Global Theme on Agroecosystems

Report no. 21

Morphological Properties of Red and Black Soils of Selected Benchmark Spots in Semi-Arid Tropics of India

International Crops Research Institute for the Semi-Arid Tropics

National Bureau of Soil Survey & Land Use Planning (NBSS&LUP)
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Abstract

Morphological properties of red and black soils are described. Soil depth, color, texture, consistence, structure, roots, coarse fragments, nodules, effervescence, slickensides, cracks and clay cutans are described in sub-humid (moist and dry), semi-arid (moist, dry) and arid ecosystems.

Soils under high management are darker in color indicating more soil organic carbon content. Wet consistence such as *very sticky* and *very plastic* corresponds with those horizons in black soils showing well developed slickensides. *Firm* moist consistence may indicate development of sodicity problems provided there are no or very less amount of soil modifiers such as zeolites and gypsum.

Higher root density in soils corresponds with lower degree of $CaCO_3$ content as indicated by *slight* effervescence with dilute HCl in the field. Black soils contained coarse fragments of 3-8%, 1-10%, 1-10% and 5-15% in sub-humid (moist), semi-arid (moist), semi-arid (dry) and arid bioclimatic system, respectively. In general, the degree of effervescence is in line with size and quantity of coarse fragments and calcium concretions observed in the field.

In general black soils under high management show slickensides at lower depths. With decrease in mean annual rainfall, the depth of occurrence of slickensides decreases from 60 cm in sub-humid (moist) to 30 cm in semi-arid (dry) bioclimate. Management interventions including irrigation in drier tracts push the slickensides further down in the profile.

The formation of Sodic Haplusterts indicate poor organic carbon accumulation but a very high inorganic carbon sequestration in soils of dry part of the arid bioclimatic system. It manifests natural chemical degradation of soils with mean annual rainfall of <550 mm.

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Contents

1. Introduction

The study of soil morphology provides a scope to know more about the external features and structures of soil body in a profile such as color, texture, structure, horizonation, consistence, mottles, roots, coarser fragments; and other features such as concretions, depth and width of cracks, presence of slickensides and reaction with dilute HCl to show effervescence, confirming the presence of carbonates. The morphological features are often related with the physical, chemical and mineralogical properties of soils. This essentially shows the interactions of various soil forming factors on some soil characteristics important to maintain the soil health by sequestering carbon in both organic and inorganic forms.

2. Materials and Methods

2.1 Background

Recent studies of forest soils [Alfisols (red soils) of eastern India] (Saikh et al. 1998) indicate that soil organic carbon (SOC) content of soils sharply declines when put to cultivation. Reduction of SOC level is significant even within 5 to 15 years of cultivation. Saikh et al. (1998) 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. 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) vary across sites.

Increase in SOC increases the SCD of soils and the ratio of internal/external exchange sites (Poonia and Niedderbudde 1990). The dominant soils in the semi-arid tropics (SAT) are black soils (Vertisols and their intergrades, with some inclusions of Entisols of the hills) and associated red soils. All these soils are dominated by smectites (Pal and Deshpande 1987a, 1987b, Pal et al. 1989, 2000, Bhattacharyya et al. 1993). Presence of smectite also increases the SCD of soils, which offer 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% SOC in surface layers of black soils from Mandla, Madhya Pradesh. More recently, Dalal and Canter (2000) also indicated the scope of higher SOC content in the shrink-swell soils of Australia. To find out the sufficient and deficient zone 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, 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 million ha. This value is more than 3 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 in the Indian subcontinent could be fruitfully prioritized for carbon management.

2.2 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 million ha area

in this subcontinent. While selecting the soil-sites, the specific bioclimatic systems were identified in view of the mean annual rainfall (MAR) as mentioned below:

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

2.3 Soils

The soils for this study were chosen from the already established benchmark (BM) sites because each soil will cover a widely extensive area in the landscape and monitoring the BM sites would be easy. Though some soils, which are chosen, do not belong to the BM sites, it has been ascertained that each of these soil series cover an area of more than 20,000 ha (area required for any soil series to have BM status).

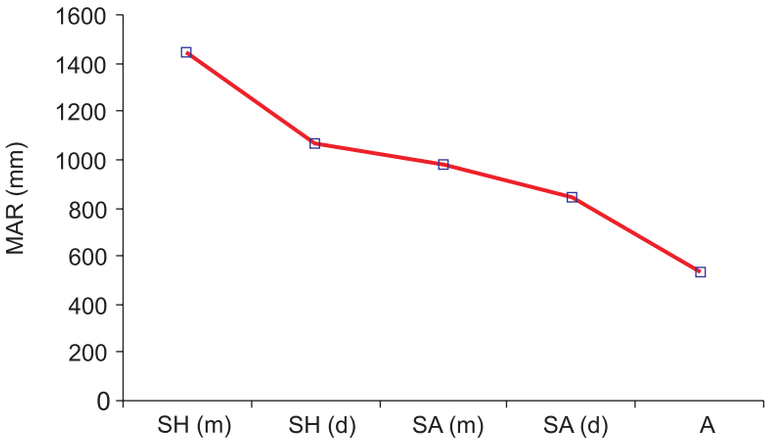

Figure 2.1. Mean annual rainfall (MAR) at the BM spots.
(Note: SH (m) = Sub-humid (moist); SH (d) = Sub-humid (dry);
SA (m) = Semi-arid (moist); SA (d) = Semi-arid (dry); A = Arid.)

In order to keep the soils similar for comparison, 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 BM sites were selected. Some associated black soils under forest were also, however, taken as control. In addition, some red soils from both cultivated and forest (as control) ecosystems 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 those of red soils.

For this study 28 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.

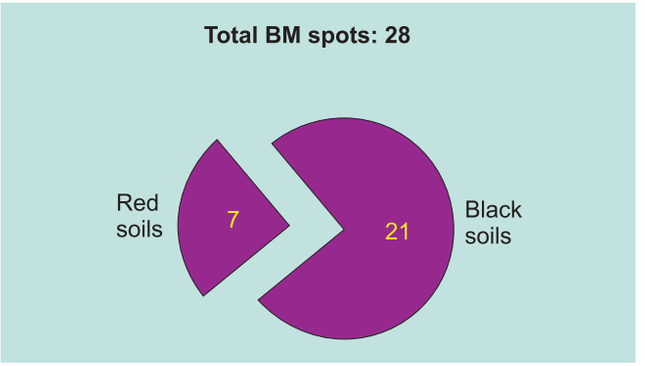

Figure 2.2. Distribution of BM spots by soil type.

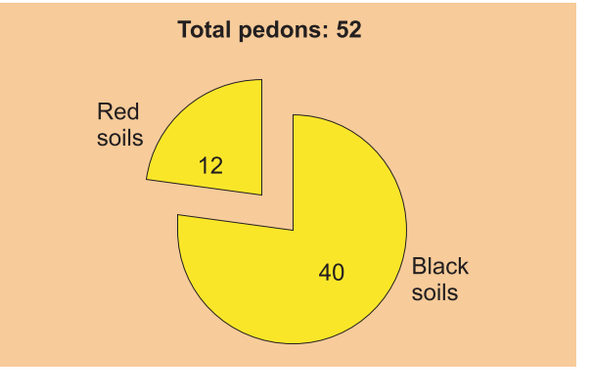

Figure 2.3. Distribution of pedons by soil type.

