mg m^{-3}$)	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–20	1.5	0.2	1.5	11.9
20–42	1.5	0.2	2.5	12.3
42–63	1.5	0.2	2.3	13.9
63–84	1.5	0.2	2.1	14.4
84–115	1.5	0.2	2.8	9.6
115–160	1.8	0.2	1.2	9.1

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KHERI 1 **BM Spot: 13 (Black soil)**

Profile No: P28 ***System: Agriculture (Soybean/Paddy-Wheat)* (LM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1448 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: Khajri Kheria, Jabalpur (Tah), Jabalpur, Madhya Pradesh.		Sampling Date: 17.10.2001

Physical Properties of Profile No. 28 (Kheri, Jabalpur)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3259	Ap	0–14	18.4	30.5	51.1	27.3	53.4
3260	Bw1	14–32	16.6	29.7	53.7	32.2	60.0
3261	Bw2	32–61	16.8	36.9	46.3	31.0	67.0
3262	Bss1	61–82	6.0	40.4	53.6	28.7	53.4
3263	Bss2	82–112	14.8	38.6	46.6	33.7	72.3
3264	Bss3	112–133	16.4	39.0	44.6	27.0	60.5
3265	Bss4	133–156	15.9	37.4	46.7	34.8	74.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–4	1.4	0.2	2.3	8.1
14–32	1.4	0.2	3.2	8.0
32–61	1.4	0.2	2.2	8.3
61–82	1.4	0.3	2.1	9.8
82–112	1.5	0.2	1.6	8.0
112–133	1.5	0.2	1.0	6.5
133–156	1.5	0.2	2.0	6.6

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

BLACK SOILS

Sub-humid dry

(MAR > 1100–1000 mm)

- **Benchmark Spots: 1, 4, 26, 27**
- **No. of Pedons: 9 (P1, P2, P3, P7, P8, P9, P48, P49, P50)**

Series: LINGA **BM Spot: 1 (Black soil)**

Profile No: P1 ***System: Horticulture (Citrus)* (HM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1011 mm	Classification: Very fine, smectitic, hyperthermic *Typic, Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: Wandli, Katol, Nagpur, Maharashtra.		Sampling Date : 04.11.2000

Physical Properties of Profile No. 1 (Linga, Katol, Nagpur)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←---------------(% of <2 mm) ------------------→				
3038	Ap	0–15	0.9	33.4	65.7	46.0	70.0
3039	Bw	15–41	0.5	30.5	69.0	51.0	74.0
3040	Bss1	41–70	0.3	29.0	70.7	55.7	78.8
3041	Bss2	70–95	0.2	28.7	71.1	56.0	78.7
3042	Bss3	95–135	0.3	27.0	72.7	58.2	80.0
3043	Bss4	135–155+	0.2	28.8	71.0	51.0	71.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–15	1.5	0.2	0.6	2.1
15–41	1.5	0.2	1.0	7.1
41–70	1.3	0.2	1.5	9.0
70–95	1.3	0.2	0.5	10.2
95–135	1.4	0.2	1.0	12.3
135–155+	1.3	0.3	0.8	8.0

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: LINGA BM Spot: 1 (Black soil)

Profile No: P2 ***System: Agriculture (Soybean-Gram/Wheat)* (FM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1011 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location : Ridhora, Katol, Nagpur, Maharashtra		Sampling Date: 07.11.2000

Physical Properties of Profile No. 2 (Linga, Katol, Nagpur)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3044	Ap	0–13	0.8	35.1	64.1	46.0	71.7
3045	Bw	13–33	0.5	33.5	66.0	50.0	75.7
3046	Bw1	33–55	0.5	33.5	66.0	61.2	92.7
3047	Bss1	55–81	0.3	29.5	70.2	56.2	80.0
3048	Bss2	81–119	0.3	30.1	69.6	60.0	86.2
3049	Bss3	119–150+	0.2	28.4	71.4	62.0	86.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–13	1.5	0.2	5.0	8.0
13–33	1.5	0.2	2.7	8.7
33–55	1.5	0.2	1.2	17.2
55–81	1.5	0.3	1.6	11.3
81–119	1.4	0.3	1.4	10.2
119–150+	1.5	0.3	1.6	18.6

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: LINGA BM Spot: 1 (Black soil)

Profile No: P3 ***System: Horticulture (Citrus)*** **(LM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1011 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Wandli, Katol, Nagpur, Maharashtra		Sampling Date: 07.11.2000

Physical Properties of Profile No. 3 (Linga, Katol, Nagpur)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3050	Ap	0–16	1.2	33.3	65.5	42.3	64.6
3051	Bw1	16–44	0.7	32.5	66.8	46.7	69.9
3052	Bw2	44–69	0.7	32.4	66.9	51.9	77.6
3053	Bss1	69–102	0.6	28.4	71.0	50.0	70.4
3054	Bss2	102–128	0.5	28.4	71.1	48.9	68.8
3055	Bss3	128–150+	0.5	29.2	70.3	51.2	72.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–16	1.4	0.2	2.3	6.9
16–44	1.4	0.2	2.8	10.9
44–69	1.4	0.2	2.5	9.2
69–102	1.5	0.2	1.8	10.5
102–128	1.5	0.3	2.8	17.9
128–150+	1.4	0.3	2.6	12.9

1. BD: Bulk Density
2.COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: SAROL **BM Spot: 4 (Black soil)**

Profile No: P7 ***System: Agriculture (Soybean-Wheat*) (HM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1053 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: National Research Centre for Soybean (ICAR) Farm, Bhavarkuan, Indore, M.P.		Sampling Date: 07.12.2000

Physical Properties of Profile No. 7 (Sarol, Bhavarkuan, Indore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3095	Ap	0–14	1.9	37.0	61.1	35.2	57.6
3096	Bw1	14–28	1.9	32.8	65.3	44.5	68.1
3097	Bss1	28–57	1.8	30.0	68.2	46.3	67.9
3098	Bss2	57–85	1.7	22.6	75.7	46.2	61.0
3099	Bss3	85–109	1.7	35.5	62.8	44.4	70.7
3100	Bss4	109–130	1.6	35.4	63.0	40.4	64.1
3101	Bss5	130–155	1.5	35.5	63.0	34.4	54.6

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–14	1.5	0.2	2.6	12.9
14-–8	1.5	0.2	2.5	10.1
28–57	1.4	0.2	2.3	13.0
57–85	1.4	0.3	1.5	13.5
85–109	1.5	0.2	1.5	12.9
109–130	1.5	0.2	1.8	17.9
130–155	1.4	0.2	0.6	7.3

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: SAROL **BM Spot: 4 (Black soil)**

Profile No: P8 ***System: Agriculture (Soybean-Wheat)* (FM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1053 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Limbodi, Indore, Madhya Pradesh		Sampling Date: 7.12.2000

Physical Properties of Profile No. 8 (Sarol, Limbodi, Indore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm) Total: Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)	Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			←----------------(% of <2 mm) ------------------→				
3102	Ap	0–18	1.7	34.2	64.1	45.2	70.5
3103	Bw1	18–45	2.3	25.7	72.1	57.8	80.3
3104	Bw2	45–66	1.6	37.2	61.2	47.7	77.9
3105	Bss1	66–90	1.7	33.9	64.5	46.3	71.8
3106	Bss2	90–124	1.6	40.9	57.5	39.9	69.4
3107	Bss3	124–159	1.2	39.2	58.9	39.6	67.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–18	1.4	0.2	0.9	13.4
18–45	1.4	0.2	1.3	18.5
45–66	1.4	0.2	1.3	16.2
66–90	1.4	0.2	0.9	16.4
90–124	1.4	0.2	0.7	14.9
124–159	1.4	0.2	0.9	15.9

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: SAROL BM Spot: 4 (Black soil)

Profile No: P9 ***System: Agriculture or Agri-horticulture (Soybean-Gram in Mango Orchard*) (HM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1053 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: National Research Centre for Soybean (ICAR) Farm, Bhavarkuan, Indore, Madhya Pradesh		Sampling Date: 7.12.2000

Physical Properties of Profile No. 9 (Sarol, Bhavarkuan, Indore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay(%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3108	Ap	0–17	1.6	39.0	59.4	47.5	80.1
3109	Bw	17–44	1.4	40.7	57.9	42.5	73.4
3110	Bss1	44–79	1.1	38.8	60.1	46.3	76.9
3111	Bss2	79–102	1.2	34.8	64.0	45.1	70.6
3112	Bss3	102–127	1.1	39.2	59.7	50.4	84.4
3113	Bss4	127–152	1.0	38.5	60.5	44.4	73.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–17	1.4	0.2	1.2	6.4
17–44	1.4	0.2	2.4	8.5
44–79	1.4	0.2	1.3	10.1
79–102	1.4	0.2	1.1	5.9
102–127	1.4	0.2	0.8	9.7
127-–52	1.4	0.2	0.8	9.0

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: NIPANI **BM SPOT: 26 (Black soil)**

PROFILE NO: P48 ***System: Agriculture (Cotton + Pigeonpea)* (FM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1071 mm	Classification: Fine, smectitic (cal), hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Nipani, Mandal-Tamsi, Adilabad, Andhra Pradesh		Sampling Date: 04.07.2002

Physical Properties of Profile No. 48 (Nipani, Adilabad)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3557	Apk	0–13	8.4	48.3	43.3	21.9	50.6
3558	Bwk1	13–35	6.7	41.3	52.0	37.1	71.3
3559	Bwk2	35–62	6.7	44.0	49.3	30.3	61.3
3560	Bssk1	62–88	5.3	43.2	51.5	37.2	72.1
3561	Bssk2	88–-27	5.1	45.2	49.7	31.7	63.9
3562	Bssk3	127–155+	6.1	41.4	52.5	35.2	67.0

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–13	1.4	0.2	1.3	12.6
13–35	1.7	0.2	1.8	14.5
35–62	1.3	0.2	1.7	8.8
62–88	1.5	0.1	2.0	10.1
88–127	1.5	0.2	2.8	10.1
127–155+	1.6	0.2	1.0	13.1

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: PANGIDI **BM SPOT: 27 (Black soil)**

PROFILE NO: P49 *System: Agriculture (Cotton + Pigeonpea)* (FM)

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1071 mm	Classification: Very fine, smectitic, hyperthermic, *Typic, Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Pangidi, Mandal-Jainur, Adilabad, Andhra Pradesh		Sampling Date: 05.07.2002

Physical Properties of Profile No. 49 (Pangidi, Adilabad)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3563	Ap	0–14	2.7	27.1	70.2	54.2	77.3
3564	Bw1	14-36	2.3	22.6	75.1	59.4	79.1
3565	Bw2	36–62	1.9	23.4	74.7	61.2	81.9
3566	Bss1	62–87	1.4	20.5	78.1	64.3	82.3
3567	Bss2	87–110	1.5	19.0	79.5	65.5	82.2
-	R	110+	---------- Limestone rock ----------				

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–14	1.2	0.06	0.8	12.6
14–36	1.1	0.05	1.1	12.4
36–62	1.2	0.16	0.8	11.4
62–87	1.3	0.23	1.0	11.5
87–110	1.2	0.29	1.7	11.9
110+	---------- Limestone rock ----------			

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: PANGIDI 1 **BM SPOT: 27 (Black soil)**

PROFILE NO: P50 ***System: Agriculture (Soybean)*** **(ITDA)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1071 mm	Classification: Very fine, smectitic, hyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ITDA – ICRISAT Project Area, Pangidi, Mandal-Jainur, Adilabad, Andhra Pradesh		Sampling Date: 05.07.2002

Physical Properties of Profile No. 50 (Pangidi, Adilabad)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3568	Ap	011	4.0	17.7	78.3	50.8	64.8
3569	Bw1	11–27	3.3	14.4	82.3	61.9	75.2
3570	Bwk1	27–41	6.2	12.7	81.1	61.0	75.2
3571	Crk	41–55	50.9	23.1	26.0	21.5	83.0

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–11	1.3	0.28	2.5	10.9
11–27	1.3	0.29	1.9	12.2
27–41	1.3	0.28	1.4	12.1
41–55	-	0.11	1.4	3.1

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

BLACK SOILS

(Semi-arid moist)

(MAR > 1000–850 mm)

- **Benchmark Spots: 5, 22**
- **No. of Pedons: 4 (P10, P11, P12, P42)**

Series: ASRA **BM Spot: 5 (Black soil)**

Profile No: P10 ***System: Agriculture*** **(*Cotton/Green gram + Pigeonpea*) (FM) (ORG)**

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 975 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Asra, Bahtkuli, Amravati, Maharashtra		Sampling Date: 16.01.2001

Physical Properties of Profile No. 10 (Asra, Amravati)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3114	Ap	0–14	0.9	36.7	62.4	26.7	42.8
3115	Bw1	14–40	0.8	34.3	64.9	26.7	41.1
3116	Bw2	40–59	0.8	33.3	65.9	28.9	43.8
3117	Bss1	59–91	1.4	35.3	63.3	29.0	45.7
3118	Bss2	91–125	2.4	37.3	60.3	28.7	47.6
3119	Bss3	125–150	1.9	38.1	60.0	25.7	42.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–14	1.6	0.3	1.1	6.6
14–40	1.6	0.3	2.1	13.9
40–59	1.7	0.3	1.0	14.8
59–91	1.5	0.3	0.5	6.4
91–125	1.5	0.3	0.4	7.6
125–150	1.6	0.3	0.3	10.0

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: ASRA **BM Spot: 5 (Black soil)**

Profile No: P11 ***System: Agriculture (Soybean + Pigeonpea)* (FM)**

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 975 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Asra, Bahtkuli, Amravati, Maharashtra		Sampling Date: 16.01.2001

Physical Properties of Profile No. 11 (Asra, Amravati)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3120	Ap	0–14	2.8	36.1	61.1	28.9	47.5
3121	Bw1	14–35	2.7	34.6	62.7	32.5	51.8
3122	Bss1	35–69	2.7	34.8	62.5	32.4	51.8
3123	Bss2	69–107	2.6	36.1	61.3	35.0	57.1
3124	Bss3	107–150	2.1	35.8	62.1	35.3	56.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–14	1.5	0.2	1.1	2.0
14–35	1.5	0.2	1.7	6.8
35–69	1.5	0.2	1.4	12.2
69–107	1.6	0.2	1.3	7.0
107–150	1.6	0.2	0.9	10.6

1. BD: Bulk Density
2.COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: ASRA **BM Spot: 5 (Black soil)**

Profile No: P12 ***System: Agriculture (Cotton + Pigeonpea / Soybean-Gram*)(HM)**

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 975 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Seed Multiplication Centre, Walgaon, Amravati (Tah), Amravati, Maharashtra		Sampling Date: 17.01.2001

Physical Properties of Profile No. 12 (Asra, Walgaon, Amravati)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3125	Ap	0–12	1.2	27.5	71.3	43.2	60.6
3126	Bw1	12–40	1.5	30.7	67.8	37.6	55.4
3127	Bss1	40–79	1.0	26.1	72.9	44.6	61.2
3128	Bss2	79–116	1.6	30.8	67.6	39.9	59.0
3129	Bss3	116–150	1.4	32.7	66.0	41.5	63.0

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	1.5	0.2	0.7	11.7
12–40	1.5	0.2	1.0	9.9
40–79	1.5	0.3	1.1	13.4
79–116	1.5	0.3	1.5	6.9
116–150	1.5	0.3	3.8	10.2

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: BHATUMBRA BM SPOT: 22 (Black soil)

PROFILE NO: P42 *System: Agriculture (Sorghum +Pigeonpea/ Black gram–Chickpea)*(FM)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 977 mm	Classification: Very fine, smectitic, isohyperthermic, *Udic Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Bhatumbra, Bhakli (Tah), Bidar, Karnataka		Sampling Date: 04.01.2002

Physical Properties of Profile No. 42 (Bhatumbra, Bhakli, Bidar)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3402	Ap	0–12	3.6	36.3	60.1	25.3	42.1
3403	Bw	12–37	5.2	35.8	59.0	27.4	46.4
3404	Bssk1	37–79	5.6	33.8	60.6	34.6	57.1
3405	Bssk2	79–110	4.5	25.9	69.6	45.3	65.1

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	1.3	0.3	1.3	13.3
12–37	1.4	0.2	0.7	14.0
37–79	1.3	0.2	0.5	12.3
79–110	1.3	0.3	0.6	16.6

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

BLACK SOILS

(Semi-arid dry)

(MAR: 850–550 mm)

- **Benchmark Spots: 6, 9, 14, 16, 18, 20, 23, 24, 25**
- **No. of Pedons: 17 (P13, P14, P19, P20, P21, P29, P32, P33, P35, P36, P39, P40, P43, P44, P45, P46, P47)**

Series: PARAL BM Spot: 6 (Black soil)