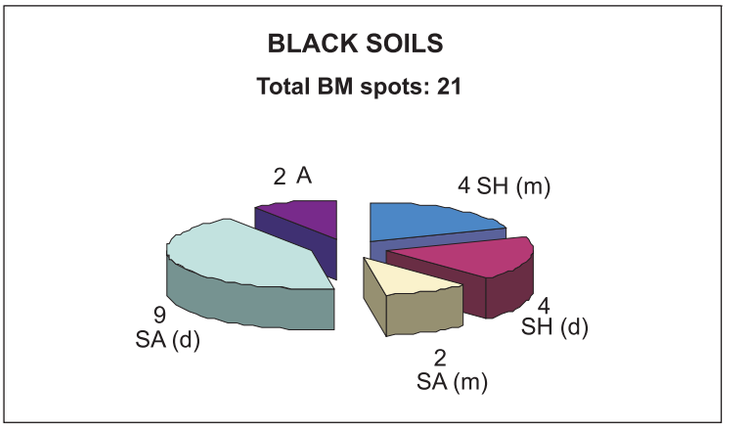

Figure 2.4. Distribution of BM spots (black soils) in different ecosystems.

(Note: SH (m) = Sub-humid (moist); SH (d) = Sub-humid (dry); SA (m) = Semi-arid (moist); SA (d) = Semi-arid (dry); A = Arid.)

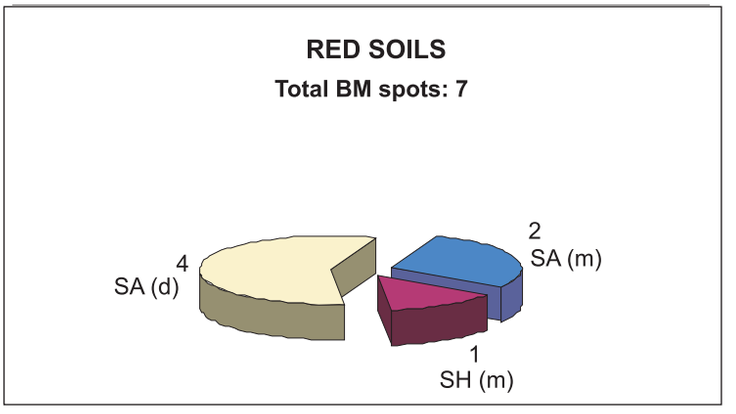

Figure 2.5. Distribution of BM spots (red soils) in different ecosystems.

(Note: SH (m) = Sub-humid (moist); SH (d) = Sub-humid (dry); SA (m) = Semi-arid (moist); SA (d) = Semi-arid (dry); A = Arid.)

2.4 Systems

The selected BM spots in the black and red soils area were given another dimension in the form of systems. A total of 5 systems, viz., agriculture, horticulture, forest, wasteland and permanent fallow were selected. By far agricultural systems dominate the chosen BM spots as well as total number of pedons (Figs. 2.6 and 2.7).

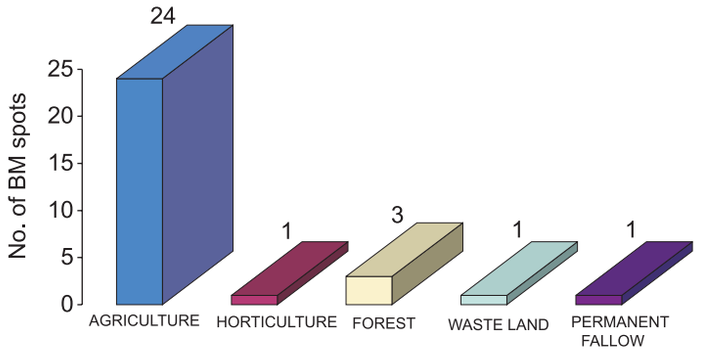

Figure 2.6. Distribution of BM spots by production system.

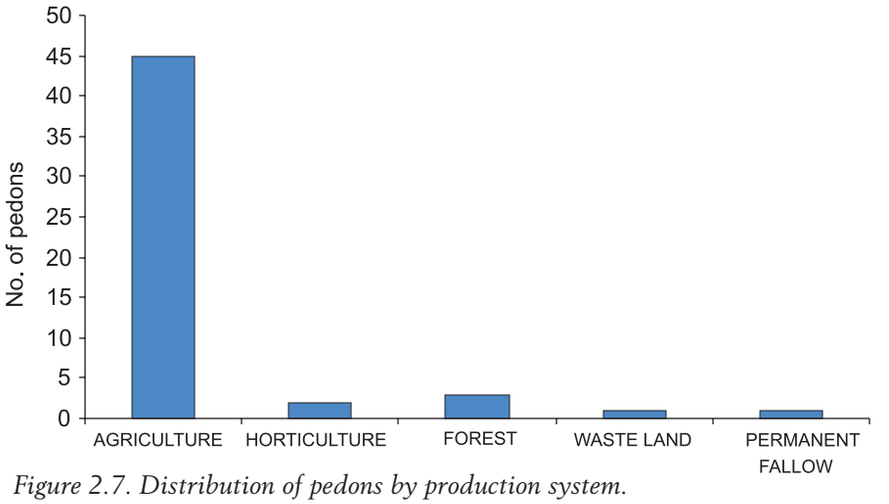

Figure 2.7. Distribution of pedons by production system.

The soil series were selected in such a way that in agricultural system under a particular cropping pattern, two representative pedons (under the same soil series) were included, one having farmers' management (FM), generally low management (LM) and the other having high management (HM), i.e., improved management. Wherever possible within the same soil series, different cropping patterns were also taken having the same FM. 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.

High management	Low management
Higher NPK	Low NPK
Regular application of manures	Manures rarely applied
Intercropping with legumes	Sole crop
Incorporation of residues	Removal of residues and biomass
Soil moisture conservation (ridge furrows, bunding, broad-bed and furrow)	-

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

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

Cropping pattern	Pedons
Cotton	P4
Cotton + Pigonpea	P48, P49
Cotton + Pigeonpea/Soybean-Chickpea	P12
Cotton + Pigeonpea/Sorghum	P13, P14
Cotton/Mung bean + 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 system 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

Table 2.4. Agricultural system with cereals under fourteen pedons.

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

Following the entire 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 and the database generated through this project have been arranged following mainly the five bioclimatic systems. The detailed materials and study area are given in Table 2.5.

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

BM spot	District/State	Series	System	Mean annual rainfall (mm)	Profile no.
Black Soils					
Sub-humid (moist) (Mean annual rainfall >1100 mm)					
13	Jabalpur/Madhya Pradesh	Kheri	Agriculture (HM) Paddy-Wheat	1448	P27
13	Jabalpur/Madhya Pradesh	Kheri 1	Agriculture (LM) Soybean/Paddy-Wheat	1448	P28
7	Nagpur/Maharashtra	Boripani	Forest (Teak)	1279	P15
3	Bhopal/Madhya Pradesh	Nabibagh	Agriculture (HM) Soybean-Wheat	1209	P5
3	Bhopal/Madhya Pradesh	Nabibagh	Agriculture (FM) Soybean-Wheat	1209	P6
2	Nagpur/Maharashtra	Panjri	Agriculture (HM) Cotton	1127	P4
Sub-humid (dry) (Mean annual rainfall 1000-1100 mm)					
26	Adilabad/Andhra Pradesh	Nipani	Agriculture (FM) Cotton + Pigeonpea	1071	P48
27	Adilabad/Andhra Pradesh	Pangidi	Agriculture (FM1) Cotton + Pigeonpea	1071	P49
27	Adilabad/Andhra Pradesh	Pangidi 1	Agriculture (ITDA) Soybean	1071	P50
4	Indore/Madhya Pradesh	Sarol	Agriculture (HM) Soybean-Wheat	1053	P7
4	Indore/Madhya Pradesh	Sarol	Agriculture (FM) Soybean-Wheat	1053	P8
4	Indore/Madhya Pradesh	Sarol	Agri-horticulture (HM) Soybean-Chickpea in mango orchard	1053	P9
1	Nagpur/Maharashtra	Linga	Horticulture (HM) Citrus	1011	P1
1	Nagpur/Maharashtra	Linga	Horticulture (LM)* Citrus	1011	P3
1	Nagpur/Maharashtra	Linga	Agriculture (FM) Soybean-Chickpea/Wheat	1011	P2
Semi-arid (moist) (Mean annual rainfall 850-1000 mm)					
22	Bidar/Karnataka	Bhatumbra	Agriculture (FM) Sorghum + Pigeonpea/ Black gram-Chickpea	977	P42
5	Amravati/Maharashtra	Asra	Agriculture (FM)* Cotton/Mung bean + Pigeonpea	975	P10
5	Amravati/Maharashtra	Asra	Agriculture (FM) Soybean + Pigeonpea	975	P11
5	Amravati/Maharashtra	Asra	Agriculture (HM) Cotton + Pigeonpea/ Soybean-Chickpea	975	P12
Semi-arid (dry) (Mean annual rainfall 550-850 mm)					
16	Kota/Rajasthan	Jhalipura	Agriculture (FM1) Soybean-Wheat	842	P32
16	Kota/Rajasthan	Jhalipura	Agriculture (FM2) Paddy-Wheat	842	P33
6	Akola/Maharashtra	Paral	Agriculture (LM) Cotton + Pigeonpea/Sorghum	794	P13
6	Akola/Maharashtra	Paral	Agriculture (HM) Cotton + Pigeonpea/Sorghum	794	P14

continued

Table 2.5. continued

BM spot	District/State	Series	System	Mean annual rainfall (mm)	Profile no.
18	Mahbubnagar/Andhra Pradesh	Jajapur	Agriculture (FM1) Sorghum/Pigeonpea + Mung bean	792	P35
18	Mahbubnagar/Andhra Pradesh	Jajapur 1	Agriculture (FM2) Paddy-Paddy	792	P36
20	Medak/Andhra Pradesh	Kasireddipalli	Agriculture (HM) Soybean + Pigeonpea	764	P39
20	Medak/Andhra Pradesh	Kasireddipalli	Agriculture (TM) Fallow-Chickpea	764	P40
24	Solapur/Maharashtra	Konheri	Agriculture (FM) Pigeonpea/Sunflower-Sorghum	742	P45
24	Solapur/Maharashtra	Konheri 1	Agriculture (LM) Fallow-Sorghum + Safflower	742	P46
25	Nashik/Maharashtra	Kalwan	Agriculture (FM) Sugarcane/Sorghum-Wheat/Chickpea	692	P47
9	Tuticorin/Tamil Nadu	Kovilpatti	Agriculture Sorghum/Sunflower/Cotton	660	P19
9	Tuticorin/Tamil Nadu	Kovilpatti 1	Wasteland	660	P20
9	Tuticorin/Tamil Nadu	Kovilpatti	Agriculture (HM) Cotton + Black gram	660	P21
14	Rajkot/Gujarat	Semla	Agriculture Cotton/Groundnut-Wheat	635	P29
23	Bellary/Karnataka	Teligi	Agriculture (LM) Paddy-Paddy	632	P43
23	Bellary/Karnataka	Teligi 1	Agriculture (HM) Paddy-Paddy	632	P44
Arid (Mean annual rainfall <550 mm)					
15	Rajkot/Gujarat	Sokhda	Agriculture (FM1) Cotton-Pearl millet	533	P30
15	Rajkot/Gujarat	Sokhda 1	Agriculture (FM2) Cotton-Pearl millet/Linseed	533	P31
28	Ahmednagar/Maharashtra	Nimone	Agriculture (HM) Cotton-Wheat/Chickpea	520	P51
28	Ahmednagar/Maharashtra	Nimone	Agriculture (FM) Sugarcane-Soybean/Wheat/Chickpea	520	P52
Red Soils					
Sub-humid (moist) (Mean annual rainfall >1100 mm)					
11	Dindori/ Madhya Pradesh	Dadarghugri	Agriculture (LM) Maize/Mustard	1420	P23
11	Dindori/ Madhya Pradesh	Dadarghugri	Forest (Teak)	1420	P24
12	Umeria/ Madhya Pradesh	Karkeli	Forest (Sal)	1352	P25
12	Umeria/ Madhya Pradesh	Karkeli 1	Agriculture (LM) Minor millet/Sweet potato	1352	P26

continued

Table 2.5. continued

BM spot	District/State	Series	System	Mean annual rainfall(mm)	Profile no.
Semi-arid (moist) (Mean annual rainfall 850-1000 mm)					
8	Bangalore/Karnataka	Vijaypura	Agriculture (FM) Finger millet	924	P16
8	Bangalore/Karnataka	Vijaypura 1	Agriculture* Finger millet/Pigeonpea/Groundnut	924	P17
8	Bangalore/Karnataka	Vijaypura 1	Agriculture (HM) Finger millet	924	P18
Semi-arid (dry) (Mean annual rainfall 850-1000 mm)					
19	Rangareddy/Andhra Pradesh	Hayatnagar	Agriculture (HM) Sorghum-Castor	764	P37
19	Rangareddy/Andhra Pradesh	Hayatnagar	Agriculture (LM) Sorghum-Castor	764	P38
21	Medak/Andhra Pradesh	Patancheru	Permanent Fallow	764	P41
17	Mahbubnagar/Andhra Pradesh	Kaukuntla	Agriculture (FM) Castor + Pigeonpea	674	P34
10	Coimbatore/Tamil Nadu	Palathurai	Agriculture Horsegram/Vegetables	612	P22

* *Original BM spots.*

2.5 Methods

The profiles were examined following standard methods (Soil Survey Division Staff 1995). The concept of bioclimatic system was adopted from Bhattacharjee et al. (1982). The soils were classified following Soil Taxonomy (Soil Survey Staff 1999). The morphological properties as shown in Appendix 1 have been studied by standard procedures (Soil Survey Division Staff 1995, Soil Survey Staff 1999).