Profile No: P13 ***System: Agriculture (Cotton + Pigeonpea / Sorghum*) (LM)**

CLIMATE: SEMI-ARID (DRY) **RAINFALL: 794 mm**	**Classification: Very fine, smectitic hyperthermic, *Sodic Haplusterts***	**Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur**
Location: Paral (Parala), Akot, Akola, Maharashtra		**Sampling Date: 19.01.2001**

Physical Properties of Profile No. 13 (Paral, Akola)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)	(<0.0002)	
			←----------------(% of <2 mm) ------------------→				
3130	Ap	0–9	2.5	42.2	55.3	22.6	40.9
3131	Bw1	9–35	0.9	40.2	58.9	30.7	52.1
3132	Bss1	35–69	2.6	40.5	56.9	29.5	51.8
3133	Bss2	69–105	1.6	35.7	62.6	35.6	56.9
3134	Bss3	105–132	1.0	37.3	61.8	37.6	60.8
3135	Bss4	132–150	0.5	43.1	56.3	37.6	66.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–9	1.6	0.2	1.7	4.1
9–35	1.6	0.2	0.5	4.0
35–69	1.5	0.2	0.2	6.1
69–105	1.5	0.2	0.1	7.2
105–132	1.5	0.2	0.1	8.6
132–150	1.5	0.2	0.1	6.2

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: PARAL **BM Spot: 6 (Black soil)**

Profile No: P14 ***System: Agriculture (Cotton + Pigeonpea / Sorghum*) (HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 793 mm	Classification: Very fine, smectitic, hyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Paral (Parala), Akot, Akola, Maharashtra		Sampling Date: 19.01.2001

Physical Properties of Profile No. 14 (Paral, Akola)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3136	Ap	0–8	1.7	39.3	59.0	19.9	33.7
3137	Bw1	8–35	0.5	35.6	63.9	36.0	56.3
3138	Bss1	35–68	0.6	35.0	64.4	37.6	58.3
3139	Bss2	68–97	0.5	36.1	63.4	40.2	63.4
3140	Bss3	97–129	0.6	36.1	63.3	43.4	68.6
3141	Bss4	129–150	0.5	37.7	61.8	39.3	63.6

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–8	1.6	0.2	1.3	3.8
8–35	1.6	0.2	0.6	5.1
35–68	1.6	0.2	0.2	7.4
68–97	1.6	0.2	0.1	17.6
97–129	1.6	0.2	0.1	15.0
129–150	1.6	0.2	0.1	12.6

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KOVILPATTI BM Spot: 9 (Black soil)

Profile No: P19 *System: Agriculture (Sorghum/Sunflower/ Cotton-2 year rotation)* (ORG)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 660 mm	Classification: Very fine, smectitic, isohyperthermic, *Gypsic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: TNAU Res. Stn. Farm, Kovilpatti, Thoothokudi, Tamil Nadu		Sampling Date: 14.02.2001

Physical Properties of Profile No. 19 (Kovilpatti, Thoothokudi)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3166	Ap1	0–6	22.8	21.0	56.2	31.9	56.8
3167	Ap2	6–20	17.6	20.8	61.6	44.3	72.0
3168	Bw1	20–41	15.6	19.3	65.1	46.3	71.0
3169	Bw2	41–74	15.0	19.3	65.7	50.3	76.5
3170	Bss1	74–104	13.0	20.1	66.9	50.8	76.0
3171	Bss2	104–118	10.2	17.7	72.1	60.0	83.2
3172	BCky	118–128	9.8	19.9	70.3	54.8	78.0
3173	2Cky	128–140+	22.9	52.4	24.7	10.2	41.3

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–6	1.2	0.2	1.9	11.5
6–20	1.2	0.2	2.2	12.0
20–41	1.4	0.2	4.5	16.5
41–74	1.5	0.2	3.0	12.3
74–104	1.4	0.2	3.8	20.7
104–118	1.4	0.3	3.5	20.1
118–128	-	0.2	3.2	12.8
128–140+	-	0.1	4.8	7.1

- *Nil or not determined (whenever applicable)*

1. BD: Bulk Density
2.COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KOVILPATTI 1 **BM Spot: 9 (Black soil)**

Profile No: P20 ***System: Wasteland***

CLIMATE: SEMI-ARID (DRY) RAINFALL: 660 mm	Classification: Fine, smectitic, isohyperthermic, *Leptic Gypsiusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Avalnatham, Behind TNAU Farm, Kovilpatti, Thoothukudi, Tamil Nadu		Sampling Date: 14.02.2001

Physical Properties of Profile No. 20 (Kovilpatti, Thoothokudi)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3174	Ap	0–11	29.2	16.9	53.9	36.1	67.0
3175	Bw1	11–31	22.4	17.1	60.6	47.0	77.6
3176	Bw2	31–55	19.3	23.2	57.5	53.5	93.0
3177	Bss	55–79	12.7	29.6	57.7	51.9	89.0
3178	2C1y	79–91	10.3	20.4	69.3	57.0	82.2
3179	2C2y	91–105	17.6	17.2	65.2	53.6	82.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–11	1.4	0.2	1.2	16.9
11–31	1.4	0.1	2.7	20.4
31–55	1.4	0.2	2.1	20.4
55–79	1.3	0.1	2.8	21.1
79–91	-	0.1	3.3	18.8
91–105	-	0.1	4.8	15.8

- *Nil or not determined (wherever applicable)*

1.BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KOVILPATTI BM Spot: 9 (Black soil)

Profile No: P21 ***System: Agriculture (Cotton + Black gram) (*****HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 660 mm	Classification: Very fine, smectitic, isohyperthermic, *Gypsic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Kumaragiri, Ettayapuram (Kovilpatti), Thoothukudi, Tamil Nadu		Sampling Date: 15.02.2001

Physical Properties of Profile No. 21 (Kovilpatti, Thoothokudi)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3180	Ap1	0–9	28.1	19.1	52.8	37.7	71.4
3181	Ap2	9–20	23.7	17.0	59.3	43.5	73.3
3182	Bw1	20–58	17.8	17.6	64.7	49.2	76.0
3183	Bss1	58–100	15.2	18.9	66.0	43.4	65.8
3184	2Cky1	100–126	15.3	44.4	40.3	25.2	62.5
3185	2Cky2	126–155	33.4	13.6	53.0	46.0	86.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–9	1.3	0.2	2.1	12.3
9–20	1.3	0.2	2.1	12.6
20–58	1.4	0.2	2.6	17.8
58–100	1.4	0.2	3.4	14.1
100–126	-	0.2	7.2	-
126–155	-	0.2	10.1	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: SEMLA **BM Spot: 14 (Black soil)**

Profile No: P29 ***System: Agriculture (Cotton / Groundnut-Wheat)* (ORG)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 635 mm	Classification: Fine, smectitic(cal), hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Semla, Gondal, Rajkot, Gujarat		Sampling Date: 06.11.2001

Physical Properties of Profile No. 29 (Semla, Rajkot)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3266	Ap	0–17	25.1	39.9	35.0	15.6	44.6
3267	Bw1	17–42	13.8	42.8	43.4	18.7	43.1
3268	Bw2	42–57	11.8	38.2	50.0	24.9	49.8
3269	Bss1	57–86	7.8	42.1	50.1	29.2	58.3
3270	Bss2	86–115	9.7	40.9	49.4	24.3	49.2
3271	Bss3	115–144	9.4	42.8	47.8	28.2	59.0
3272	BC	144–155	20.8	45.4	33.8	13.5	40.0

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–17	1.4	0.2	2.3	6.0
17–42	1.4	0.2	4.2	8.8
42–57	1.4	0.2	2.1	8.6
57–86	1.4	0.2	1.7	9.1
86–115	1.8	0.2	2.2	10.4
115–144	1.5	0.2	0.9	8.3
144–155	1.5	0.2	1.2	5.4

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: JHALIPURA **BM Spot: 16 (Black soil)**

Profile No: P32 ***System: Agriculture (Soybean-Wheat)* (FM/1)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 842 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Jhalipura, Kota(Tah), Kota, Rajasthan		*Sampling Date: 10.11.2001*

Physical Properties of Profile No. 32 (Jhalipura, Kota)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3285	Ap	0–12	9.8	45.2	45.0	25.1	55.8
3286	Bw1	12–31	7.8	44.6	47.6	27.9	58.6
3287	Bw2	31–48	6.5	41.1	52.4	31.4	60.0
3288	Bss1	48–74	8.0	41.6	49.2	31.4	61.6
3289	Bss2	74–110	8.5	41.5	50.0	31.2	62.4
3290	Bss3	110–148	8.4	40.7	50.9	32.6	64.0
3291	Bss4	148–165	8.0	39.7	52.4	29.1	55.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	1.4	0.2	0.8	3.9
12–31	1.7	0.2	1.5	3.7
31–48	1.4	0.2	0.7	3.2
48–74	1.7	0.2	0.6	3.3
74–110	1.7	0.2	1.3	3.1
110–148	1.7	0.2	1.4	3.1
148–165	1.7	0.2	1.0	3.0

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: JHALIPURA **BM Spot: 16 (Black soil)**

Profile No: P33 ***System: Agriculture (Paddy-Wheat)* (FM/2)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 842 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Daslana (Jhalipura), Kota, Rajasthan		Sampling Date: 11.11.2001

Physical Properties of Profile No. 33 (Jhalipura, Kota)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3292	Ap	0–13	18.7	30.6	50.7	23.3	45.9
3293	Bw1	13–36	10.7	39.9	50.3	26.6	52.8
3294	Bw2	36–58	10.3	40.2	49.5	24.0	48.5
3295	Bss1	58–82	10.8	38.4	50.8	28.9	56.8
3296	Bss2	82–107	10.5	39.6	49.9	21.2	42.4
3297	Bss3	107–132	11.1	49.2	39.7	15.9	40.0
3298	Bss4	132–156	13.8	52.0	34.2	14.2	41.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–13	1.7	0.2	1.7	10.0
13–36	1.7	0.2	0.9	10.0
36–58	1.6	0.2	0.3	9.2
58–82	1.7	0.2	0.6	19.5
82–07	1.7	0.2	0.7	7.5
107–132	1.7	0.2	0.6	7.4
132–156	1.8	0.2	0.5	6.4

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: JAJAPUR **BM SPOT: 18 (Black soil)**

PROFILE NO: P35 ***System: Agriculture (Sorghum/Pigeonpea + Green gram)*** **(FM1)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 792 mm	Classification: Fine, smectitic, isohyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Jajapur, Narayanpeth (Mandal), Makthal, Mehboobnagar, Andhra Pradesh		Sampling Date: 15.12.2001

Physical Properties of Profile No. 35 (Jajapur, Mehboobnagar)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay / Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3356	Ap	0–12	48.5	16.4	35.1	23.5	67.0
3357	Bw1	12–35	47.3	17.2	35.5	26.8	75.5
3358	Bw2	35–48	45.5	17.4	37.1	28.3	76.3
3359	Bw3	48–76	45.7	17.6	36.7	27.7	75.5
3360	Bwk1	76–96	38.7	19.3	42.0	33.0	78.4
3361	Bwk2	96–126	38.6	19.5	41.9	32.5	77.6
3362	BCk	126–155	27.4	24.1	48.5	35.5	73.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	-	0.1	1.92	2.0
12–35	1.8	0.2	1.96	2.7
35–48	1.7	0.1	1.30	2.6
48–76	1.6	0.1	0.30	2.7
76–96	1.7	0.1	<0.1	2.6
96–126	1.6	0.2	<0.1	3.1
126–155	1.6	0.2	<0.1	3.2

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: JAJAPUR 1 **BM SPOT: 18 (Black soil)**

PROFILE NO: P36 ***System: Agriculture (Paddy - Paddy)*** **(FM/2)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 792 mm	Classification: Fine-loamy, smectitic, isohyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Jajapur, Narayanpeth (Mandal), Makthal, Mehboobnagar, Andhra Pradesh		Sampling Date: 15.12.2001

Physical Properties of Profile No. 36 (Jajapur, Mehboobnagar)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3363	Ap	0–10	54.2	19.4	26.4	20.6	78.0
3364	Bw1	10–28	59.4	16.8	23.8	19.5	81.9
3365	Bw2	28–53	58.1	15.6	26.3	21.5	81.7
3366	Bw3	53–76	51.2	15.4	33.4	26.1	78.1
3367	BwK1	76–98	45.6	18.5	35.9	24.7	68.8
3368	BwK2	98–128	52.9	15.8	31.4	22.0	70.3
3369	BCK1	128–150	57.4	14.2	28.4	20.1	70.8
3370	BCK2	150+	57.2	16.2	26.7	18.4	69.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–10	-	0.2	0.43	2.9
10–28	1.9	0.1	<0.1	2.6
28–53	1.9	0.1	<0.1	2.6
53–76	1.8	0.2	0.5	3.0
76–98	1.8	0.2	0.5	2.9
98–128	1.8	0.2	0.5	2.8
128–150	1.8	0.2	0.7	2.8
150+	1.8	0.2	0.6	3.0

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KASIREDDIPALLI BM SPOT: 20 (Black soil)

PROFILE NO: P39 *System: Agriculture (Soybean-Pigeonpea)* (HM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Fine, smectitic, isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ICRISAT Farm BW7, Patancheru, Ramchandrapuram, Medak, Andhra Pradesh		Sampling Date: 18.12.2001

Physical Properties of Profile No. 39 (Kasireddipalli, Medak)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3381	Ap	0–12	21.5	26.4	52.1	28.8	55.3
3382	Bw1	12–31	20.4	28.1	51.5	28.1	54.6
3383	Bss1	31–54	16.7	29.1	54.2	34.0	62.7
3384	Bss2	54–84	13.9	28.8	57.3	40.0	69.8
3385	Bss3	84–118	10.9	32.6	56.5	26.0	46.0
3386	Bss4	118–146	3.6	37.1	59.3	31.7	53.4
3387	BC	146–157	9.9	30.1	60.0	41.5	69.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–12	1.6	0.2	1.7	3.2
12–31	1.6	0.2	1.6	3.5
31–54	1.6	0.2	1.0	3.7
54–84	1.5	0.3	0.9	3.7
84–118	1.6	0.3	0.7	3.2
118–146	1.4	0.3	0.3	3.2
146–157	1.4	0.3	-	3.4

- *Nil or not determined (wherever applicable)*

1.BD: Bulk Density
2.COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KASIREDDIPALLI BM SPOT: 20 (Black soil)

PROFILE NO: P40 *System: Agriculture (Fallow-Chickpea)* (TM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Fine, smectitic, isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ICRISAT farm, Kasireddipalli, Patancheru, Medak, Andhra Pradesh		Sampling Date: 18.12.2001

Physical Properties of Profile No. 40 (Kasireddipalli, Medak)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3388	Ap	0–12	22.5	29.6	47.9	26.4	55.1
3389	Bw1	12–30	18.7	29.9	51.4	29.7	57.7
3390	Bss1	30–59	17.9	29.6	52.5	32.5	61.9
3391	Bss2	59–101	16.6	27.8	55.6	36.4	65.5
3392	Bss3	101–130	7.2	33.4	59.4	30.8	51.8
3393	BCk	130–160	13.0	29.1	57.9	38.7	66.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–12	1.6	0.3	0.7	6.3
12–30	1.6	0.2	0.6	10.0
30–59	1.6	0.2	0.6	11.6
59–101	1.5	0.2	0.2	11.8
101–130	1.6	0.3	0.2	14.7
130-–60	1.7	0.2	0.1	11.3

1.BD: Bulk Density
2.COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: TELIGI **BM SPOT: 23 (Black soil)**

PROFILE NO: P43 ***System: Agriculture (Paddy-Paddy)* (LM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 632 mm	Classification: Fine, smectitic, isohyperthermic, *Sodic Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ARS (UAS, Dharwad) Research Farm, Siruguppa, Siruguppa, Bellary, Karnataka		Sampling Date: 07.01.2002

Physical Properties of Profile No. 43 (Teligi, Bellary)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3406	Apk	0–10	19.6	24.3	56.1	30.4	54.2
3407	Bwk1	10–25	18.9	22.1	59.0	45.2	76.6
3408	Bwk2	25–44	19.4	22.4	58.2	44.0	75.6
3409	Bssk1	44–69	34.3	19.1	46.6	36.1	77.5
3410	Bssk2	69–97	29.5	21.8	48.7	34.9	71.7
3411	Bssk3	97–123	11.4	36.3	52.3	25.8	49.3
3412	Bssk4	123–150	6.3	32.4	61.3	25.9	42.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–10	1.2	0.24	6.2	11.5
10–25	1.5	0.26	2.7	11.4
25–44	1.6	0.22	2.9	11.5
44–69	1.5	0.20	2.1	11.5
69–97	1.4	0.18	1.1	14.8
97–123	1.4	0.21	0.3	20.4
123–150	1.4	0.22	0.1	16.0