3. Results and Discussion

The discussion on various morphological properties is made for all the pedons on the basis of bioclimatic system for the black soils and red soils separately.

3.1 Soil Depth

3.1.1 Black Soils

In the sub-humid (moist) bioclimate 6 pedons represent 4 BM spots. Except Boripani series (P15), all the soils are very deep.

In the sub-humid (dry) bioclimatic zone, 8 pedons represent 4 BM spots. Except Pangidi and Pangidi 1 soils (P49 and P50) all the soils are very deep (more than 150 cm depth). Pangidi soils under cotton and pigeonpea (P49) extend up to 110 cm depth whereas the Pangidi 1 soil (P50) is shallow and extends only up to 41 cm depth.

The semi-arid (moist) bioclimate zone is represented by 4 pedons covering 2 BM spots. All these soils are very deep except Bhatumbra (P42), which is about 120 cm in depth. Bhatumbra soils are actually very deep but there is seepage of water from adjacent irrigation canal system at about a depth of 120 cm.

The semi-arid (dry) bioclimate is represented by 9 BM spots consisting of 17 pedons. Except Kovilpatti (P19 and P20), all soils are deep with a depth of more than 150 cm. Kovilpatti soils, P19 extend up to 118 cm, whereas Kovilpatti P20 is 79 cm deep followed by mixture of gypsum and $CaCo_3$ as massive and partially indurated layers.

The black soils in arid ecosystem are represented by 2 BM spots having 4 pedons. Except Sokhda (P30), all the soils are very deep with more than 150 cm depth. Sokhda (P30) soils are, however, limited to 90-100 cm depth followed by a layer of highly calcareous, powdery lime mixed with little amount of soil.

All these soils have A, B and C horizons. The A horizon is a plowed layer in most of the cases under agricultural system as indicated by horizon designation, Ap. The B horizon in the Vertisols indicate both structural (Bw) as well as slickensided (Bss) horizons. The associated Inceptisols, however, show only Bw horizons. The C horizons are either calcareous or dominated by gypsum and $CaCo_3$ as indicated by the Ck or Cky horizon (Soil Survey Staff 1999).

The detailed information on soil depth and horizon designation is shown in Appendix 1.

3.1.2 Red Soils

Four pedons have been studied in sub-humid (moist) bioclimate represented by 2 BM sites. The Dadarghugri soils are shallow to medium in depth developed in basalt whereas Karkeli soils are very deep and are developed in sandstone.

Three pedons were studied in semi-arid (moist) bioclimatic zone representing one BM soil namely Vijayapura. All the pedons are very deep and are developed in granite-gneiss.

Five pedons representing 4 BM spots were studied in semi-arid (dry) bioclimatic zone. Kaukuntala (P34) and Patancheru (P41) are very deep soils developed in gneissic parent material. The Palathurai (P22) and Hayatnagar (P37 and P38) soils are medium to deep. Both these soils are developed in gneissic parent material. The layer below 50 cm in Palathurai soil (P22) is highly impervious and resembles calcrete layer.

Red soils are also designated by A, B and C horizons. All the red soils indicate clay illuviation as shown by horizon designation Bt. Palathurai and Hayatnagar soils have calcareous C horizon as designated by the Ck horizon.

The detailed information on soil depths and horizon designation is shown in Appendix 1.

3.2 Soil Color

Soil color is one of the important characteristics that help to identify a particular group of soils and also recognize the successions of soil horizons in a soil profile. Indirectly, it has a tremendous influence in terms of numerous physical, chemical and bio-geochemical reactions in soils, so far as absorption of solar heat on the soil surface is concerned. The study of soil color has its own significance in interpreting acquired soil properties, which are dynamic in nature. These properties depend on pedogenic processes, which are again dependent on different soil forming factors (Jenny 1941). Normally, the content of SOC determines the relative darkness of soil color especially in the surface. Light gray or gray with or without mottles indicates reduced SOC content prevailing in the soil environment. Dark gray color indicates gleyed horizon, which is very common in waterlogged paddy soils. Carbonates and gypsum are lighter in color and as such their presence in the soil matrix shows lighter soil colors. Soil colors are most conventionally measured by comparison with a color chart called Munsell Color Chart.

3.2.1 Black Soils

In the sub-humid (moist) bioclimate zone the soils are in general very dark grayish brown to dark grayish brown. The Nabibagh soils are darker (10YR 3/2) in HM (P5) than the soils under FM (10YR 3.5/2 to 10YR 4/2 in P6). This is also reflected by higher SOC content in P5 (HM) than P6 (FM). Darker color (10YR 3/2) in Boripani surface soils also matches with relatively higher soil organic matter (0.9%). Although such observations indicate a strong degree of correlation between soil color and SOC, such interpretation may be accepted based on large number of observations (Bhattacharjee 1997). Interestingly, similar dark color in Kheri soils in both HM and LM (P27 and P28) does not, however, indicate a direct relation with color and SOC.

In the sub-humid (dry) ecosystem also, the soil color ranges from very dark grayish brown (10YR 3/2) to dark grayish brown (10YR 4/2), although field observations indicate at least in four sites (P3, P48, P49, P40) that the soil color is more dark (10YR 3/1.5). The soil with darker chroma (10YR 3/1.5) in Linga soils (P3) contain relatively high SOC than other two soils (P1 and P2).

In semi-arid (moist) bioclimate the 4 studied soils have similar color ranging from very dark grayish brown to dark grayish brown.

In the semi-arid (dry) bioclimate, the range of color is dominantly very dark grayish brown to dark grayish brown with Paral and Teligi soils being exceptions. Paral soils are dark brown to very dark brown (7.5YR 3/1 to 3/2) and the Teligi (P43) soils are very dark gray (10YR 3/1). Lower chroma values in Teligi soils indicate presence of redoximorphic features such as iron and manganese mottles as characteristics of gleyed horizon. Incidentally, mottles were not identified during profile examination in the field, although these soils are being continuously cultivated for paddy under bunded conditions. Presence of redoximorphic features such as mottles or gleyed horizons or if redoximorphic features are not present but 50% or more chroma of 1 or less of the profile is present, then the soil qualifies for aquic moisture regime (Soil Survey Staff 1999). Identification of aquic moisture regime might justify grouping these soils under great group level as Aquerts. However, lack of data on redoximorphic features led to actually classifying these soils as Usterts. It has been reported that the waterlogged soils contain higher SOC as compared to other upland soils (Narteh and Sahrawat 1999, Sahrawat and Narteh 2001). High SOC content in surface soils (1.5%) in particular and relatively high SOC content throughout the soil profile (0.5 to 0.8%) in these Vertisols (Teligi series) perhaps support the observation earlier made by these authors.

In the arid ecosystem, the soil color ranges from very dark grayish brown to dark grayish brown. The Nimone soils (P51 and P52) under different management systems are dark brown. In general, the black soils studied do not show variation in color when the color was compared in different bioclimate systems. However, there are examples where darker color indicates a direct relation with SOC content. Nevertheless, the examples of reverse relation also exist. It is expected to have black soils with darker color in relatively moist soil environment in bioclimatic systems experiencing higher rainfall than those with lower rainfall. Incidentally, introduction of irrigation in drier parts of SAT [semi-arid (dry) and arid ecosystems] might have influenced the soil to have darker color as seen in Teligi soils, similar to soils of sub-humid climate.

3.2.2 Red Soils

The red soils in sub-humid (moist) bioclimate have dark brown color in the surface soil of Dadarghugri (P23) and Karkeli (P25). The dark brown (7.5YR 4/2) color extends beyond 50 cm in Dadarghugri soils (P24) under forest and Karkeli soils (P26) under minor millets. The lower horizons of these soils, however, show dark reddish brown color (5YR 3/4). It is interesting to observe that the surface soils, which show darker color, contain high SOC, viz, 2.4%, 3.3% and 1.9% in P23 and P24 (Dadarghugri) and P25 (Karkeli), respectively. The direct relation between higher SOC and darker soil color is observed in the forest soils.

In semi-arid (moist) bioclimate soil color is less red by 1 hue in the surface soils than the subsurface soils. Interestingly, in FM, Vijaypura soils have dark reddish brown (5YR 4/4) color up to 9 cm depth; this color with a lighter shade (5YR 4/6) extends up to 92 cm depth in P17 whereas same color extends to more than 150 cm depth in P18. The subsurface horizons, however, indicate dark color ranging from reddish brown to red (2.5YR 4/4 to 4/6). The Vijaypura soils (P16) reflect the color due to laterite gravels (dark colored), mottles and minerals of lepidocrocite.

Red soils in semi-arid dry bioclimatic system have color ranging from dark reddish brown (2.5YR 4/4) to yellowish red (5YR 4/6). The detailed information on color of soils is given in Appendix 1.

3.3 Texture

Texture of soils refers to the relative proportion of the various soil separates of different size limits in the fine earth fractions (<2 mm) of soil mass. The particles larger than 2 mm size are recognized by modifiers of various textural class names, viz, gravelly, cobbly, etc. During profile examination the tentative textural class of the fine earth fraction of the soil was determined by hand "feel" (Shaw 1928) method. The actual composition of soil was determined in the laboratory by particle-size analysis to cross check the field observation. Laboratory data of particle-size distribution in terms of sand, silt and clay are utilized to arrive at the exact textural class using the triangular chart of USDA System. The detailed dataset on particle-size separates is discussed in the Working Report on Physical Properties of Selected Soils on SAT. The general observations on texture in the field are discussed here.

3.3.1 Black Soils

The Panjiri soils (P4) under HM is very fine (>60% clay) in the soil control section (SCS) at the family level of Soil Taxonomy (Soil Survey Staff 1999). The laboratory data confirm the observation made in the field.

The black soils in the sub-humid dry system are also clayey. However, the Linga soils (P1, P2 and P3) indicate more than 60% clay in the SCS and therefore qualify for very fine textural class at the family level of Soil Taxonomy. Similar observations were made with respect to Sarol soils (P7, P8 and P9) and Pangidi soils (P49). Nipani soils are silty clay in texture.

The soils in semi-arid dry and moist bioclimate are in general, clayey in texture. Interestingly, some of these soils (Asra and Bhatumbra) contain >60% clay in the SCS and therefore qualify for very fine textural class at family level of Soil Taxonomy. In the semi-arid dry bioclimate, the clay texture is common in all the soils in the SCS. The content of clay is >60% for Paral (P14), Kovilpatti (P19 and P21), Teligi (P44) and Konheri (P46) soils. But in the Jajapur soils, P35 (FM1) is sandy clay up to a depth of 76 cm and P36 (FM2) is sandy clay loam up to 150 cm depth.

In the arid ecosystem, the soils are clayey in Sokhda and Nimone series. The Nimone soils in HM (P51) qualify for very fine whereas Sokhda and Nimone 1 soils (P52) qualify for fine textural class at family level of soil classification.

The clay texture of black soils under study influences other morphological properties such as structure, consistence and porosity. The chemical analysis of these soils indicate higher clay CEC values suggesting dominant clay minerals as smectite. High content of smectitic clay minerals which varies from one soil to the other also reflects in other morphological properties such as depth and size of cracks and slickensides. The textural class of all these soils are detailed in Appendix 1.

3.3.2 Red Soils

The soils in sub-humid moist ecosystem are clayey in texture in SCS in Dadarghugri soils. The Karkeli soils (P25) on the other hand are sandy loam in texture under forest ecosystem, sandy clay loam under LM (P26) and sandy clay loam in the SCS. Both the soils (P25 and P26) are coarser at the surface with loamy sand texture. The content of clay, which increases down the profile observed during profile examination was later confirmed by laboratory data.

The red soils in the semi-arid (moist) bioclimatic system represented by Vijayapura soils (P16 and P17) have sandy clay loam texture in the SCS except the soils of P16 in FM, which have clayey texture throughout the SCS.

The red soils under semi-arid (dry) bioclimatic system are sandy clay loam to sandy clay texture in SCS, except Kaukuntla soils which have clayey texture. Presence of >35% coarse fragments (>2.0 to 7.5 cm diameter) in the SCS of these soils qualifies the textural class as loamy-skeletal in Soil Taxonomy.

The detailed information on texture is given in Appendix 1.

3.4 Consistence

Soil consistence is the function of soil-water relationship. It is one of the important morphological properties, which indicates the degree of cohesion among the soil particles and the degree of adhesion to other objects. Soil consistence also indicates resistance to the deformation of cast prepared under applied stress. Soil consistence is generally described in terms of:

- Degree of resistance to break or to crush the cast under applied force (soil strength)
- Ability to deform the cast without rupture under applied stress (plasticity)
- Degree of adherence of other objects (stickiness)
- Ability to change shape continuously under the influence of an applied stress and retain the impressed shape upon removal of the stress (plasticity)

As mentioned earlier, soil consistence indicates a relationship between soil and moisture. Therefore, during the examination of the profile, consistence is studied under dry, moist and wet conditions.

3.4.1 Black Soils

The black soils in the sub-humid moist ecosystem indicates *hard* consistence in dry soils. For almost all the soils, the moist consistence is *friable*. The lower horizons beyond 84 cm in Kheri soil (P27) indicate *firm* consistence in moist soils. It is interesting to observe that the Nabibagh soils under HM (P5) have *very friable* moist consistence as compared to soils under FM (P6) which show *friable* consistence. The wet consistence of the soils are, in general, sticky and plastic which becomes *very sticky* and *very plastic* with depth, except Boripani (P15) and Nabibagh soils (P6). A closer look at the other morphological properties indicates that *very sticky* and *very plastic* moist consistence corresponds with those horizons, which have well developed slickensides (Appendix 1).