1.BD: Bulk Density
2.COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: TELIGI **BM SPOT: 23 (Black soil)**

PROFILE NO: P44 ***System: Agriculture (Paddy-Paddy)* (HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 632 mm	Classification: Very fine, smectitic, isohyperthermic, *Sodic Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ARS (UAS, Dharwad) Farm, Siruguppa, Siruguppa, Bellary, Karnataka		Sampling Date: 07.01.2002

Physical Properties of Profile No. 44 (Teligi, Bellary)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3413	Apk	0–10	45.4	15.8	38.8	32.2	83.0
3414	Bwk1	10–34	8.6	29.4	62.0	34.1	55.0
3415	Bwk2	34–54	18.2	21.1	60.7	44.0	72.5
3416	Bssk1	54–89	13.2	23.5	63.3	42.3	66.8
3417	Bssk2	89–119	8.6	27.2	64.2	41.7	65.0
3418	Bssk3	119–142	10.7	25.1	64.2	37.4	58.2
3419	BCk	142–150	8.5	27.5	64.0	51.9	81.0

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–10	1.5	0.2	1.8	6.7
10–34	1.6	0.2	0.9	8.3
34–54	1.5	0.2	0.9	14.9
54-89	1.4	0.2	0.2	10.4
89–119	1.3	0.2	0.1	19.3
119–142	1.3	0.1	0.1	18.7
142–150	1.7	0.2	1.6	12.2

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KONHERI BM SPOT: 24 (Black soil)

PROFILE NO: P45 *System: Agriculture (Pigeonpea / Sunflower - Sorghum)* (FM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 745 mm	Classification: Fine, smectitic, hyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Konheri, Mohol, Solapur, Maharashtra.		Sampling Date: 09.01.2002

Physical Properties of Profile No. 45 (Konheri, Solapur)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←---------------(% of <2 mm) -----------------→				
3420	Ap	0–13	27.3	37.3	35.4	26.8	75.7
3421	Bw	13–33	24.8	33.8	41.4	30.7	74.1
3422	Bwk1	33–69	18.1	38.9	43.0	34.4	80.0
3423	Bwk2	69–93	22.8	33.9	43.3	32.9	76.0
3424	Bwk3	93–113	12.0	44.3	43.7	38.8	88.8
3425	BC	113–129	15.7	39.7	44.6	35.6	80.0
3426	Bss	129–160	9.8	32.3	57.9	46.4	80.1

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–13	-	0.2	2.6	4.6
13–33	1.5	0.2	2.1	4.3
33–69	1.6	0.2	3.0	6.5
69-93	1.5	0.2	3.2	5.7
93–113	1.5	0.2	1.3	7.3
113–129	1.7	0.2	1.4	6.5
129–160	1.6	0.3	1.7	14.5

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KONHERI 1 BM SPOT: 24 (Black soil)

PROFILE NO: P46 *System: Agriculture (Fallow-Sorghum+Safflower)* (LM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 745 mm	Classification: Very fine, smectitic, hyperthermic, *Leptic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Konheri, Mohol, Solapur, Maharashtra.		Sampling Date: 10.01.2002

Physical Properties of Profile No. 46 (Konheri, Solapur)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay / Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3427	Apk	0–13	2.0	19.7	78.2	54.3	69.4
3428	Bwk	13–34	1.5	19.9	78.6	59.2	75.3
3429	Bssk1	34–53	1.3	19.5	79.2	60.5	76.4
3430	Bssk2	53-83	1.1	19.8	79.2	64.6	81.6
3431	Ck1	83–17	2.8	19.7	77.5	54.5	70.3
3432	Ck2	117–155	5.6	22.7	71.6	47.4	66.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–13	1.3	0.1	1.6	15.8
13–34	1.3	0.2	3.7	18.2
34–53	1.3	0.1	1.9	19.9
53–83	1.4	0.2	1.7	20.9
83–117	1.6	0.1	1.4	7.7
117–155	-	0.1	1.2	4.1

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KALWAN BM SPOT: 25 (Black soil)

PROFILE NO: P47 *System: Agriculture (Sugarcane/Jowar-Wheat/Gram) (FM)*

CLIMATE: SEMI-ARID (DRY) RAINFALL: 692 mm	Classification: Fine, smectitic (Cal), hyperthermic, *Typic Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Kalwan, Kalwan, Nasik, Maharashtra.		Sampling Date: 20.02.2002

Physical Properties of Profile No. 47 (Kalwan, Nasik)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3438	Ap	0–20	14.2	37.2	48.6	26.5	54.5
3439	Bw1	20–48	27.8	25.0	47.2	31.3	66.3
3440	Bss1	48–70	16.1	32.9	51.0	32.6	63.9
3441	Bssk1	70–88	18.4	40.7	40.9	25.4	62.1
3442	2BCk1	88–133	34.5	44.1	21.4	14.7	68.7
3443	2BCk2	133–154	40.3	47.5	12.2	8.2	67.2

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–20	1.4	0.2	0.6	12.8
20–48	1.4	0.2	0.5	12.1
48–70	1.5	0.1	0.6	12.6
70–88	1.5	0.2	0.7	9.4
88–133	1.4	0.1	0.9	5.6
133–154	-	0.03	1.5	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

BLACK SOILS

(Arid)

(MAR : < 550 mm)

- **Benchmark Spots: 15, 28**
- **No. of Pedons: 4 (P30, P31, P51, P52)**

Series: SOKHDA **BM Spot: 15 (Black soil)**

Profile No: P30 ***System: Agriculture (Cotton-Pearl millet)*** **(FM/I)**

CLIMATE: ARID RAINFALL: 533 mm	Classification: Fine, smectitic (cal), hyperthermic, *Leptic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Sokhda, Morbi, Rajkot, Gujarat		Sampling Date: 07.11.2001

Physical Properties of Profile No. 30 (Sokhda, Rajkot)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%)	Fine clay / Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)	(<0.0002)	
			←----------------(% of <2 mm) ------------------→				
3273	Apk	0–11	24.1	34.8	41.1	14.9	36.2
3274	Bwk1	11–32	25.6	33.3	41.1	18.0	43.8
3275	Bwk2	32–57	28.8	28.5	42.7	19.6	46.0
3276	Bssk	57–91	28.7	27.1	44.2	22.0	49.7
3277	Ck1	91–107	43.5	30.2	26.3	11.9	45.0
3278	Ck2	107–135	23.7	52.1	24.2	11.7	48.3

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–11	1.6	0.1	1.9	4.1
11–32	1.6	0.2	2.4	5.3
32–57	1.6	0.1	2.2	5.7
57–91	1.8	0.2	3.0	5.8
91–107	1.9	0.2	2.9	3.3
107–135	-	0.2	2.6	3.3

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: SOKHDA 1 **BM Spot: 15 (Black soil)**

Profile No: P31 ***System: Agriculture (Cotton–Pearl millet/Linseed)* (FM/2)**

CLIMATE: ARID RAINFALL: 533 mm	Classification: Fine, smectitic (cal), hyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Sokhda, Morbi (Tah), Rajkot, Gujarat		Sampling Date: 07.11.2001

Physical Properties of Profile No. 31 (Sokhda, Rajkot)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)	(<0.0002)	
			←----------------(% of <2 mm) ------------------→				
3279	Apk	0–11	29.9	38.4	31.7	12.6	39.7
3280	Bwk1	11–37	29.4	40.1	30.5	13.4	43.9
3281	Bwk2	37–63	26.4	33.5	40.1	17.9	44.6
3282	Bssk1	63–98	26.6	32.6	40.8	19.2	47.0
3283	Bssk2	98–145	22.8	34.5	42.7	20.4	47.7
3284	BCk	145–160	7.9	42.0	50.1	33.0	65.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–11	1.4	0.2	3.2	1.0
11–37	1.4	0.2	3.0	4.4
37–63	1.6	0.2	1.5	3.8
63–98	1.8	0.1	0.4	3.6
98–145	1.6	0.1	0.2	3.5
145–160	1.7	0.2	0.2	3.7

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: NIMONE BM SPOT: 28 (Black soil)

PROFILE NO: P51 *System: Agriculture (Cotton-Wheat/ Chickpea [Irrigated])* (HM)

CLIMATE: ARID RAINFALL: 520 mm	Classification: Very fine, smectitic (cal), isohyperthermic *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Cotton Project (Plot No/Survey No. 51C), area of MPKV, Village-Rahuri Khurd, Rahuri, Ahmednagar, Maharashtra.		Sampling Date: 18/12/2002

Physical Properties of Profile No. 51 (Nimone, Rahuri)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay / Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3574	Apk	0–13	4.0	29.6	66.4	46.0	69.3
3575	Bwk1	13–8	4.0	28.3	67.7	48.7	71.9
3576	Bwk2	38–55	4.2	29.7	66.1	47.2	71.4
3577	Bssk1	55–94	4.5	26.2	69.3	50.2	72.4
3578	Bssk2	94–128	2.7	26.6	70.7	52.4	74.1
3579	Bwk3	128–150+	2.7	26.8	70.5	53.2	75.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] (cm hr^{-1})	WDC[4] (%)
0–13	1.4	0.2	2.6	2.3
13–38	1.4	0.3	2.0	3.8
38–55	1.4	0.3	1.5	2.8
55–94	1.3	0.3	1.5	2.8
94–128	1.4	0.3	1.5	4.5
128–150+	1.3	0.2	2.8	2.0

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: NIMONE BM SPOT: 28 (Black soil)

PROFILE NO: P52 System: *Agriculture (Sugarcane[Ratoon]-Soybean-Wheat/Chickpea)* (FM)

CLIMATE: ARID RAINFALL: 520 mm	Classification: Fine, smectitic (cal), isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Village - Nirmal Pimpari, Rahata (Tah), Ahmednagar, Maharashtra.		Sampling Date: 18.12.2002

Physical Properties of Profile No. 52 (Nimone, Ahmednagar)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm) Total Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)	Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			←----------------(% of <2 mm) ------------------→				
3580	Apk	0–12	7.6	38.4	54.0	36.1	0.7
3581	Bwk1	12–29	7.1	38.7	54.2	41.1	0.8
3582	Bwk2	29–50	5.6	38.2	56.2	43.7	0.8
3583	Bssk1	50–84	4.7	37.9	57.4	46.1	0.8
3584	Bssk2	84–113	4.2	38.2	57.6	45.1	0.8
3585	Bssk3	113–148	4.0	38.6	57.4	41.9	0.7
3586	BCk	148–165+	4.0	37.5	58.5	41.8	0.7

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	1.3	0.21	2.9	0.5
12–29	1.3	0.21	1.2	2.3
29–50	1.5	0.22	0.2	4.9
50–84	1.4	0.25	-	13.5
84–113	1.4	0.28	-	14.4
113–148	1.3	0.19	-	14.9
148–165+	1.3	0.22	-	8.8

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

RED SOILS

(Sub-humid moist)

(MAR: > 1100 mm)

- **Benchmark Spots: 11, 12**
- **No. of Pedons: 4 (P23, P24, P25, P26)**

Series: DADARGHUGRI BM Spot: 11 (Red soil)

Profile No: P23 ***System: Agriculture (Maize/Mustard)* (FM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1420 mm	Classification: Clayey-skeletal, mixed, hyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Dadarghugri, Sehapura, Dindori, Madhya Pradesh		Sampling Date: 11.06.2001

Physical Properties of Profile No. 23 (Dadarghugri, Dindori)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3212	Ap	0–11	10.3	53.1	36.6	22.8	62.3
3213	Bt1	11–29	5.9	39.0	55.1	50.0	90.6
3214	Bt2	29–55	7.9	36.8	55.3	54.2	97.8
3215	C1	55–74	19.7	25.7	54.6	48.5	88.8
3216	C2	74–100	14.6	26.9	58.5	40.2	68.7

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0-11	-	0.1	-	-
11–29	-	0.1	-	-
29–55	-	0.1	-	-
55–74	-	0.1	-	-
74–100	-	0.1	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: DADARGHUGRI **BM Spot: 11 (Red soil)**

Profile No: P24 ***System: Forest (Teak)***

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1420 mm	Classification: Clayey-skeletal, mixed, hyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Dadarghugri, Sehapura, Dindori, Madhya Pradesh		Sampling Date: 11.06.2001

Physical Properties of Profile No. 24 (Dadarghugri, Dindori)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay / Total clay (%)
			Total				
			Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3208	A1	0–10	8.1	41.2	50.7	33.3	65.6
3209	Bt1	10–26	10.7	39.6	49.7	33.3	67.0
3210	C1	26–0	32.1	14.9	53.1	46.8	88.3
3211	C2	50–85	38.9	15.2	45.9	36.9	80.4

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–10	-	0.1	-	-
10–26	-	0.1	-	-
26–50	-	0.1	-	-
50–85	-	0.1	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KARKELI **BM Spot: 12 (Red soil)**

Profile No: P25 ***System: Reserve Forest (Sal)***

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1352 mm	Classification: Coarse-loamy, mixed, hyperthermic, *Typic Paleustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Karkeli Tolla, Bandhavgarh, Umeria, Madhya Pradesh		Sampling Date: 13.06.2001

Physical Properties of Profile No. 25 (Karkeli, Umeria)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm) Total			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3217	A	0–11	80.3	13.1	6.6	3.1	46.3
3218	Bw1	11–23	80.0	12.4	7.6	5.2	68.4
3219	Bw2	23–47	79.6	12.7	7.7	4.8	62.3
3220	Bt1	47–77	73.9	13.6	12.5	6.1	48.8
3221	Bt2	77–101	74.8	13.0	12.2	6.6	53.6
3222	Bt3	101–123	74.0	12.5	13.5	7.0	51.4
3223	Bt4	123–137	76.4	11.6	12.0	5.9	49.2
3224	Bt5	137–152	77.2	10.7	12.1	6.1	50.4

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–11	-	0.02	-	-
11–23	-	0.01	-	-
23–47	-	0.01	-	-
47–77	-	0.02	-	-
77–101	-	0.04	-	-
101–123	-	0.02	-	-
123–137	-	0.03	-	-
137–152	-	-	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KARKELI 1 **BM Spot: 12 (Red soil)**

Profile No: P26 ***System: Agriculture (Minor millet/Sweet potato)* (LM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1352 mm	Classification: Fine-loamy, mixed, hyperthermic, *Typic Paleustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Karkeli Tolla, Bandhavgarh (Tah), Umeria, Madhya Pradesh		Sampling Date: 13.06.2001

Physical Properties of Profile No. 26 (Karkeli, Umeria)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3225	Ap	0–15	79.3	12.5	8.2	7.3	89.0
3226	Bt1	15–39	65.1	21.4	13.5	9.1	67.4
3227	Bt2	39-62	54.2	21.3	24.5	17.1	69.8
3228	Bt3	62-84	39.9	29.9	30.2	21.6	71.3
3229	Bt4	84–127	38.6	28.7	32.7	21.5	65.7
3230	Bt5	127–155	52.2	20.8	27.0	16.6	61.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–15	-	0.01	-	-
15–39	-	0.04	-	-
39–62	-	0.07	-	-
62–84	-	0.12	-	-
84-127	-	0.10	-	-
127–155	-	0.08	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

RED SOILS

(Semi-arid moist)

(MAR : > 1000-850 mm)

- **Benchmark Spots: 8**
- **No. of Pedons: 3 (P16, P17, P18)**

Series: VIJAYPURA BM Spot: 8 (Red soil)

Profile No: P16 *System: Agriculture (Finger millet*) (FM)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 924 mm	Classification: Fine, kaolinitic, isohyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Nagenehalli, Bangalore, Karnataka		Sampling Date: 09.02.2001

Physical Properties of Profile No. 16 (Vijaypura, Bangalore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm) Total			Fine clay (%) (<0.0002)	Fine clay / Total clay (%)
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3146	Ap	0–9	68.7	7.7	23.6	18.7	79.2
3147	Bt1	9–22	50.3	7.0	42.7	25.1	58.8
3148	Bt2	22–42	35.2	9.4	55.4	33.8	61.0
3149	Bt3	42–69	32.0	19.5	48.5	32.8	67.6
3150	Bt4	69–98	32.5	13.7	53.8	38.7	72.0
3151	Bt5	98–120	36.4	16.5	47.1	31.6	67.1
3152	BC1	120–150	25.8	21.5	52.7	35.6	67.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0-9	-	0.02	-	-
9–22	1.7	0.07	-	-
22-42	1.6	0.10	-	-
42–69	1.6	0.08	-	-
69–98	1.5	0.10	-	-
98-120	1.5	0.08	-	-
120–150	-	0.09	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: VIJAYPURA 1 BM Spot: 8 (Red soil)