In sub-humid (dry) bioclimate, the dry consistence ranges from *slightly hard* to *very hard*. When dry consistence of Linga soils is compared, it is observed that surface soils under HM (P1) is *hard* as compared to soils under FM (P2) and LM (P3). Interestingly the surface soils of Sarol under HM (P7) indicate *slightly hard* to *hard* consistence as compared to *very hard* consistence under FM (P9). Moist consistence is *friable* to *very friable* in all the 8 pedons studied in this bioclimatic system with Sarol soils under soybean and chickpea being an exception indicating *firm* consistence. A closer look at the various physical and chemical characteristics of the soils fails to bring any relation with the *firm* consistence of these soils (P9). Moist consistence indicates *sticky* and *plastic* for all the soils in this ecosystem. However, Linga soils (P1 and P2) and Pangidi soils (P49) show *very sticky* and *very plastic* wet consistence from depth below 30-40 cm. Relatively high total and fine clay justifies greater stickiness and plasticity of surface soils in these pedons. Moreover, sometimes, soils (P1, P2, P3 and P49) show *very sticky* and *very plastic* wet consistence for those horizons where well developed slickensides are formed. Plasticity was poor (*non-plastic* to *slightly plastic*) when the quantity of gravel was higher.

In the semi-arid (moist) bioclimatic system, Asra soils (P10, P11 and P12) and Bhatumbra soils (P42) show *friable* moist consistence. In Asra, the subsurface soils show *firm* consistence in P10 and P11 (both under FM). *Firm* consistence (under moist condition) in these soils may indicate higher ESP in the subsurface of these soils in the absence of any natural modifiers like gypsum or zeolites. All the surface and subsurface (Bw horizon) soils are normally *sticky* and *plastic* under wet condition whereas the subsurface soils indicate *very sticky* and *very plastic* wet consistence. A closer look at the total clay and fine clay percentage of the soils do not show any relation with the moist and wet consistence. However, it is commonly observed that the horizons which show well developed slickensides have *very sticky* and *very plastic* consistence in wet condition. The soils of Asra (P12) (under HM) are *friable* throughout the depth. This may be because these soils have higher SOC than P10 and P11 due to inclusion of sunnhemp in crop rotation.

Dry consistence in semi-arid (dry) bioclimatic system varies from *soft* to *very hard* in the surface horizons. The gypsum-rich black soils in the wasteland of Kovilpatti (P20) and Kasireddipalli (P39) under HM showed *soft* consistence; Semla soils under cotton/groundnut-wheat (P29) showed *slightly hard* consistence; Jhalipura (P32), Jajapur (P35 and P36), Teligi (P43) and Kalwan (P47) showed *hard* consistence; and Jhalipura under paddy-wheat (P33), Kasireddipalli (P40) and Teligi (P44) showed *very hard* consistence.

In general, moist consistence for all the soils is *friable*. For those soils where moist consistence in the subsurface is *slightly firm* to *very firm*, surface soil consistence remains *friable*. Soils with wet consistence, in general, are *sticky* and *plastic*, and become *very sticky* and *very plastic* in the subsurface layer beyond 40-50 cm. It is interesting to observe that wet consistence normally is *very sticky* and *very plastic* from that depth which corresponds to depth of occurrence of well-developed slickensides as observed in P13, P14, P19, P20, P21, P29, P32, P33, P39, P40, P43 and P44. Wet consistence is *sticky* and *slightly plastic* in those horizons where slickensides are weak (P35, P39 and P46) or very weak (P45).

In the arid bioclimatic system, dry consistence ranges from *slightly hard* (P30 and P31) to *hard* (P51). All the soils have *friable* to *very friable* consistence in the moist condition with some exception in Nimone soils (P52). These soils are *friable* to *very friable* (with some exception) though they have higher ESP indicating the possible presence of some natural modifiers such as zeolites in soils of Nimone and Sokhda. Wet consistence is *sticky* and *plastic* and in the subsurface soils of few pedons (P31, P51 and P52) it is *very sticky* and *very plastic* as observed in soils of semi-arid (dry) bioclimatic system. The soil horizons showing well-developed slickensides generally indicate *very sticky* and *very plastic* wet consistence. Detailed information on consistence is given in Appendix 1.

3.4.2 Red Soils

The sub-humid (moist) bioclimatic system indicates *soft* to *slightly hard* dry consistence. Soils with moist consistence are *very friable* in almost all cases. Dadarghugri soils (P23 and P24), developed in basalt, indicate *sticky* and *non-plastic* consistence (due to presence of gravel) in wet condition. The Karkeli soils (P25 and P26) are *non-sticky* and *non-plastic* in the surface due to higher sand content than the subsurface soils, which are *slightly sticky* and *slightly plastic*. Vijayapura soils in semi-arid (moist) bioclimate indicate *slightly hard* dry consistence. Soils under HM (P17 and P18) have moist consistence and are *very friable*. The wet consistence is *sticky* and *plastic* and moist consistence is *friable* in Vijayapura soils (P16) under FM. The wet consistence in other Vijaypura soils (P17 and P18) is *non-sticky* and *non-plastic*.

In the semi-arid (dry) bioclimatic system, dry consistence ranges from *loose* (Palathurai) to *slightly hard* to *hard*. Moist consistence ranges from *friable* to *very friable* except Kaukuntala soils (P34), which are *slightly firm* at 25 to 100 cm depth. A closer look at the clay distribution indicates nearly 45 to 50% clay and almost similar amount of sand within this depth range of these soils. Moreover, the ESP also varied between 4 and 6 in the same depth range; hence, perhaps a *firm* consistence in moist condition of this soil. Wet consistence is generally *sticky* and *plastic* with most of the soils showing *non-sticky* and *non-plastic* consistence in the surface soils, which is due to presence of more sand. Plasticity was poor (*non-plastic* to *slightly plastic*) where the quantity of gravel was higher or the texture was lighter.

The detailed information regarding consistence of the BM soils is given in Appendix 1.

3.5 Structure

Soil structure refers to an arrangement of soil particles, both primary and secondary in a natural soil aggregate or ped. This is recognized as one of the most important properties of the soil mass as it influences the soil in almost all of its reactions, especially those related to aeration, moisture, temperature, permeability and water-holding capacity. Structure is also linked with fertility parameters of a soil. To some extent, structure also bears a relationship with liability to erosion. Soil structure is the most striking aspect of Vertisol morphology (Krishna and Perumal 1949). It is most strongly expressed when the soil has a minimum water content. Thus soils in field are studied when the profile is dry. De Vos and Virgo (1969) indicate that the occurrence of wedge-shaped structural aggregates and angular blocky structure are the most characteristic aspects of Vertisols. Soil structure is studied in the field in the form of class or size, type or shape, and grade or distinctness. For example, the abbreviation c3abk or m2sbk indicates coarse (c-size), strong (s-type), angular blocky (abk1-grade) or moderate (m1-size), medium (2-type), subangular blocky (sbk1-grade) structure.

3.5.1 Black Soils

The soils in the sub-humid (moist) bioclimatic system have moderate medium subangular blocky structure at the surface and coarse strong angular blocky structure in the subsurface horizons in Panjri (P4) and Nabibagh (P6) soils. Soils under HM such as Nabibagh (P5) and Kheri (P27, P25) have moderate structure throughout the depth. Boripani soils have similar structure except that these are massive below 55 to 60 cm depth due to presence of calcareous weathered basalt.

In the semi-arid (dry) bioclimate, the soil structure varies from m2sbk (moderate medium subangular blocky) to m3sbk (moderate strong subangular blocky) in the surface soils. The structure in the subsurface horizon is c3abk (coarse strong angular blocky) or m3abk (moderate strong angular blocky). In general, angular blocky structures (abk) are observed in those horizons, which have slickensides. It has also been observed that wedge-shaped aggregates (or slickensides) break into weak to strong angular peds depending upon the degree of slickenside character which depends upon the smectite content.

In semi-arid (moist) systems, surface soils are dominated by subangular blocky structure, whereas in the subsurface, slickensided horizon indicated angular blocky structure. Similar observations were made in semi-arid (dry) and arid bioclimatic systems.

3.5.2 Red Soils

In the sub-humid (moist) bioclimatic system, subangular blocky structures predominate. The Vijayapura soils in semi-arid (moist) bioclimatic system have also subangular structure throughout the pedon depth except in one or two horizons. Subangular blocky structures in semi-arid (dry) system are commonly observed. It is interesting to observe that the grade of soil structure is strong in 25 to 100 cm depth in soils of Kaukuntla (P34) and in 10 to 75 cm depth in Patancheru (P41) which corresponds to soil horizons showing the presence of slight pressure faces.

3.6 Roots

Quantity of roots is described in terms of number of roots of different sizes per unit area. The class placement for quantity of roots is pertained to an area in a horizontal plane (Soil Survey Division Staff 1995). This unit area changes with root size as mentioned below:

- 1 cm^2 for very fine (<1 mm diameter) to fine (1-2 mm diameter);
- 1 cm^2 for medium (2-5 mm diameter) and coarse (5-10 mm diameter); and
- 1 m^2 for very coarse (>10 mm diameter)

3.6.1 Black Soils

Panjri and Nabibagh soils in sub-humid (moist) ecosystem show very fine (<1 mm diameter), few (<1 per unit area), fine (1-2 mm diameter) roots almost throughout the pedon depth. In Nabibagh soils under FM, very fine and fine roots are common. Since the Boripani soils are under forests, the roots show fine, medium (2-5 mm diameter) and coarse (5-10 mm diameter) sizes and are common (1-5 per unit area) and many (>5 per unit area) in quantity. In Kheri soils under HM (P27), fine roots are limited to 40 to 50 cm depth only. This could be due to the contribution of paddy-wheat crop combination for a considerable period of time. Interestingly, Kheri soils under LM (P28) show plenty of fine roots throughout the depth of soils.

Fresh and decayed roots of crops and trees identified in a soil profile do not contribute to SOC determined by Walkley and Black method (Walkley and Black 1934, Jackson 1973) unless they are decomposed. Higher root concentration leads to release of greater amount of root exudates. These exudates in turn dissolve $CaCO_3$ present in soil, which help in better Ca nutrition in plants as well as form a better soil structure enhancing aeration and hydraulic conductivity. This process again brings better soil environment for crop growth and biological activities. It therefore, appears that concentration of root either in surface or throughout the depth of the pedon may have an interacting role in modifying soil structure, to enhance organic carbon sequestration and retard the sequestration of inorganic carbon. A closer look at the root distribution indicates a relatively low $CaCO_3$ content (3.5 to 5.1%) in the surface soil, where most of the roots are concentrated.

In the sub-humid (dry) climate, fine, medium and coarse roots are common in Linga soils (P1) under HM (citrus) as compared to similar soils under LM (P3). Sarol soils under HM show more roots in first 100 cm of soil than similar soils under FM (P8) and LM (P9). Nipani and Pangidi soils indicate greater root concentration within 40 to 60 cm depth of soil, although very fine roots extend up to a depth of 150 cm.

When morphological and chemical characteristics of few profiles were compared, it was observed that higher root concentration corresponds to those horizons, which show low $CaCO_3$ content. Such inverse relation has been found in horticultural system (P1 and P3) and agricultural system under cotton and pigeonpea (P49) and soybean (P50).

The root distribution in semi-arid (moist) system in Asra soils indicate very fine and fine roots in P10 and P11 (under LM). However, within first 50 cm, very fine, fine and medium roots are relatively more in similar (Asra) soils under HM. In Bhatumbra soils (P42) root growth is limited up to 40 cm. A closer look at the root distribution and $CaCO_3$ content shows an inverse relation as found in a few selected soils of sub-humid (moist) bioclimatic system.

Paral soils (P13 and P14) in the semi-arid (dry) agroclimatic system indicate that very fine to fine roots are common even beyond 100 cm depth. Kovilpatti soils, rich in gypsum, show roots of various sizes beyond 150 cm depth. Jhalipura, Jajapur and Kasireddipalli soils show very fine to fine and medium roots up to a depth of 50 to 60 cm beyond which only very fine roots are observed. Medium to coarse roots are also common in surface soils (up to 25-30 cm) in Jajapur (P35) and Kasireddipalli (P39) soils. Teligi soils under HM and LM indicate many, very fine to fine roots up to 100 to 120 cm depth. Similar observations are made for Konheri soils, except that the soils under FM show medium to coarse roots even up to 60 cm. Kalwan soils (P47) indicate many fine to medium roots up to 70 to 75 cm depth, although fine roots extend beyond 125 cm. While comparing the root distribution in terms of size and quantity vis-à-vis the distribution of $CaCO_3$ an inverse relation was observed in Paral soils (P13), Kovilpatti (P19, P21), Jhalipura (P32), Jajapur (P35, P36), Kasireddipalli (P39, P40), Teligi (P43, P44), Konheri (P46) and Kalwan (P47) soils.

In the arid bioclimatic system both Sokhda and Nimone soils indicate very fine to fine roots up to a depth of 55 to 60 cm; very fine roots extend beyond 125 to 140 cm. The Nimone soils (P52) under sugarcane show fine to medium roots up to 120 cm whereas very fine roots are observed beyond 160 cm. On comparing the $CaCO_3$ content and distribution of roots, no definite relation was observed. The details of size and quantity of root distribution in the soils are given in Appendix 1.

3.6.2 Red Soils

The red soils in the sub-humid (moist) bioclimate indicate very fine roots in the entire pedon depth extending to 100 cm in Dadarghugri and 150 to 160 cm in Karkeli soils. Since P24, P25 and P26 are in forest, very fine, fine, medium and coarse roots are plenty in the entire pedon depth.

The red soils in the semi-arid (moist) bioclimatic system show very fine to fine roots throughout the depth of soil profile except the soils under FM (P16). While comparing the pedons under different management systems (P16, P17 and P18), it was observed that the soils under HM (P18) have more roots both in terms of size and quantity.

The root distribution in semi-arid (dry) bioclimatic system is similar in Palathurai (P22) and Hayatnagar (P37 and P38), while Patancheru (P41) soils under permanent fallow show root distribution up to 160 to 170 cm depth. The comparison of root distribution and $CaCO_3$ content indicate an overall inverse relation.

Detailed information on roots is given in Appendix 1.