Profile No: P17 ***System: Agriculture (Finger millet/Pigeonpea/Red gram/Groundnut)*** **(ORG)**

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 924 mm	Classification: Fine-loamy, kaolinitic, isohyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Plot No. 16, GKVK Farm, Bangalore, Karnataka		Sampling Date: 9.02.2001

Physical Properties of Profile No. 17 (Vijaypura, Bangalore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm) Total Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)	Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			←----------------(% of <2 mm) ------------------→				
3153	Ap	0–12	76.6	8.7	14.7	9.7	66.0
3154	Bt1	12–37	59.7	8.8	31.5	12.4	39.3
3155	Bt2	37–62	53.2	13.2	33.6	15.7	46.7
3156	Bt3	62–92	50.0	12.8	37.2	16.8	45.2
3157	Bt4	92–116	50.1	15.6	34.3	18.6	54.2
3158	Bt5	116–143	50.2	17.1	32.7	11.4	35.0
3159	Bt6	143–155	48.7	25.1	26.2	12.0	45.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	-	0.01	-	-
12–37	-	0.08	-	-
37–62	-	0.09	-	-
62–92	-	0.10	-	-
92–116	-	0.09	-	-
116–143	-	0.10	-	-
143–155	-	0.08	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: VIJAYPURA 1 **BM Spot: 8 (Red Soil)**

Profile No: P18 ***System: Agriculture (Finger millet*) (HM)**

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 924 mm	Classification: Fine-loamy, kaolinitic, isohyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Opp. to Plot No. 16, GKVK Farm, Bangalore, Karnataka		Sampling Date: 10.02.2001

Physical Properties of Profile No. 18 (Vijaypura, Bangalore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3160	Ap	0–11	73.4	8.2	18.4	11.8	64.1
3161	Bt1	11–32	61.6	11.4	27.0	13.9	51.5
3162	Bt2	32–64	49.5	12.1	38.4	24.0	62.5
3163	Bt3	64-100	52.4	15.8	31.7	13.8	43.4
3164	Bt4	100–130	52.9	15.7	31.3	15.5	49.4
3165	Bt5	130–150	48.8	20.7	30.5	13.5	44.3

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–11	-	0.08	-	-
11–32	-	0.05	-	-
32–64	-	0.07	-	-
64–100	-	0.07	-	-
100–130	-	0.07	-	-
130–150	-	0.10	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

RED SOILS

(Semi-arid dry)

(MAR : 850-550 mm)

- **Benchmark Spots: 10, 17, 19, 21**
- **No. of Pedons: 5 (P22, P34, P37, P38, P41)**

Series: PALATHURAI BM Spot: 10 (Red soil)

Profile No: P22 *System: Agriculture (Horse gram/Vegetables)* (ORG)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 612 mm	Classification: Fine-loamy, mixed, isohyperthermic (cal), *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Palathurai, Coimbatore, Tamil Nadu		Sampling Date: 17.02.2001

Physical Properties of Profile No. 22 (Palathurai, Coimbatore)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm) Total			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3186	Ap	0–16	79.3	6.6	14.1	11.4	80.8
3187	Bt1	16–33	67.7	3.7	28.7	21.9	76.6
3188	Bt2	33–46	76.5	5.6	17.9	14.5	81.0
3189	Ck1	46–73	77.7	6.9	15.4	12.2	79.2
3190	Ck2	73–95	81.3	6.7	12.1	9.5	78.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–16	-	0.01	-	-
16–33	-	0.07	-	4.6
33–46	-	0.03	-	4.2
46–73	-	0.04	-	3.3
73–95	-	0.02	-	3.0

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: KAUKUNTLA **BM SPOT: 17 (Red soil)**

PROFILE NO: P34 ***System: Agriculture (Castor + Pigeonpea)* (FM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 674 mm	Classification: Fine, mixed, isohyperthermic, *Vertic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Kaukuntla, Atmakar (Tah), Mehboobnagar, Andhra Pradesh		Sampling Date: 14.12.2001

Physical Properties of Profile No. 34 (Kaukuntla, Mehboobnagar)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3348	Ap	0–8	81.9	6.3	11.8	18.5	89.8
3349	Bt1	8–27	40.7	7.4	51.9	45.1	82.0
3350	Bt2	27–43	43.8	9.6	46.6	45.9	84.0
3351	Bt3	43–68	45.9	6.6	47.5	33.9	71.4
3352	Bt4	68–98	41.6	8.6	49.8	38.5	77.3
3353	Bt5	98–121	43.0	7.1	49.9	36.0	72.1
3354	Bt6	121–156	47.5	7.7	44.8	32.8	73.2
3355	BC	156-+	57.0	8.6	34.4	24.8	72.1

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–8	-	0.03	-	-
8–27	1.5	0.19	-	-
27–43	1.6	0.14	-	-
43–68	1.6	0.15	-	-
68–98	1.8	0.17	-	-
98–121	-	0.14	-	-
121–156	1.8	0.14	-	-
156 – +	-	0.14	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: HAYATNAGAR BM SPOT: 19 (Red soil)

PROFILE NO: P37 *System: Agriculture (Sorghum-Castor)* (HM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Loamy-skeletal, mixed, isohyperthermic, *Typic Rhodustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: CRIDA Research Farm, Hayatnagar (Mandal), Rangareddy, Andhra Pradesh		Sampling Date: 16.12.2001

Physical Properties of Profile No. 37 (Hayatnagar, Rangareddy)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3371	Ap	0–12	73.4	3.4	23.2	21.3	91.8
3372	Bt1	12–29	66.9	7.5	25.6	21.6	84.3
3373	Bt2	29–67	69.0	8.8	22.2	18.2	82.0
3374	Bt3	67–101	66.8	10.2	23.0	18.8	81.7

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–12	-	0.1	-	-
12–29	-	0.1	-	-
29–67	-	0.1	-	-
67–101	-	0.1	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: HAYATNAGAR BM SPOT: 19 (Red soil)

PROFILE NO: P38 *System: Agriculture (Sorghum-Castor)* (LM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Loamy-skeletal, mixed, isohyperthermic, *Typic Rhodustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: CRIDA Research Farm, Hayatnagar (Village & Mandal), Rangareddy, Andhra Pradesh		Sampling Date: 16.12.2001

Physical Properties of Profile No. 38 (Hayatnagar, Rangareddy)

Laboratory No	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3376	Ap	0–16	72.8	9.8	17.4	16.0	92.0
3377	Bt1	16–41	59.3	12.0	28.7	23.4	81.5
3378	Bt2	41–62	45.6	18.8	35.6	27.9	78.4
3379	Bt3	62–89	64.1	13.0	22.9	17.9	78.2
3380	Cr	89–115	65.2	13.6	21.2	17.5	82.5

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–16	-	0.1	-	-
16–41	-	0.1	-	-
41–62	-	0.1	-	-
62–89	-	0.1	-	4.4
89–115	-	-	-	3.7

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Series: PATANCHERU BM SPOT: 21 (Black soil)

PROFILE NO: P41 *System: Permanent Fallow*

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Fine, mixed, isohyperthermic, *Typic Rhodustalfs*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ICRISAT Research Farm (RUS6B), Manmul (Near Talapur Gate), Patancheru (Mandal), Sangareddy, Medak, Andhra Pradesh		Sampling Date: 18.12.2001

Physical Properties of Profile No. 41 (Patancheru, Medak)

Laboratory No.	Horizon	Depth (cm)	Size class and particle diameter (mm)			Fine clay (%) (<0.0002)	Fine clay/ Total clay (%)
			Total				
			Sand (2–0.05)	Silt (0.05–0.002)	Clay (<0.002)		
			←----------------(% of <2 mm) ------------------→				
3394	A1	0–4	66.7	15.4	17.9	12.5	69.8
3395	A2	4–11	74.7	10.8	14.5	11.0	75.8
3396	Bt1	11–38	50.6	5.3	44.1	37.3	84.6
3397	Bt2	38–65	35.9	11.5	52.6	41.9	79.6
3398	Bt3	65–79	34.8	12.0	53.2	40.9	76.9
3399	BC	79–109	50.4	14.4	35.2	25.9	73.6
3400	C	109–163	61.1	16.4	22.5	17.5	77.8

Depth (cm)	BD[1] (Mgm^{-3})	COLE[2]	HC[3] ($cm\ hr^{-1}$)	WDC[4] (%)
0–4	-	0.04	-	-
4–11	-	0.03	-	-
11–38	1.6	0.11	-	-
38–65	1.7	0.16	-	-
65-79	-	0.14	-	-
79–109	1.7	0.12	-	-
109–163	1.8	0.12	-	-

- *Nil or not determined (wherever applicable)*

1. BD: Bulk Density
2. COLE: Coefficient of Linear Extensibility
3. HC: Hydraulic Conductivity
4. WDC: Water Dispersible Clay

Appendix-II

CHEMICAL PROPERTIES
OF
SELECTED SOILS
IN
28 BENCHMARK SPOTS

BLACK SOILS

(Sub-humid moist)

(MAR: > 1100 mm)

- **Benchmark Spots: 2, 3, 7, 13**
- **No. of Pedons: 6 (P4, P5, P6, P15, P27, P28)**

Series: PANJRI BM Spot: 2 (Black soil)

Profile No: P4 ***System: Agriculture (Cotton)* (HM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1127 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location : Panjri, CICR farm, Nagpur, Maharashtra		Sampling Date: 30.11.2000

Chemical Properties of Profile No. 4 (Panjri, CICR Farm, Nagpur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm $^{-1}$)	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–13	8.0	6.5	0.14	0.7	4.8	2.6
13–38	7.9	6.5	0.18	0.6	5.8	3.1
38–60	8.1	6.5	0.10	0.5	6.8	2.4
60–89	8.1	6.7	0.18	0.5	7.3	2.5
89–131	7.8	6.6	0.20	0.4	7.2	2.2
131–150	7.8	6.6	0.14	0.3	7.4	2.4

Depth (cm)	Extractable bases				CEC	BS (%)	ESP
	Ca	Mg	Na	K			
	←---------------------------------[cmol(p+)kg $^{-1}$]---------------------------→						
0–13	45.8	8.9	0.7	1.0	63.0	90	1.1
13–38	45.1	9.5	0.5	0.7	57.6	97	0.9
38–60	43.8	11.3	0.7	0.7	64.1	88	1.1
60–89	38.4	13.3	0.6	0.7	59.8	89	1.0
89–131	37.6	15.5	0.5	0.7	61.8	88	0.8
131–150	35.6	18.9	0.5	0.7	64.5	86	0.8

**Percent of water dispersible clay size carbonate*

Series: NABIBAGH BM Spot: 3 (Black soil)

Profile No: P5 ***System: Agriculture (Soybean-Wheat)* (HM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1209 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Nabibagh, Bhopal, Madhya Pradesh		Sampling Date: 5.12.2000

Chemical Properties of Profile No. 5 (Nabibagh, Bhopal)

Depth (cm)	pH (1:2)		EC (1:2) (dSm $^{-1}$)	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–15	7.9	6.7	0.18	0.8	5.1	1.7
15–42	7.9	6.5	0.13	0.7	5.9	1.6
42–69	7.9	6.5	0.12	0.6	5.5	1.7
69–107	7.9	6.5	0.12	0.6	5.0	2.1
107–135	8.0	6.6	0.13	0.6	5.3	1.8
135–150	8.1	6.7	0.13	0.5	5.6	1.6

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[cmol(p+)kg $^{-1}$]---→							
0–15	36.8	5.4	0.3	0.5	45.9	90	93	0.7
15–42	36.4	6.3	0.3	0.4	45.7	83	95	0.7
42–69	37.7	8.3	0.3	0.4	46.7	84	100	0.7
69–107	35.8	9.5	0.3	0.4	47.8	90	96	0.6
107–135	33.9	10.4	0.3	0.4	45.7	83	98	0.7
135–150	33.9	12.8	0.3	0.4	47.8	84	99	0.7

**Percent of water dispersible clay size carbonate*

Series: NABIBAGH BM Spot: 3 (Black soil)

Profile No: P6 *System: Agriculture (Soybean-Wheat)* (FM)

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1209 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Islamnagar, Bhopal, Madhya Pradesh		Sampling Date: 5.12.2000

Chemical Properties of Profile No. 6 (Nabibagh, Bhopal)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–23	7.8	6.5	0.18	0.7	3.8	1.6
23–42	7.9	6.6	0.11	0.5	4.5	2.0
42–81	8.0	6.6	0.13	0.5	4.2	2.7
81–122	8.0	6.5	0.12	0.5	4.1	2.4
122–150	8.0	6.7	0.18	0.4	5.3	2.7

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0–23	39.2	7.8	0.3	0.5	46.7	95	102	0.6
23–42	38.4	5.6	0.3	0.5	51.8	101	86	0.6
42–81	37.9	7.8	0.4	0.6	45.7	82	102	0.9
81–122	37.7	7.1	0.4	0.6	44.3	84	103	0.9
122–150	36.6	8.2	0.4	0.7	45.7	82	100	0.9

* *Percent of water dispersible clay size carbonate*

Series: BORIPANI BM Spot: 7 (Black soil)

Profile No: P15 *System: Forest (Teak)*

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1279 mm	Classification: Very fine, smectitic, hyperthermic,Ver*tic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Boripani-Sirajpur, Umred, Nagpur, Maharashtra		Sampling Date: 24.01.2001

Chemical Properties of Profile No. 15 (Boripani, Umred, Nagpur)

Depth (cm)	PH (1:2)		EC (1:2)	OC	$CaCO_3$	Clay CO_3
	H_2O	1*N* KCl	(dSm^{-1})	(%)	(%)	(%)
0–16	7.3	5.6	0.90	0.9	4.0	3.0
16–44	7.4	5.7	0.12	0.7	4.0	3.0
44–57	7.6	6.0	0.14	0.7	8.0	3.4
57–94	7.7	6.1	0.15	0.1	11.0	3.3

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0-–6	50.2	13.1	0.3	0.6	55.5	79	94	-
16–44	46.0	9.3	0.3	0.5	64.6	96	83	-
44–57	48.8	8.0	1.9	0.3	61.0	82	87	3
57–94	55.7	16.0	1.9	0.2	67.9	140	109	3

- *Nil or not determined (wherever applicable)*

Series: KHERI **BM Spot: 13 (Black soil)**

Profile No: P27 ***System: Agriculture (Paddy-Wheat)* (HM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1448 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: N R C for Weed Science Farm, Jabalpur, Madhya Pradesh		Sampling Date: 17.10.2001

Chemical Properties of Profile No. 27 (Kheri, Jabalpur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–20	7.1	6.2	0.16	0.6	3.5	4.6
20–42	7.4	6.4	0.18	0.4	4.0	4.2
42–63	7.1	5.8	0.11	0.3	2.9	4.5
63–84	7.2	6.0	0.13	0.3	2.9	4.3
84–115	7.4	6.3	0.20	0.6	3.5	3.9
115–160	7.5	6.3	0.09	0.4	3.7	4.5

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←--------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0–20	28.2	12.3	1.0	0.5	47.9	89	88	2
20-–2	36.3	12.4	0.8	0.7	52.1	80	96	2
42–63	37.8	14.8	1.2	0.5	52.1	84	104	2
63–84	25.6	16.0	0.4	0.5	52.1	85	81	1
84–115	27.0	14.6	0.6	0.4	49.3	82	86	1
115–160	26.5	16.0	1.0	0.4	47.9	85	91	2

- *Nil or not determined (wherever applicable)*

Series: KHERI **BM Spot: 13 (Black soil)**

Profile No: P28 ***System: Agriculture (Soybean/Paddy-Wheat)* (LM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1448 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Khajri Kheria, Jabalpur (Tah), Jabalpur, Madhya Pradesh		Sampling Date: 17.10.2001

Chemical Properties of Profile No. 28 (Kheri, Jabalpur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–14	7.5	6.4	0.13	0.7	3.6	3.7
14–32	7.6	6.5	0.15	0.6	4.4	3.7
32–61	7.6	6.5	0.14	0.5	3.9	3.7
61–82	7.6	6.5	0.15	0.6	7.1	3.9
82–112	7.8	6.7	0.16	0.4	7.3	4.2
112–133	7.7	6.6	0.16	0.6	5.0	4.1
133–156	8.0	6.6	0.15	0.4	5.5	4.0

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←------[cmol(p+)kg $^{-1}$]------→							
0–14	36.0	10.4	0.4	0.4	47.9	94	90	0.8
14–32	34.2	8.2	0.4	0.4	47.9	89	90	0.8
32–61	34.2	10.7	0.5	0.4	53.5	116	86	0.9
61–82	42.9	9.6	0.4	0.9	49.3	92	109	0.8
82–112	31.3	8.4	0.6	0.5	49.3	106	83	1.2
112–133	35.3	5.6	0.4	0.5	49.3	110	85	0.8
133–156	29.6	11.1	0.6	0.5	52.1	112	80	1.1

BLACK SOILS

Sub-humid dry

(MAR > 1100–1000 mm)

- **Benchmark Spots: 1, 4, 26, 27**
- **No. of Pedons: 9 (P1, P2, P3, P7, P8, P9, P48, P49, P50)**

Series: LINGA BM Spot: 1 (Black soil)

Profile No: P1 *System: Horticulture (Citrus)* (HM)

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1011 mm	Classification: Very fine, smectitic, hyperthermic *Typic Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Wandli, Katol, Nagpur, Maharashtra		Sampling Date: 04.11.2000

Chemical Properties of Profile No. 1 (Linga, Katol, Nagpur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay* CO_3 (%)
	H_2O	1*N* KCl				
0–15	8.0	6.9	0.17	0.9	6.5	1.8
15–41	7.9	6.7	0.14	0.6	6.2	2.5
41–70	7.9	6.6	0.17	0.7	6.8	2.6
70–95	7.8	6.4	0.19	0.5	7.4	2.5
95–135	7.8	6.5	0.22	0.4	8.4	3.0
135–155+	7.9	6.7	0.10	0.2	10.5	2.9

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←--------------------------[cmol(p+)kg^{-1}]---------------→							
0–15	36.8	10.7	0.3	1.1	48.9	74	74	0.5
15–41	37.0	9.8	0.4	0.6	47.8	69	76	0.6
41–70	38.0	9.8	0.7	0.6	49.1	69	78	1.2
70–95	38.5	13.4	1.0	0.6	53.6	75	103	1.9
95–135	38.2	16.6	1.0	0.7	56.5	78	100	1.8
135–155+	35.0	17.1	0.7	0.6	53.4	75	94	1.2

* *Percent of water dispersible clay size carbonate.*

Series: LINGA BM Spot: 1 (Black soil)

Profile No: P2 ***System: Agriculture (Soybean-Gram/Wheat)* (FM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1011 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Ridhora, Katol, Nagpur, Maharashtra		Sampling Date: 07.11.2000

Chemical Properties of Profile No. 2 (Linga, Katol, Nagpur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay* CO_3 (%)
	H_2O	1*N* KCl				
0–13	7.7	6.4	0.16	1.0	6.0	2.5
13–33	7.9	6.4	0.17	0.7	6.4	2.7
33–55	7.8	6.5	0.17	0.6	5.1	3.1
55–81	7.9	6.4	0.17	0.5	6.7	3.0
81–119	7.8	6.3	0.15	0.4	4.6	3.0
119–150+	7.8	6.5	0.05	0.3	6.2	2.8

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ---[cmol(p+)kg^{-1}]--- →							
0–13	40.4	10.8	0.3	0.5	57.7	90	90	0.52
13–33	40.7	6.4	0.3	0.6	56.4	85	85	0.53
33–55	40.7	8.2	0.3	0.6	56.6	86	88	0.53
55–81	40.9	11.0	0.3	0.6	56.4	80	94	0.53
81–119	38.6	13.4	0.3	1.0	56.0	80	95	0.54
119–150+	37.8	17.3	0.3	0.7	51.7	72	109	0.58

** Percent of water dispersible clay size carbonate.*

Series: LINGA BM Spot: 1 (Black soil)

Profile No: P3 *System: Horticulture (Citrus)* (LM)

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1011 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Wandli, Katol, Nagpur, Maharashtra		Sampling Date: 07.11.2000

Chemical Properties of Profile No. 3 (Linga, Katol, Nagpur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–16	7.9	6.6	0.16	1.0	6.9	2.8
16–44	8.0	6.4	0.15	0.7	7.6	3.1
44–69	7.8	6.6	0.14	0.6	7.2	2.5
69–102	7.9	6.4	0.16	0.5	9.0	3.0
102–128	8.0	4.5	0.17	0.5	9.2	2.9
128–150+	7.9	6.4	0.25	0.4	9.4	2.6

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	--------------------------------[cmol(p+)kg^{-1}]----------------------------							
0–16	40.0	11.8	0.6	1.3	65.2	99	82	0.9
16–44	43.6	10.9	0.5	0.7	64.1	96	87	0.8
44–69	41.3	10.2	0.6	0.7	63.0	94	84	0.9
69–102	40.2	13.1	0.7	0.7	63.0	89	87	1.1
102–128	37.8	14.4	0.9	0.8	61.8	87	87	1.4
128–150+	40.4	19.1	0.8	0.8	63.0	90	97	1.3

* *Percent of water dispersible clay size carbonate*

Series: SAROL BM Spot: 4 (Black soil)

Profile No: P7 ***System: Agriculture (Soybean-Wheat)*** **(HM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1053 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: National Research Centre for Soybean (ICAR) Farm, Bhavarkuan, Indore, M.P		Sampling Date: 7.12.2000

Chemical Properties of Profile No.7 (Sarol, Bhavarkuan, Indore)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–14	7.8	6.5	0.19	0.7	6.5	2.6
14–28	7.9	6.6	0.18	0.4	5.7	2.6
28–57	7.9	6.6	0.22	0.4	6.5	2.2
57–85	7.9	6.5	0.21	0.4	5.9	2.5
85–109	7.9	6.5	0.17	0.3	6.1	2.7
109–130	7.9	6.6	0.20	0.3	5.1	3.0
130–155	8.0	6.7	0.25	0.2	7.5	2.7

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ------------------[cmol(p+)kg^{-1}]------------------→							
0–14	37.0	10.7	0.7	0.9	51.3	84	96	1.4
14–28	38.1	6.9	1.0	0.7	47.8	73	97	2.0
28–57	36.7	11.7	1.5	0.5	43.5	64	116	3.4
57–85	35.8	13.1	0.7	0.7	43.5	57	115	1.6
85–109	35.2	12.3	1.2	0.8	60.9	97	81	2.0
109-130	35.4	13.1	1.4	0.7	58.6	93	86	2.4
130–155	27.8	17.4	1.8	0.5	56.5	90	84	3.2

* *Percent of water dispersible clay size carbonate*

Series: SAROL BM Spot: 4 (Black soil)

Profile No: P8 *System: Agriculture (Soybean-Wheat)* (FM)

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1053 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Limbodi, Indore, Madhya Pradesh		Sampling Date: 7.12.2000

Chemical Properties of Profile No. 8 (Sarol, Limbodi, Indore)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–18	7.8	6.6	0.15	0.8	6.6	2.9
18–45	7.9	6.6	0.14	0.7	6.3	2.5
45–66	7.9	6.6	0.14	0.5	6.6	3.1
66–90	7.9	6.6	0.16	0.5	5.6	3.1
90–124	7.9	6.7	0.16	0.4	7.5	2.4
124–159	8.0	6.7	0.13	0.3	6.9	2.7

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←------[cmol(p+)kg^{-1}]------→							
0–18	40.0	5.1	0.4	0.7	45.7	71	101	0.9
18–45	39.1	9.6	0.4	0.6	43.5	60	114	0.9
45–66	36.4	10.7	2.1	0.6	45.7	75	109	4.6
66–90	36.4	12.0	2.1	0.7	46.7	72	110	4.5
90–124	32.9	15.5	2.0	0.6	43.5	76	117	4.6
124–159	32.6	14.0	2.1	0.7	45.7	78	108	4.6

* *Percent of water dispersible clay size carbonate*

Series: SAROL BM Spot: 4 (Black soil)

Profile No: P9 *System: Agriculture or Agri-horticulture (Soybean-Chickpea in Mango Orchard*) (HM)

CLIMATE: SUB-HIMID (DRY) RAINFALL: 1053 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: National Research Centre for Soybean (ICAR) Farm, Bhavarkuan, Indore, Madhya Pradesh		Sampling Date: 7.12.2000

Chemical Properties of Profile No. 9 (Sarol, Bhavarkuan, Indore)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–17	7.7	6.6	0.23	0.9	5.7	2.0
17–44	7.8	6.6	0.19	0.5	5.3	2.4
44–79	7.9	6.6	0.15	0.5	6.8	2.5
79–102	7.9	6.6	0.09	0.5	5.9	2.7
102–127	7.9	6.7	0.11	0.4	7.2	3.0
127–152	8.0	6.8	0.22	0.2	7.2	2.7

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← [cmol(p+)kg^{-1}] →							
0–17	36.6	9.2	0.3	0.5	42.4	71	110	0.7
17–44	37.0	12.4	0.3	0.5	45.7	79	110	0.7
44–79	35.6	15.4	0.4	0.4	43.5	72	119	0.9
79–102	37.0	19.0	0.5	0.6	49.5	77	114	1.0
102–127	34.6	22.3	0.7	0.6	47.8	80	122	1.5
127–152	34.1	23.1	1.1	0.6	47.8	79	123	2.3

**Percent of water dispersible clay size carbonate.*

Series: NIPANI **BM SPOT: 26 (Black soil)**

PROFILE NO: P48 ***System: Agriculture (Cotton + Pigeonpea)* (FM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1071 mm	Classification: Fine, smectitic (cal), hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Nipani, Mandal-Tamsi, Adilabad, Andhra Pradesh		Sampling Date: 04.07.2002

Chemical Properties of Profile No. 48 (Nipani, Adilabad)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–13	8.0	7.1	0.28	1.1	24.0	4.0
13–35	8.0	7.1	0.21	0.6	26.3	4.4
35–62	8.1	7.2	0.23	0.5	24.7	3.4
62–88	8.4	7.4	0.17	0.4	25.0	3.1
88–127	8.4	7.4	0.09	0.3	24.7	3.3
127–155+	8.5	7.4	0.30	0.3	25.2	3.3

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← [cmol(p+)kg^{-1}] →							
0–13	23.2	9.6	0.9	1.0	42.2	97	82	2
13–35	19.2	17.9	0.9	0.3	40.4	78	94	2
35–62	14.3	22.2	0.8	0.3	39.5	80	95	2
62–88	9.9	27.8	0.9	0.2	43.2	84	89	2
88–127	8.3	30.1	1.3	0.2	42.2	85	94	3
127–155+	8.3	28.3	1.5	0.2	42.2	80	91	4

Series: PANGIDI **BM SPOT: 27 (Black soil)**

PROFILE NO: P49 ***System: Agriculture (Cotton + Pigeonpea)*** **(FM)**

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1071 mm	Classification: Very fine, smectitic, hyperthermic, *Typic, Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Pangidi, Jainur Mandal, Adilabad, Andhra Pradesh		Sampling Date: 05.07.2002

Chemical Properties of Profile No. 49 (Pangidi, Adilabad)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–14	7.6	6.5	0.07	1.1	5.8	3.1
14–36	7.7	6.6	0.14	1.0	6.8	3.3
36–62	7.7	6.6	0.07	1.0	6.2	3.2
62–87	7.8	6.6	0.12	0.9	6.3	3.0
87–110	7.8	6.7	0.13	0.6	8.0	3.1
110+	---------- Limestone rock ----------					

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	--------------------------------[cmol(p+)kg^{-1}]----------------------------							
0–14	48.9	12.2	0.8	1.3	66.7	95	95	1
14–36	45.5	13.1	0.9	1.2	64.0	85	95	1
36–62	46.9	12.8	1.0	1.2	65.8	88	94	2
62–87	42.0	18.0	0.8	0.9	66.8	85	92	1
87–110	39.2	18.3	1.2	1.0	64.9	82	92	1
110+	---------- Limestone rock ----------							

Series: PANGIDI 1 BM SPOT: 27 (Black soil)

PROFILE NO: P50 *System: Agriculture (Soybean)* (ITDA)

CLIMATE: SUB-HUMID (DRY) RAINFALL: 1071 mm	Classification: Very Fine, smectitic, hyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ITDA – ICRISAT Project Area, Pangidi, Jainur Mandal, Adilabad, Andhra Pradesh		Sampling Date: 05.07.2002

Chemical Properties of Profile No. 50 (Pangidi, Adilabad)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–11	7.4	6.3	0.09	1.2	4.1	3.0
11–27	7.5	6.3	0.13	0.8	6.2	3.3
27–41	7.5	6.3	0.19	0.7	11.1	3.2
41–55	7.8	6.6	0.21	0.2	16.7	2.9

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	--------------------------------[cmol(p+)kg^{-1}]----------------------------							
0–11	32.3	12.9	0.9	1.5	65.8	84	72	1
11–27	37.2	11.6	0.8	0.7	64.9	79	78	1
27–41	45.0	13.7	0.9	0.5	65.8	81	91	1
41–55	36.3	13.5	0.9	0.2	63.5	-	80	1

- *Nil or not determined (wherever applicable)*

BLACK SOILS

(Semi-arid moist)

(MAR > 1000–850 mm)

- **Benchmark Spots: 5, 22**
- **No. of Pedons: 4 (P10, P11, P12, P42)**

Series: ASRA BM Spot: 5 (Black soil)

Profile No: P10 *System: Agriculture* (*Cotton/Green gram + Pigeonpea*) (FM) (ORG)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 975 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Asra, Bahtkuli, Amravati, Maharashtra		Sampling Date: 16.01.2001

Chemical Properties of Profile No. 10 (Asra, Amravati)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–14	7.8	6.5	0.11	0.8	9.3	1.4
14–40	8.0	6.5	0.13	0.7	9.4	1.4
40–59	8.0	6.5	0.21	0.6	10.7	1.2
59–91	8.1	6.6	0.04	0.6	11.0	3.2
91–125	8.3	6.7	0.11	0.5	13.7	1.8
125–150	8.3	6.7	0.25	0.4	15.6	1.9

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←--------[cmol(p+)kg^{-1}]--------→							
0–14	46.2	14.4	0.7	1.1	65.2	104	96	1
14–40	44.7	16.6	1.3	0.8	61.0	94	104	2
40–59	42.0	17.8	2.8	0.7	63.0	105	100	4
59–91	38.2	20.2	4.2	0.7	63.0	99	100	7
91–125	28.9	22.0	5.8	0.6	62.2	103	92	9
125–150	25.8	22.4	8.6	1.1	66.7	111	87	13

* *Percent of water dispersible clay size carbonate*

Series: ASRA **BM Spot: 5 (Black soil)**

Profile No: P11 ***System: Agriculture (Soybean + Pigeonpea)* (FM)**

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 975 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Asra, Bahtkuli, Amravati, Maharashtra		Sampling Date: 16.01.2001

Chemical Properties of Profile No. 11 (Asra, Amravati)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–14	7.8	6.7	0.10	0.8	8.1	1.3
14–35	7.9	6.7	0.15	0.7	9.4	1.8
35–69	7.8	6.7	0.14	0.6	9.6	1.9
69–107	7.9	6.7	0.32	0.6	9.7	1.9
107–150	8.1	6.7	0.23	0.5	10.6	2.1

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	[cmol(p+)kg^{-1}]							
0–14	40.1	12.2	0.4	1.1	60.9	100	88	0.6
14–35	39.0	14.9	0.6	0.8	56.5	90	97	1.0
35–69	38.0	16.9	0.8	0.8	59.8	96	94	1.3
69–107	37.8	19.0	1.7	0.8	63.0	98	94	2.8
107–150	36.2	22.2	2.6	0.8	61.9	100	100	4.2

* *Percent of water dispersible clay size carbonate*

Series: ASRA BM Spot: 5 (Black soil)

Profile No: P12 *System: Agriculture (Cotton + Pigeonpea / Soybean-Chickpea)* (HM)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 975 mm	Classification: Very fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Seed Multiplication Centre, Walgaon, Amravati (Tah), Amravati, Maharashtra		Sampling Date: 17.01.2001

Chemical Properties of Profile No. 12 (Asra, Walgaon, Amravati)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–12	7.8	6.5	0.13	1.1	5.2	1.8
12–40	7.9	6.5	0.24	0.8	5.4	1.7
40–79	7.8	6.3	0.19	0.7	5.6	2.0
79–116	7.8	6.4	0.18	0.6	6.5	1.8
116–150	7.9	6.4	0.18	0.6	8.5	1.4

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	---------------------------------[cmol(p+)kg^{-1}]-----------------------------							
0–12	49.7	12.0	1.9	1.2	69.6	98	93	3
12–40	54.5	12.7	2.6	0.9	71.7	106	99	4
40–79	52.1	14.1	1.6	0.7	76.1	104	90	2
79–116	51.2	17.2	1.2	0.8	76.1	113	92	2
116–150	47.8	14.3	1.0	0.8	69.6	105	92	1

* *Percent of water dispersible clay size carbonate*

Series: BHATUMBRA BM SPOT: 22 (Black soil)

PROFILE NO: P42 *System: Agriculture (Sorghum + Pigeonpea/ Black gram–Chickpea)* (FM)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 977 mm	Classification: Very fine, smectitic, isohyperthermic, *Udic Haplusterts*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Bhatumbra, Bhakli (Tah), Bidar, Karnataka		Sampling Date: 04.01.2002

Chemical Properties of Profile No. 42 (Bhatumbra, Bhakli, Bidar)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	8.2	6.8	0.40	1.0	9.0	3.4
12–37	8.2	6.6	0.20	0.8	10.2	3.3
37–79	7.8	6.5	0.26	0.9	10.0	3.3
79–110	8.0	6.8	0.13	0.6	10.8	3.8

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	---[cmol(p+)kg^{-1}]---							
0–12	29.1	24.8	2.6	0.8	58.6	97	98	4
12–37	33.7	21.4	2.3	0.3	58.6	99	98	4
37–79	20.7	24.4	2.0	0.3	49.8	82	95	4
79–110	20.1	38.8	2.0	0.4	63.0	90	97	3

- *Nil or not determined (wherever applicable)*

BLACK SOILS

(Semi-arid dry)

(MAR: 850–550 mm)

- **Benchmark Spots: 6, 9, 14, 16, 18, 20, 23, 24, 25**
- **No. of Pedons: 17 (P13, P14, P19, P20, P21, P29, P32, P33, P35, P36, P39, P40, P43, P44, P45, P46, P47)**

Series: PARAL BM Spot: 6 (Black soils)

Profile No: P13 *System: Agriculture (Cotton+Pigeonpea / Sorghum)* (LM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 793 mm	Classification: Very fine, smectitic hyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Paral (Parala), Akot, Akola, Maharashtra		Sampling Date: 19.01.2001

Chemical Properties of Profile No. 13 (Paral, Akola)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–9	8.0	6.7	0.18	0.7	9.7	1.9
9–35	8.2	6.7	0.21	0.6	10.0	2.3
35–69	8.4	6.7	0.30	0.6	10.2	3.0
69–105	8.4	6.8	0.39	0.6	10.4	2.8
105–132	8.5	6.8	0.25	0.6	10.2	3.9
132–150	8.5	6.8	0.62	0.5	11.8	2.9

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ---[cmol(p+)kg^{-1}]--- →							
0–9	36.3	7.6	0.7	1.2	54.4	98	84	1
9–35	32.2	9.2	2.3	0.9	56.5	96	79	4
35–69	28.5	11.0	3.9	0.9	47.8	84	92	8
69–105	28.2	13.9	7.4	0.9	51.8	83	97	14
105–132	23.7	14.6	8.8	0.9	52.5	85	91	17
132–150	18.9	14.5	9.1	0.8	43.3	77	100	21

* *Percent of water dispersible clay size carbonate*

Series: PARAL BM Spot: 6 (Black soil)

Profile No: P14 *System: Agriculture (Cotton + Pigeonpea / Sorghum)* (HM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 793 mm	Classification: Very fine, smectitic, hyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Paral (Parala), Akot, Akola, Maharashtra		Sampling Date: 19.01.2001

Chemical Properties of Profile No. 14 (Paral, Akola)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–8	7.9	6.7	0.18	0.6	9.5	2.8
8–35	8.3	6.7	0.21	0.6	12.8	3.0
35–68	8.4	6.7	0.28	0.5	13.2	3.6
68–97	8.5	6.7	0.23	0.5	12.0	3.7
97–129	8.5	6.8	0.41	0.3	14.3	3.8
129–150	8.6	6.9	0.61	0.3	16.7	3.0

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← [cmol(p+)kg^{-1}] →							
0–8	36.4	8.7	0.5	1.3	48.4	82	97	1
8–35	30.8	12.4	2.1	0.8	47.5	74	97	4
35–68	29.0	13.4	3.6	0.9	48.4	75	97	7
68–97	27.1	14.3	3.8	0.9	48.1	76	96	8
97–129	22.6	15.6	4.3	0.9	43.8	69	99	10
129–150	19.3	16.1	8.5	0.8	44.8	73	99	19

* *Percent of water dispersible clay size carbonate*

Series: KOVILPATTI **BM Spot: 9 (Black soil)**

Profile No: P19 ***System: Agriculture (Sorghum/Cotton-2year rotation)* (ORG)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 660 mm	Classification: Very fine, smectitic, isohyperthermic, *Gypsic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: TNAU Res. Stn. Farm, Kovilpatti, Thoothokudi, Tamil Nadu		Sampling Date: 14.02.2001

Chemical Properties of Profile No. 19 (Kovilpatti, Thoothokudi)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–6	8.0	6.7	0.10	0.3	5.4	2.7
6–20	8.0	6.7	0.13	0.4	4.3	2.5
20–41	7.9	6.6	0.16	0.4	5.3	2.7
41–74	8.0	6.5	0.16	0.3	7.9	2.8
74–104	7.9	6.5	0.17	0.3	12.5	3.4
104–118	7.9	6.6	0.11	0.3	12.8	3.2
118–128	7.4	6.7	1.86	0.3	15.6	3.1
128–140+	7.5	6.8	1.97	0.1	17.4	4.5

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ---[cmol(p+)kg^{-1}]--- →							
0–6	47.3	11.3	0.3	0.7	60.9	108	98	0.6
6–20	48.2	13.1	0.3	0.6	56.7	92	110	0.5
20–41	50.8	14.2	0.4	0.4	65.2	100	101	0.6
41–74	50.6	18.0	0.6	0.4	63.0	96	110	1.0
74–104	53.7	15.3	0.8	0.4	71.7	107	98	1.1
104–118	55.5	14.0	0.9	0.5	65.2	90	109	1.4
118–128	57.2	12.3	1.0	0.5	54.4	77	131	1.9
128–140+	47.9	8.1	0.1	0.2	32.6	132	173	0.3

- *Nil or not determined (wherever applicable)*

Series: KOVILPATTI 1 **BM Spot: 9 (Black soil)**

Profile No: P20 ***System: Wasteland***

CLIMATE: SEMI-ARID (DRY) RAINFALL: 660 mm	Classification: Fine, smectitic, isohyperthermic, *Leptic Gypsiusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Avalnatham, Behind TNAU Farm, Kovilpatti, Thoothokudi, Tamil Nadu		Sampling Date: 14.02.2001

Chemical Properties of Profile No. 20 (Kovilpatti, Thoothokudi)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–11	7.8	6.6	0.15	0.6	8.8	2.2
11–31	7.9	6.6	0.13	0.4	5.2	2.9
31–55	7.9	6.5	0.13	0.5	14.5	2.7
55–79	7.9	6.6	0.13	0.4	10.6	3.3
79–91	8.0	6.7	0.15	0.4	10.6	3.2
91–105	8.0	6.7	0.16	0.3	6.0	2.7

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←- -- ---------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0–11	39.9	8.5	0.4	0.6	50.0	93	99	1
11–31	43.2	12.4	0.5	0.4	56.7	94	99	1
31–55	45.9	11.4	0.5	0.4	58.5	102	100	1
55–79	46.8	12.5	0.5	0.4	65.2	113	92	1
79–91	38.4	12.0	0.5	0.4	54.4	79	94	1
91–105	40.0	12.6	0.5	0.4	58.7	90	91	1

- *Nil or not determined (wherever applicable)*

Series: KOVILPATTI **BM Spot: 9 (Black soil)**

Profile No: P21 ***System: Agriculture (Cotton + Black Gram)*** **(HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 660 mm	Classification: Very fine, smectitic, isohyperthermic, *Gypsic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Kumaragiri, Ettayapuram (Kovilpatti), Thoothokudi, Tamil Nadu		Sampling Date: 15.02.2001

Chemical Properties of Profile No. 21 (Kovilpatti, Thoothokudi)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–9	8.0	6.7	0.12	0.5	7.4	2.6
9–20	8.0	6.7	0.18	0.4	6.7	2.7
20-–8	8.0	6.5	0.16	0.4	7.2	2.8
58–100	7.9	6.5	0.18	0.4	8.7	2.8
100–126	7.5	6.7	1.70	0.2	25.1	-
126–155	7.5	6.7	1.96	0.1	17.8	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←[cmol(p+)kg^{-1}]→							
0–9	39.1	7.8	0.2	0.6	52.2	99	91	0.4
9–20	41.6	8.6	0.3	0.7	52.2	88	98	0.5
20–58	46.9	9.9	0.3	0.6	57.7	89	100	0.4
58–100	47.1	9.4	0.3	0.3	60.9	92	94	0.5
100–126	50.0	6.7	0.3	0.2	63.0	156	91	0.4
126–155	47.6	5.1	0.3	0.2	53.3	101	100	0.5

- *Nil or not determined (wherever applicable)*

Series: SEMLA **BM Spot: 14 (Black soil)**

Profile No: P29 ***System: Agriculture (Cotton / Groundnut-Wheat)* (ORG)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 635 mm	Classification: Fine, smectitic(cal), hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Semla, Gondal, Rajkot, Gujarat		Sampling Date: 06.11.2001

Chemical Properties of Profile No. 29 (Semla, Rajkot)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–17	7.8	6.7	0.17	0.8	15.4	4.1
17–42	7.8	6.7	0.12	0.7	18.2	4.3
42–57	7.9	6.7	0.29	0.7	18.7	4.1
57–86	7.9	6.6	0.08	0.5	14.5	3.9
86–115	8.0	6.6	0.43	0.6	17.2	4.9
115–144	7.9	6.6	0.16	0.5	17.8	4.7
144–155	8.0	6.8	0.11	0.2	23.3	3.6

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ---[cmol(p+)kg^{-1}]--- →							
0–17	33.8	15.1	0.7	1.1	49.5	141	103	1.4
17–42	36.4	17.3	1.1	0.5	50.1	115	110	2.2
42–57	30.9	22.0	2.6	0.3	53.2	106	105	4.9
57–86	33.8	15.6	2.2	0.8	48.3	96	108	4.5
86–115	30.2	21.8	3.3	0.3	52.5	106	106	6.3
115–144	28.9	16.4	1.6	0.7	47.0	98	101	3.4
144–155	18.0	16.9	2.9	0.2	37.5	111	101	7.7

Series: JHALIPURA **BM Spot: 16 (Black soil)**

Profile No: P32 ***System: Agriculture (Soybean-Wheat)* (FM/1)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 842 mm	Classification : Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Jhalipura, Kota (Tah), Kota, Rajasthan		*Sampling Date: 10.11.2001*

Chemical Properties of Profile No. 32 (Jhalipura, Kota)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	8.3	6.8	0.24	0.58	0.9	5.7
12–31	8.3	6.8	0.21	0.34	5.7	4.3
31–48	7.7	6.5	0.21	0.33	5.4	10.5
48–74	8.1	6.8	0.18	0.30	5.9	8.7
74–110	8.3	6.7	0.17	0.31	7.3	9.3
110–148	8.1	6.8	0.19	0.27	7.1	9.7
148–165	8.4	6.9	0.24	0.25	7.1	9.6

Depth (cm)	Extractable bases				CEC	Clay CEC	*BS (%)	ESP
	Ca	Mg	Na	K				
	← --------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0–12	26.2	8.0	1.3	0.6	36.5	81	98	2.5
12–31	30.9	7.3	0.9	0.4	36.5	77	108	2.5
31–48	32.3	9.1	0.6	0.4	40.2	77	103	1.5
48–74	32.0	7.9	0.6	0.4	37.0	75	111	1.6
74–110	25.8	12.0	0.6	0.4	36.5	73	106	1.6
110–148	30.0	9.1	0.7	0.4	37.0	73	109	1.9
148–165	28.9	11.6	1.6	0.7	36.0	72	113	4.4

** Presence of base-rich zeolites is confirmed by XRD. These zeolites are responsible for higher BS%.*

Series: JHALIPURA **BM Spot: 16 (Black soil)**

Profile No: P33 ***System: Agriculture (Paddy-Wheat)* (FM/2)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 842 mm	Classification: Fine, smectitic, hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Daslana (Jhalipura), Kota, Rajasthan		Sampling Date: 11.11.2001

Chemical Properties of Profile No. 33 (Jhalipura, Kota)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–13	8.1	6.9	0.16	0.7	6.7	2.8
13–36	8.2	6.9	0.11	0.4	11.0	3.0
36–58	8.1	6.9	0.61	0.3	22.8	2.9
58–82	8.5	7.0	0.20	0.3	12.0	2.7
82–107	8.4	6.9	0.20	0.2	12.1	2.9
107–132	8.6	7.1	0.17	0.2	14.4	2.8
132–156	8.7	7.1	0.19	0.2	14.8	2.7

Depth (cm)	Extractable bases				CEC	Clay CEC	*BS (%)	ESP
	Ca	Mg	Na	K				
	---------------------------------[cmol(p+)kg^{-1}]-----------------------------							
0–13	25.5	14.9	1.5	0.5	40.2	79	105	4
13–36	28.3	10.0	1.2	0.7	37.4	74	107	3
36–58	24.2	11.4	1.6	0.4	31.3	63	120	5
58–82	24.3	9.8	1.3	0.4	34.8	68	102	4
82–107	24.6	8.5	1.6	0.4	33.7	67	104	5
107–132	21.4	11.2	1.4	0.5	32.4	82	106	4
132–156	19.0	7.9	1.7	0.5	28.3	83	103	6

** Presence of base-rich zeolites is confirmed by XRD. These zeolites are responsible for higher BS%.*

Series: JAJAPUR BM SPOT: 18 (Black soil)

PROFILE NO: P35 ***System: Agriculture (Sorghum/ Pigeonpea + Green gram)*** **(FM1)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 792 mm	Classification: Fine, smectitic, isohyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Jajapur, Narayanpeth (Mandal), Makthal, Mehboobnagar, Andhra Pradesh		Sampling Date: 15.12.2001

Chemical Properties of Profile No. 35 (Jajapur, Mehboobnagar)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	7.8	6.9	0.36	0.5	3.5	4.5
12–35	8.5	7.0	0.18	0.3	3.4	6.7
35–48	8.5	7.1	0.21	0.3	5.4	6.2
48–76	8.9	7.2	0.20	0.3	5.5	6.3
76–96	9.1	7.2	0.57	0.2	10.4	9.6
96–126	9.1	7.4	0.76	0.2	12.8	13.1
126–155	9.2	7.3	1.00	0.2	11.8	19.6

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	--------------------------------[cmol(p+)kg^{-1}]----------------------------							
0–12	20.1	6.0	1.3	0.4	27.8	79	100	5
12–35	17.5	9.2	2.0	0.2	28.7	81	101	7
35–48	15.6	8.9	3.0	0.2	27.8	75	100	11
48–76	12.8	9.7	4.6	0.1	29.6	81	92	16
76–96	10.6	14.0	7.2	0.2	31.3	74	102	23
96–126	9.3	11.8	7.9	0.1	28.7	68	101	28
126–155	9.5	14.8	10.0	0.2	36.5	75	94	27

- *Nil or not determined (wherever applicable)*

Series: JAJAPUR 1 **BM SPOT: 18 (Black soil)**

PROFILE NO: P36 ***System: Agriculture (Paddy-Paddy)* (FM/2)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 792 mm	Classification: Fine-loamy, smectitic, isohyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Jajapur, Narayanpeth (Mandal), Makthal, Mehboobnagar, Andhra Pradesh		Sampling Date: 15.12.2001

Chemical Properties of Profile No. 36 (Jajapur, Mehboobnagar)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–10	8.2	7.1	0.26	1.5	2.2	4.2
10-–8	8.7	7.2	0.24	0.6	2.0	4.6
28–53	8.5	7.2	0.22	0.3	3.5	5.5
53–76	8.8	7.2	0.21	0.2	8.7	7.1
76–98	8.8	7.3	0.16	0.1	16.6	8.2
98–128	8.5	7.2	0.19	0.1	12.3	7.0
128–150	8.6	7.2	0.19	0.1	10.8	6.6
150+	8.8	7.2	0.20	0.1	10.1	5.4

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ---------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0–10	10.3	8.5	2.0	0.2	18.2	69	115	11
10–28	8.8	5.5	2.0	0.2	13.9	58	119	14
28–53	8.7	8.8	2.2	0.2	17.4	66	114	12
53–76	10.0	11.4	2.3	0.2	22.2	66	107	10
76–98	9.5	10.7	1.9	0.2	22.6	63	99	8
98–128	9.9	8.4	1.7	0.2	19.1	61	105	9
128–150	10.4	8.0	1.6	0.1	17.4	61	115	9
150+	9.5	8.4	2.2	0.2	17.8	67	113	12

Series: KASIREDDIPALLI **BM SPOT: 20 (Black soil)**

PROFILE NO: P39 ***System: Agriculture (Soybean-Pigeonpea)* (HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Fine, smectitic, isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ICRISAT Farm BW7, Patancheru, Ramachandrapuram, Medak, Andhra Pradesh		Sampling Date: 18.12.2001

Chemical Properties of Profile No. 39 (Kasireddipalli, Medak)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	7.5	6.4	0.14	1.0	4.2	7.9
12–31	7.8	6.6	0.15	0.6	4.5	9.6
31–54	7.8	6.5	0.22	0.4	6.2	10.8
54–84	8.2	6.7	0.31	0.4	5.1	12.0
84–118	8.1	6.6	0.23	0.5	8.6	7.5
118–146	8.2	6.6	0.30	0.5	8.4	7.9
146–157	8.2	6.8	0.62	0.3	7.4	11.3

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←-----[cmol(p+)kg^{-1}]-----→							
0–12	36.5	12.5	1.0	0.5	50.4	97	100	2
12–31	34.7	14.4	1.0	0.4	54.3	105	93	2
31–54	31.9	19.0	1.8	0.4	55.6	103	95	3
54–84	28.9	15.3	3.7	0.4	56.4	98	86	7
84–118	38.7	10.2	4.2	0.7	61.6	109	87	7
118–146	34.6	16.8	4.2	0.5	58.2	98	96	7
146–157	24.4	22.8	5.1	0.7	55.2	92	96	9

Series: KASIREDDIPALLI **BM SPOT: 20 (Black soil)**

PROFILE NO: P40 ***System: Agriculture (Fallow-Chickpea)* (TM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Fine, smectitic, isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: ICRISAT Farm, Kasireddipalli, Patancheru, Medak, Andhra Pradesh		Sampling Date: 18.12.2001

Chemical Properties of Profile No. 40 (Kasireddipalli, Medak)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	7.8	6.7	0.08	0.6	5.9	3.4
12–30	7.8	6.7	0.16	0.4	6.2	3.1
30–59	8.1	6.6	0.17	0.4	6.0	3.0
59–101	8.3	6.7	0.10	0.4	6.4	3.3
101–130	8.3	6.8	0.29	0.4	6.5	3.2
130–160	8.2	6.8	0.47	0.1	9.1	3.4

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←--------------------------------[cmol(p+)kg^{-1}]--------------------------→							
0–12	34.2	10.7	0.9	0.4	48.7	102	95	1.8
12–30	34.9	12.7	1.9	0.3	52.1	101	96	3.6
30–59	29.3	14.0	3.7	0.3	52.2	99	91	7.1
59–101	26.2	14.4	6.8	0.3	53.5	96	89	12.7
101–130	35.8	11.6	4.6	0.5	57.8	97	91	7.9
130–160	25.1	16.2	11.1	0.5	49.5	85	107	22.2

Series: TELIGI **BM SPOT: 23 (Black soil)**

PROFILE NO: P43 ***System: Agriculture (Paddy-Paddy)* (LM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 632 mm	Classification: Fine, smectitic, isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ARS (UAS, Dharwad) Research Farm, Siruguppa, Bellary, Karnataka		Sampling Date: 07.01.2002

Chemical Properties of Profile No. 43 (Teligi, Bellary)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–10	7.9	6.6	0.16	1.5	10.5	3.0
10–25	8.0	6.7	0.12	0.8	10.7	3.2
25–44	8.0	6.7	0.05	0.8	12.2	3.4
44–69	7.8	6.5	0.25	0.7	10.3	3.9
69–97	7.6	6.4	0.27	0.7	5.9	3.7
97–123	8.7	6.7	0.36	0.5	15.1	4.7
123–150	8.5	6.7	0.24	0.5	16.2	3.7

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←[cmol(p+)kg^{-1}]→							
0–10	42.2	9.6	0.8	0.6	51.4	92	104	1.6
10–25	44.7	12.9	0.9	0.4	52.2	88	113	1.7
25–44	43.3	14.4	1.0	0.4	54.2	93	109	1.8
44–69	34.7	12.4	1.7	0.3	42.0	90	117	4.0
69–97	32.0	10.2	1.4	0.6	40.8	100	108	3.4
97–123	37.8	15.1	9.6	0.3	57.2	109	110	16.8
123–150	37.3	15.6	9.6	0.5	55.5	91	114	17.3

Series: TELIGI **BM SPOT: 23 (Black soil)**

PROFILE NO: P44 ***System: Agriculture (Paddy-Paddy)* (HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 632 mm	Classification: Very Fine, smectitic, isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ARS (UAS, Dharwad) Farm, Siruguppa, Bellary, Karnataka		Sampling Date: 07.01.2002

Chemical Properties of Profile No. 44 (Teligi, Bellary)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–10	7.4	6.5	0.24	1.0	5.4	3.2
10–34	8.0	6.6	0.19	0.7	9.3	2.9
34–54	8.2	6.7	0.19	0.5	9.9	3.3
54–89	8.3	6.7	0.33	0.5	10.6	3.3
89–119	8.3	6.7	0.44	0.5	11.5	3.8
119–142	8.4	6.7	0.25	0.4	16.2	4.6
142–150	8.4	6.8	0.64	0.2	22.0	3.8

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←[cmol(p+)kg^{-1}]→							
0–10	26.2	6.3	0.8	0.3	40.1	103	89	2
10–34	40.2	17.1	1.8	0.8	60.4	97	99	3
34–54	39.7	14.1	3.3	0.3	60.4	99	95	5
54–89	37.0	12.3	7.6	0.6	62.9	99	91	12
89–119	35.1	17.1	7.6	0.6	63.8	99	95	12
119–142	31.3	15.0	13.6	0.3	63.6	99	94	21
142–150	36.1	10.2	7.1	0.1	56.8	89	94	13

Series: KONHERI **BM SPOT: 24 (Black soil)**

PROFILE NO: P45 ***System: Agriculture (Pigeonpea / Sunflower-Sorghum)*** **(FM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 745 mm	Classification: Fine, smectitic, hyperthermic, *Vertic Haplustepts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Konheri, Mohol, Solapur, Maharashtra		Sampling Date: 09.01.2002

Chemical Properties of Profile No. 45 (Konheri, Solapur)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–13	8.1	6.9	0.11	0.3	9.2	1.3
13–33	8.1	6.9	0.12	0.3	8.8	1.5
33–69	8.2	6.9	0.11	0.3	10.3	1.4
69–93	8.2	6.9	0.12	0.2	10.3	1.6
93–113	8.6	6.9	0.18	0.2	12.4	1.4
113–129	8.7	7.3	0.21	0.3	24.0	3.1
129–160	8.6	7.2	0.28	0.2	16.8	3.5

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[$cmol(p+)kg^{-1}$]---→							
0–13	32.6	10.9	0.7	0.2	48.0	136	92	1
13–33	26.4	14.6	1.0	0.1	47.2	114	89	2
33–69	25.3	15.5	1.0	0.1	49.0	114	85	2
69–93	21.9	19.9	1.2	0.1	46.2	107	93	3
93–113	20.4	20.6	3.0	0.1	47.1	108	93	6
113–129	10.8	22.5	2.7	0.1	35.0	78	103	8
129–160	16.8	15.5	3.7	0.1	42.4	73	85	7

- *Nil or not determined (wherever applicable)*

Series: KONHERI 1 **BM SPOT: 24 (Black soil)**

PROFILE NO: P46 ***System: Agriculture (Pigeonpea / Sunflower-Sorghum)* (LM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 745 mm	Classification: Very fine, smectitic, hyperthermic, *Leptic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Konheri, Mohol, Solapur, Maharashtra		Sampling Date: 10.01.2002

Chemical Properties of Profile No. 46 (Konheri, Solapur)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–13	8.1	6.7	0.13	0.9	14.9	3.4
13–34	8.1	6.7	0.12	0.8	14.6	3.7
34–53	8.1	6.7	0.12	0.8	14.3	3.8
53–83	8.0	6.7	0.14	0.8	16.2	3.6
83–117	8.2	7.0	0.14	0.2	24.2	3.8
117–155	8.2	7.0	0.10	0.1	24.1	3.4

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[cmol(p+)kg^{-1}]---→							
0–13	57.8	10.6	0.9	0.7	67.0	86	110	1
13–34	54.5	12.6	0.8	0.3	67.2	86	105	1
34–53	52.6	13.9	1.1	0.3	64.0	81	109	1
53–83	53.7	14.4	0.9	0.3	67.7	86	103	1
83–117	26.6	9.4	0.7	0.4	34.2	44	106	2
117–155	21.6	12.0	0.8	0.3	32.3	45	116	2

- *Nil or not determined (wherever applicable)*

Series: KALWAN BM SPOT: 25 (Black soil)

PROFILE NO: P47 *System: Agriculture (Sugarcane/Sorghum-Wheat/ Chickpea)* (FM)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 742 mm	Classification: Fine, smectitic (Cal), hyperthermic, *Typic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Kalwan, Kalwan, Nasik, Maharashtra		Sampling Date: 20.02.2002

Chemical Properties of Profile No. 47 (Kalwan, Nasik)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–20	8.0	6.9	0.23	1.0	2.8	3.0
20–48	7.8	6.5	0.25	0.7	3.7	3.5
48–70	7.8	6.5	0.30	0.6	7.3	4.0
70–88	7.9	6.5	0.33	0.3	12.9	4.0
88–133	8.1	6.6	0.23	0.2	14.4	4.0
133–154	8.3	6.7	0.20	0.1	13.7	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←----[cmol(p+)kg^{-1}]----→							
0–20	28.2	24.7	1.9	0.5	46.9	97	118	4.0
20–48	27.6	14.0	1.6	0.4	37.8	80	115	4.2
48–70	30.9	18.2	2.1	0.5	44.5	87	116	4.7
70–88	29.6	18.7	2.3	0.5	42.3	103	121	5.4
88–133	24.7	18.2	1.8	0.5	34.6	162	131	5.2
133–154	21.3	16.0	1.5	0.5	32.3	265	122	4.6

- *Nil or not determined (wherever applicable)*

BLACK SOILS

(Arid)

(MAR: < 550 mm)

- **Benchmark Spots: 15, 28**
- **No. of Pedons: 4 (P30, P31, P51, P52)**

Series: SOKHDA **BM Spot: 15 (Black soil)**

Profile No: P30 ***System: Agriculture (Cotton–Pearl millet)* (FM/I)**

CLIMATE: ARID RAINFALL: 533 mm	Classification: Fine, smectitic (cal), hyperthermic, *Leptic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Sokhda, Morbi, Rajkot, Gujarat		Sampling Date: 07.11.2001

Chemical Properties of Profile No. 30 (Sokhda, Rajkot)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0\–-11	7.9	6.8	0.18	0.3	20.1	4.5
11–32	8.0	6.8	0.10	0.4	20.2	4.5
32–57	7.9	6.8	0.14	0.3	21.5	5.1
57–91	7.9	6.8	0.17	0.3	21.7	4.7
91–107	8.0	7.0	0.14	0.1	23.2	5.1
107–135	8.0	7.0	0.18	0.1	24.0	4.3

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←-------------------------------[cmol(p+)kg^{-1}]--------------------------→							
0–11	26.1	7.7	0.7	0.8	45.1	110	78	2
11–32	25.3	8.4	0.9	0.7	45.1	110	78	2
32–57	23.3	9.0	0.9	0.5	42.3	99	80	2
57–91	22.0	9.0	1.0	0.4	39.4	89	82	2
91–107	14.4	10.5	1.0	0.2	33.8	128	77	3
107–135	14.9	8.7	0.8	0.2	32.6	135	75	2

- *Nil or not determined (wherever applicable)*

Series: SOKHDA 1 **BM Spot: 15 (Black soil)**

Profile No: P31 ***System: Agriculture (Cotton–Pearl millet / Linseed)* (FM/2)**

CLIMATE: ARID RAINFALL: 533 mm	Classification: Fine, smectitic (cal), hyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Sokhda, Morbi (Tah), Rajkot, Gujarat		Sampling Date: 07.11.2001

Chemical Properties of Profile No. 31 (Sokhda, Rajkot)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–11	8.2	7.0	0.18	0.5	21.9	5.8
11–37	8.4	7.1	0.18	0.5	21.4	5.2
37–63	8.7	7.1	0.24	0.4	21.5	6.2
63–98	8.8	7.1	0.35	0.4	22.0	5.8
98–145	8.6	7.1	0.43	0.3	21.6	8.7
145–160	8.5	6.9	0.22	0.2	11.6	4.5

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←----[cmol(p+)kg^{-1}]----→							
0–11	21.1	9.8	1.0	0.7	40.6	128	80	2
11–37	20.4	8.9	1.2	0.6	40.6	133	74	3
37–63	18.0	13.1	2.6	0.5	42.0	105	81	6
63–98	14.4	13.8	4.7	0.5	40.6	99	82	12
98–145	12.7	15.6	8.5	0.5	42.3	99	88	20
145–160	11.8	14.0	10.1	0.5	46.5	93	78	22

Series: NIMONE **BM SPOT: 28 (Black soil)**

PROFILE NO: P51 ***System: Agriculture (Cotton-Wheat/ Chickpea [Irrigated])(*****HM)**

CLIMATE: ARID RAINFALL: 520 mm	Classification: Very fine, smectitic (cal), isohyperthermic *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Cotton Project (Plot No/Survey No. 51C), Area of MPKV, Village- Rahuri Khurd, Rahuri, Ahmednagar, Maharashtra		Sampling Date: 18/12/2002

Chemical Properties of Profile No. 51 (Nimone, Rahuri)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–13	8.4	7.0	0.22	0.9	14.1	-
13–38	8.5	7.1	0.22	0.7	14.4	-
38–55	8.4	7.1	0.31	0.6	15.7	-
55–94	8.4	7.1	0.64	0.6	14.5	-
94–128	8.5	7.1	1.63	0.5	15.8	-
128–150+	8.5	7.1	2.34	0.4	16.3	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[cmol(p+)kg^{-1}]---→							
0–13	37.8	15.6	1.1	0.8	50.6	76	110	2.2
13–38	36.4	15.6	1.1	0.5	48.5	72	110	2.3
38–55	33.3	20.0	2.8	0.4	48.7	74	116	5.7
55–94	31.6	20.0	4.2	0.4	48.7	70	115	8.6
94–128	31.0	23.1	5.2	0.5	48.3	68	124	10.8
128–150+	39.9	20.7	4.7	0.4	42.8	61	153	11.0

- *Nil or not determined (wherever applicable)*

Series: NIMONE BM SPOT: 28 (Black soil)

PROFILE NO: P52 *System: Agriculture (Sugarcane [Ratoon]-Soybean/Wheat/ Chickpea)* (FM)

CLIMATE: ARID RAINFALL: 520 mm	Classification: Fine, smectitic (cal), isohyperthermic, *Sodic Haplusterts*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Village - Nirmal Pimpari., Rahata (Tah), Ahmednagar, Maharashtra		Sampling Date: 18.12.2002

Chemical Properties of Profile No. 52 (Nimone, Ahmednagar)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	8.7	7.2	0.21	0.7	22.1	0.3
12–29	8.8	7.2	0.30	0.8	22.0	1.4
29–50	8.9	7.3	0.36	0.7	22.2	0.9
50–84	9.5	7.3	0.07	0.6	22.2	0.6
84–113	9.7	7.5	0.05	0.4	25.5	1.1
113–148	9.7	7.6	0.57	0.3	26.3	1.8
148–165+	9.7	7.6	0.56	0.3	27.4	1.2

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←--------------------------------[cmol(p+)kg^{-1}]---------------------------→							
0–12	20.4	15.2	2.2	0.4	37.3	69	102	5.8
12–29	20.6	15.6	3.0	0.3	36.2	67	109	8.4
29–50	18.2	17.4	4.9	0.3	35.8	64	114	13.6
50–84	12.5	15.6	8.4	0.3	36.4	63	101	23.2
84–113	6.6	14.2	10.1	0.4	32.1	56	110	31.4
113–148	6.0	16.0	10.1	0.3	29.4	51	110	34.3
148–165+	7.2	17.6	9.4	0.3	30.8	53	112	30.5

RED SOILS

(Sub-humid moist)

(MAR: > 1100 mm)

- **Benchmark Spots: 11, 12**
- **No. of Pedons: 4 (P23, P24, P25, P26)**

Series: DADARGHUGRI BM Spot: 11 (Red soil)

Profile No: P23 *System: Agriculture (Maize/Mustard)* (FM)

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1420 mm	Classification: Clayey-skeletal, mixed, hyperthermic *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Dadarghugri, Sehapura, Dindori, Madhya Pradesh		Sampling Date: 11.06.2001

Chemical Properties of Profile No. 23 (Dadarghugri, Dindori)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–11	5.2	4.7	0.01	2.4	-	-
11–29	5.3	4.5	0.09	2.0	-	-
29–55	5.3	4.6	0.03	1.3	-	-
55–74	5.3	4.9	0.03	0.8	-	-
74–100	5.4	4.9	0.04	1.0	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	--------------------------------[cmol(p+)kg^{-1}]----------------------------							
0–11	11.4	2.7	0.4	2.1	26.1	71	64	2
11–29	13.9	3.7	0.3	0.9	26.5	48	71	1
29–55	12.2	5.3	0.3	0.4	24.3	44	75	1
55–74	14.5	6.8	0.3	0.5	24.3	44	91	1
74–100	15.2	6.6	0.3	0.7	24.8	42	92	1

Series: DADARGHUGRI **BM Spot: 11 (Red soil)**

Profile No: P24 ***System: Forest (Teak)***

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1420 mm	Classification: Clayey-skeletal, mixed, hyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Dadarghugri, Sehapura, Dindori, Madhya Pradesh		Sampling Date: 11.06.2001

Chemical Properties of Profile No. 24 (Dadarghugri, Dindori)

Depth (cm)	pH (1:2)		EC (1:2) (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–10	5.1	4.9	0.08	3.3	-	-
10–26	5.2	4.2	0.04	2.1	-	-
26–50	5.3	4.4	0.04	1.5	-	-
50–85	5.6	4.4	0.03	1.2	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←[cmol(p+)kg^{-1}]→							
0–10	18.4	9.0	0.3	1.4	40.8	80	71	-
10–26	16.4	9.2	0.3	0.6	35.2	71	75	-
26–50	16.0	9.6	0.4	0.7	35.2	66	76	-
50–85	15.8	12.0	0.2	0.5	35.4	77	80	-

- *Nil or not determined (wherever applicable)*

Series: KARKELI **BM Spot: 12 (Red soil)**

Profile No: P25 ***System: Reserve Forest (Sal)***

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1352 mm	Classification: Coarse-loamy, mixed, hyperthermic, *Typic Paleustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Karkeli Tolla, Bandhavgarh, Umeria, Madhya Pradesh		Sampling Date: 13.06.2001

Chemical Properties of Profile No. 25 (Karkeli, Umeria)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–11	5.2	4.5	0.04	1.9	-	-
11–23	5.2	4.7	0.01	0.7	-	-
23–47	5.2	4.8	0.03	0.5	-	-
47–77	5.2	4.5	0.02	0.3	-	-
77–101	5.2	4.3	0.01	0.3	-	-
101–123	5.3	4.3	0.02	0.3	-	-
123–137	5.3	4.3	0.02	0.3	-	-
137–152	5.3	4.5	0.02	0.3	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←--------[cmol(p+)kg^{-1}]--------→							
0–11	0.7	0.1	0.3	0.2	5.7	86	23	-
11–23	1.0	0.8	0.2	0.1	5.2	68	41	-
23–47	0.5	0.2	0.2	0.1	4.4	57	23	-
47-77	0.6	0.5	0.7	0.7	3.0	24	38	-
77–101	0.4	0.8	0.2	0.1	3.5	29	43	-
101–123	0.4	0.4	0.3	0.1	4.6	34	27	-
123–137	0.2	0.2	0.3	0.1	3.9	33	20	-
137–152	1.4	0.6	0.2	0.1	6.9	58	32	-

* *Percent of water dispersible clay size carbonate*

\- *Nil or not determined (wherever applicable)*

Series: KARKELI 1 **BM Spot: 12 (Red soil)**

Profile No: P26 ***System: Agriculture (Minor millet/Sweet potato)* (LM)**

CLIMATE: SUB-HUMID (MOIST) RAINFALL: 1352 mm	Classification: Fine-loamy, mixed, hyperthermic, *Typic Paleustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Karkeli Tolla, Bandhavgarh (Tah), Umeria, Madhya Pradesh		Sampling Date: 13.06.2001

Chemical Properties of Profile No. 26 (Karkeli, Umeria)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–15	5.1	4.6	0.04	0.7	-	-
15–39	5.3	4.2	0.04	0.5	-	-
39–62	5.4	4.4	0.03	0.7	-	-
62–84	5.3	4.4	0.02	0.5	-	-
84–127	5.4	4.5	0.01	0.3	-	-
127–155	5.5	4.6	0.01	0.2	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←[cmol(p+)kg^{-1}]→							
0–15	0.6	0.2	0.2	0.2	3.2	39	30	-
15–39	2.7	1.1	0.3	0.2	5.2	38	54	-
39–62	5.0	2.6	0.3	0.4	6.1	25	98	-
62–84	7.0	3.2	0.2	0.3	4.7	16	77	-
84–127	7.5	3.6	0.2	0.3	9.7	30	84	-
127–155	5.7	2.7	0.2	0.2	7.8	29	76	-

- *Nil or not determined (wherever applicable)*

RED SOILS

(Semi-arid moist)

(MAR: > 1000-850 mm)

- **Benchmark Spots: 8**
- **No. of Pedons: 3 (P16, P17, P18)**

Series: VIJAYPURA BM Spot: 8 (Red soil)

Profile No: P16 *System: Agriculture (Finger millet)* (FM)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 924 mm	Classification: Fine, kaolinitic, isohyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Nagenehalli, Bangalore, Karnataka		Sampling Date: 09.02.2001

Chemical Properties of Profile No. 16 (Vijaypura, Bangalore)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–9	5.4	4.7	0.18	1.4	-	-
9–22	6.0	5.0	0.05	0.8	-	-
22–42	6.3	5.2	0.06	0.5	-	-
42–69	6.7	5.6	0.05	0.4	-	-
69–98	6.7	5.2	0.05	0.3	-	-
98–120	7.3	6.3	0.11	0.2	-	-
120–150	7.4	6.5	0.15	0.2	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[cmol(p+)kg^{-1}]---→							
0–9	2.5	0.9	0.2	0.2	5.0	21	74	-
9–22	4.4	1.3	0.3	0.1	7.2	17	83	-
22–42	7.1	1.9	0.3	0.1	10.2	18	91	-
42–69	8.0	1.8	0.3	0.1	12.6	26	81	-
69–98	8.5	1.4	0.7	0.1	12.8	24	83	-
98–120	11.3	1.0	0.3	0.1	13.0	28	97	-
120–150	11.5	1.0	0.3	0.1	13.9	26	92	-

* *Percent of water dispersible clay size carbonate*

\- *Nil or not determined (wherever applicable)*

Series: VIJAYPURA 1 BM Spot: 8 (Red soil)

Profile No: P17 *System: Agriculture (Finger millet/ Pigeonpea/ Red gram/ Groundnut)*(ORG)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 924 mm	Classification: Fine-loamy, kaolinitic, isohyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Plot No. 16, GKVK Farm, Bangalore, Karnataka		Sampling Date: 9.02.2001

Chemical Properties of Profile No.17 (Vijaypura, Bangalore)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–12	5.4	4.7	0.07	0.5	-	-
12–37	4.4	3.8	0.06	0.5	-	-
37–62	5.1	5.0	0.07	0.5	-	-
62–92	5.3	4.7	0.08	0.5	-	-
92–116	6.7	5.0	0.10	0.2	-	-
116–143	5.7	5.2	0.04	0.2	-	-
143–155	5.5	5.3	0.03	0.1	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←------[cmol(p+)kg^{-1}]------→							
0–12	1.50	0.41	0.11	0.07	3.3	34	64	-
12–37	1.20	0.33	0.05	0.06	2.8	23	57	-
37–62	1.80	0.55	0.09	0.04	3.4	22	73	-
62–92	1.80	0.75	0.09	0.04	3.7	22	73	-
92–116	1.50	0.67	0.11	0.04	3.0	16	77	-
116–143	1.60	0.55	0.11	0.04	2.8	25	82	-
143–155	1.45	0.49	0.09	0.03	2.8	23	75	-

* *Percent of water dispersible clay size carbonate*

\- *Nil or not determined (wherever applicable)*

Series: VIJAYPURA 1 BM Spot: 8 (Red soil)

Profile No: P18 *System: Agriculture (Finger millet*) (HM)

CLIMATE: SEMI-ARID (MOIST) RAINFALL: 924 mm	Classification: Fine-loamy, kaolinitic, isohyperthermic, *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Opp. to Plot No. 16, GKVK Farm, Bangalore, Karnataka		Sampling Date: 10.02.2001

Chemical Properties of Profile No. 18 (Vijaypura, Bangalore)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3* (%)
	H_2O	1*N* KCl				
0–11	5.8	5.3	0.11	1.0	-	-
11–32	4.6	3.9	0.09	0.7	-	-
32–64	5.5	4.9	0.08	0.6	-	-
64–100	5.7	5.1	0.03	0.4	-	-
100–130	6.0	5.4	0.06	0.2	-	-
130–150	6.5	5.6	0.05	0.1	-	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	---------------------------------[cmol(p+)kg^{-1}]-----------------------------							
0–11	1.80	0.41	0.04	0.13	4.1	22	58	-
11–32	1.50	0.37	0.10	0.06	7.0	26	29	-
32–64	2.40	0.55	0.11	0.03	5.2	13	58	-
64–100	2.40	1.22	0.17	0.07	6.3	20	60	-
100–130	2.30	1.23	0.13	0.07	4.6	14	80	-
130–150	2.30	1.08	0.17	0.06	5.2	17	69	-

* *Percent of water dispersible clay size carbonate*

\- *Nil or not determined (wherever applicable)*

RED SOILS

(Semi-arid dry)

(MAR: 850–550 mm)

- **Benchmark Spots: 10, 17, 19, 21**
- **No. of Pedons: 5 (P22, P34, P37, P38, P41)**

Series: PALATHURAI BM Spot: 10 (Red soil)

Profile No: P22 *System: Agriculture (Horse gram/Vegetables)* (ORG)

CLIMATE: SEMI-ARID (DRY) RAINFALL: 612 mm	Classification: Fine-loamy, mixed, isohyperthermic (cal), *Typic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Palathurai, Coimbatore, Tamil Nadu		Sampling Date: 17.02.2001

Chemical Properties of Profile No. 22 (Palathurai, Coimbatore)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–16	7.8	7.4	0.18	0.8	1.0	-
16–33	7.8	6.9	0.14	0.7	1.5	60.2
33–46	7.8	7.1	0.25	0.5	10.4	-
46–73	7.9	7.3	0.13	0.3	11.7	87.4
73–95	8.1	7.3	0.14	0.3	10.9	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←[cmol(p+)kg^{-1}]→							
0–16	3.2	1.6	0.3	0.6	5.7	40	100	-
16–33	10.5	-	0.3	0.5	10.7	37	106	-
33–46	8.5	1.2	0.3	0.3	8.0	45	129	-
46–73	5.9	1.1	0.4	0.2	9.9	64	79	-
73–95	6.1	1.0	0.3	0.2	6.6	54	115	-

- *Nil or not determined (wherever applicable)*

Series: KAUKUNTLA **BM SPOT: 17 (Red soil)**

PROFILE NO: P34 ***System: Agriculture (Castor + Pigeonpea)* (FM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 674 mm	Classification: Fine, mixed, isohyperthermic, *Vertic Haplustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: Kaukuntala, Atmakar (Tah), Mehboobnagar, Andhra Pradesh		Sampling Date: 14.12.2001

Chemical Properties of Profile No. 34 (Kaukuntala, Mehboobnagar)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–8	6.3	5.6	0.06	1.1	1.2	-
8–27	5.7	4.4	0.06	0.6	1.4	-
27–43	6.0	4.7	0.05	0.5	.0.4	-
43–68	6.2	4.9	0.04	0.4	0.9	-
68–98	6.0	4.9	0.31	0.3	0.6	-
98–121	6.8	5.2	0.04	0.2	0.9	-
121–156	6.8	5.2	0.04	0.2	1.1	-
156-+	6.7	5.2	0.04	0.2	1.8	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[cmol(p+)kg^{-1}]---→							
0–8	2.5	1.9	0.9	0.3	12.2	103	45	7
8–27	6.3	2.1	0.7	0.4	17.2	33	55	4
27–43	8.3	3.0	0.9	0.3	16.4	35	76	6
43–68	9.5	3.3	0.7	0.4	17.2	36	81	4
68–98	9.9	3.4	0.9	0.4	18.2	36	80	5
98–121	11.7	2.8	0.7	0.4	19.2	38	81	4
121–156	11.1	2.8	0.9	0.4	18.2	41	84	5
156-+	11.5	2.0	0.8	0.3	15.2	44	95	5

- *Nil or not determined (wherever applicable)*

Series: HAYATNAGAR **BM SPOT: 19 (Red soil)**

PROFILE NO: P37 ***System: Agriculture (Sorghum-Castor)* (HM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Loamy-skeletal, mixed, isohyperthermic, *Typic Rhodustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur.
Location: CRIDA Research Farm, Hayatnagar (Mandal), Rangareddy, Andhra Pradesh		Sampling Date: 16.12.2001

Chemical Properties of Profile No. 37 (Hayatnagar, Rangareddy)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–12	5.6	4.4	0.05	1.0	0.3	-
12–29	5.2	4.1	0.04	0.9	0.4	-
29–67	5.8	4.6	0.06	0.6	0.4	-
67–101	6.1	4.6	0.07	0.5	0.6	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←---[cmol(p+)kg^{-1}]---→							
0–12	3.1	2.1	1.0	0.2	7.0	11	256	14
12–29	5.0	1.6	0.8	0.2	8.3	33	91	10
29–67	6.3	1.2	0.9	0.2	8.3	37	104	11
67–101	7.3	3.0	0.7	0.3	10.3	45	110	7

- *Nil or not determined (wherever applicable)*

Series: HAYATNAGAR **BM SPOT: 19 (Red soil)**

PROFILE NO: P38 ***System: Agriculture (Sorghum-Castor)* (LM)**

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Loamy-skeletal, mixed, isohyperthermic, *Typic Rhodustalfs*	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: CRIDA Research Farm, Hayatnagar (Village & Mandal), Rangareddy, Andhra Pradesh		Sampling Date: 16.12.2001

Chemical Properties of Profile No. 38 (Hayatnagar, Rangareddy)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–16	5.2	4.2	0.05	1.1	0.4	-
16–41	6.0	4.8	0.07	0.8	0.6	-
41–62	6.3	5.1	0.07	0.7	0.7	-
62–89	7.2	6.5	0.17	0.5	1.5	69.5
89–115	7.4	6.7	0.19	0.4	1.5	67.6

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	←------[cmol(p+)kg^{-1}]------→							
0–16	3.2	2.7	0.7	0.2	7.5	15	272	13
16–41	7.1	3.8	0.7	0.2	10.3	36	115	7
41–62	8.1	7.3	0.6	0.2	17.2	48	94	3
62–89	15.4	7.0	0.7	0.2	21.1	92	110	3
89–115	15.0	4.5	0.8	0.2	20.1	95	102	4

- *Nil or not determined (wherever applicable)*

Series: PATANCHERU **BM SPOT: 21 (Black soil)**

PROFILE NO: P41 ***System: Permanent fallow***

CLIMATE: SEMI-ARID (DRY) RAINFALL: 764 mm	Classification: Fine, mixed, isohyperthermic, *Typic Rhodustalfs*.	Analysis at: Division of Soil Resource Studies, NBSS&LUP, Nagpur
Location: ICRISAT Research Farm (RUS6B), Manmul (Near Talapur Gate), Patancheru (Mandal), Sangareddy, Medak, Andhra Pradesh		Sampling Date: 18.12.2001

Chemical Properties of Profile No. 41 (Patancheru, Medak)

Depth (cm)	pH (1:2)		EC (1:2) (d Sm^{-1})	OC (%)	$CaCO_3$ (%)	Clay CO_3 (%)
	H_2O	1*N* KCl				
0–4	6.4	5.8	0.17	3.1	0.6	-
4–11	6.2	5.1	0.05	1.6	0.4	-
11–38	6.1	5.1	0.03	1.0	0.6	-
38–65	6.1	4.8	0.05	0.7	0.8	-
65–79	6.0	4.7	0.06	0.6	0.8	-
79–109	6.4	4.7	0.05	0.4	0.9	-
109–163	6.6	4.6	0.04	0.2	0.9	-

Depth (cm)	Extractable bases				CEC	Clay CEC	BS (%)	ESP
	Ca	Mg	Na	K				
	← ---[cmol(p+)kg^{-1}]--- →							
0–4	4.2	3.8	0.8	1.2	10.0	36	120	8
4–11	3.3	3.4	0.6	0.3	10.0	24	76	6
11–38	8.3	3.3	0.7	0.3	11.3	26	111	6
38–65	12.5	5.2	0.8	0.3	18.2	35	103	4
65–79	12.4	5.9	0.7	0.4	21.1	40	92	3
79–109	14.8	5.7	0.8	0.2	23.1	66	93	4
109–163	16.3	5.0	0.9	0.3	22.2	100	101	4

- *Nil or not determined (wherever applicable)*

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