3.7 Coarse Fragments, Nodules and Effervescence

Significant properties of fragments (coarser than coarse sand) which are more than 2 mm and less than 25 cm in diameter are recognized as coarse fragments. These coarser materials are important constituents of whole soil. The quality and quantity of coarse fragments are important to study in the field since they largely influence soil moisture storage, infiltration and runoff and particle-size fraction, soil structure and consistence. They also have an influence on plant growth in terms of root

proliferation especially in high clay soils such as Vertisols. It is also reported that they protect the fine particles from wind and from getting washed away.

Nodules, also known as concretions, are hardened materials, which form indurated structure of various sizes, shapes and colors. They could be formed from materials like $CaCO_3$, $MgCO_3$ and Fe/Mn oxides in the soil particles. In Vertisols a major fraction of the coarse fragments are the calcareous nodules.

In the red and black soils of arid bioclimatic systems, coarse fragments identified in the field are generally observed as lime concretions or nodules (conca). For other red soils, Fe and Mn concretions have also been identified, which are basically coarser fragments in these soils.

The effervescence identified in these soils with the help of cold 2.87 N HCl (which corresponds to 1:10 dilution of the concentrated acid) is due to the reaction of carbonate present in the soil with the acid. Depending on the quantity of coarse fragments or conca, the degree of effervescence is noted as *very slight* to *slight*, *strong* and *violent*. It was also noted in the field whether the effervescence observed was due to carbonate present in the matrix of the soil (pedogenic carbonates) or due to the calcareous nodules (non-pedogenic carbonates) or due to both. To quantify the qualitative expression of effervescence such as *very slight*, *slight*, *strong* and *violent* (Soil Survey Division Staff 1995) the entire field observation of the established soil series of India (Sehgal et al. 1988, Lal et al. 1994) was correlated with the quantitative $CaCO_3$ values obtained from laboratories. The values for *very slight*, *slight*, *strong* and *violent* effervescence were assigned as <2.5%, 2.5-5.0%, 5.0-13.0% and >13.0%, respectively.

3.7.1 Black Soils

The coarse fragments range between 3 and 8% in Panjri, Nabibagh and Kheri (P28) soils. The Boripani soils have more than 50% coarse fragments in the C horizon below 55 to 60 cm depth. Unlike soils under LM, Kheri soils under HM (P27) do not have any coarse fragments in first 115 to 120 cm depth. By and large, the size and quantity of $CaCO_3$ agree with the observations made with the coarse fragments in the field.

The soils in semi-arid (moist) bioclimate generally show *slight* effervescence throughout the profile except Kheri soils in LM up to a depth of 80 cm. Boripani soils also indicate *violent* effervescence in the calcareous C horizon.

Black soils in the sub-humid (dry) agroclimatic system contain 1-10% coarse fragments. The Sarol soils under HM and LM (P7 and P9) indicate relatively high coarse fragments in the subsurface than those found in the soils under FM. This observation is in agreement with the distribution of coarse fragments according to size and quantity in three pedons (P7, P8, P9). Nipani and Pangidi soils contain stones in the surface (0-15 cm). The Pangidi soils show more than 40% coarse fragments below 40 cm depth. Field observations show *slight* effervescence in all the 8 pedons studied in sub-humid (dry) agroclimatic system. Linga soils under HM (P1) and LM (P3) and Sarol under HM (P7) indicate strong effervescence below 100-125 cm depth. Nipani soils are the only exception showing *violent* effervescence throughout the profile depth.

In general, the soils under semi-arid (dry) bioclimatic system contain 1-10% fine and coarse fragments with a general tendency for the quantity to increase with depth. This observation is in agreement with those made during the study of nodules and effervescence in the field. It is interesting to observe that gypsum-rich C-horizons of Kovilpatti soils show about 80 to 90% coarse fragments of which gypsum

content is about 4-5% and $CaCO_3$ is about 40%. Teligi soils under paddy also make an interesting observation. The coarse fragments range from 8 to 10% throughout the pedon depth (P43) under LM, whereas the same soils under HM indicate four- to five-fold increase in coarse fragments below 140 cm depth. These coarser fragments constitute $CaCO_3$ as has been confirmed through the observation of nodules and effervescence in the field and $CaCO_3$ determined in the laboratory.

Sokhda and Nimone soils under arid bioclimatic system show coarse fragments of 5-15%. The Sokhda soils under FM (FM1) indicate 30 to 70% coarse fragments below a depth of 90-95 cm. Some of these coarse fragments were identified as quartz and zeolite gravel. The nodules dominated by $CaCO_3$ concretions are common or abundant in almost all the horizons with a tendency to increase with depth. The distribution of coarse fragments and $CaCO_3$ concretions is in general agreement with the degree of effervescence observed as *strong* to *violent* with depth.

3.7.2 Red Soils

The coarse fragments in the Dadarghugri soils (P23, P24) are gravel of weathered basalt and basaltic lithorelics limited up to a depth of 30-35 cm. Below 35 cm stones are common with little amount of soils. In Karkeli soils (P25 and P26), fine and coarse gravel fragments are 1-10% in the first 100 cm depth of soil. Below this depth coarser fragments are more than 10% in P26 and nearly 30-40% in P25. In the Karkeli soils under reserve forests (P25), coarse fragments indicate partially weathered sandstone and sometimes unweathered sandstones, probably as sandstone lens. Similar soils under agriculture (P26) also show Fe and Mn concretions as fine and coarse fragments. The red soils of Karkeli (P25) and those in the Dadarghugri (P23 and P24) do not show $CaCO_3$ nodules. The Karkeli soils under agriculture, however, indicate many Fe and Mn concretions at the depth of 60 to 125 cm.

In semi-arid (moist) bioclimatic system, coarse fragments are almost insignificant in first 70 to 100 cm depth of soil (P16, P17 and P18). Below this depth coarse fragments increase to 70% due to the presence of quartz, feldspar and laterite gravel. No concretions were identified in these soils.

The red soils in the semi-arid (dry) bioclimatic system indicate coarse fragments including stones in various proportions from very low, i.e, 3% to as high as 90%. These coarser fragments contained $CaCo_3$ concretions in Palathurai and Patancheru soils (P22 and P41, respectively) and Fe concretions in Kaukuntla soils (P34). The Palathurai, Hayatnagar and Patancheru soils show *slight* to *violent* effervescence towards the lower part of the soil profiles and in the C-horizons.

3.8 Other Features

Other features include slickensides, cracks, gilgai microrelief in the black soils and clay cutans in the red soils. Presence of slickensides or wedge-shaped peds with an upper boundary within 100 cm of the soil surface is mandatory to qualify a soil to Vertisols (Soil Survey Staff 1999). A slickenside is a smooth, striated surface, formed in shrink-swell clays by the sliding of one surface against the other due to differential swelling pressures. This is a common feature of the Vertisols rich in smectite type clays.

Pressure faces are considered as weak expressions of slickensides. In most occasions this morphological feature is identified in the soil horizons immediately above the slickensided horizons. Besides slickensides, Vertisols and their intergrades should have cracks, which open and close periodically. A crack has been defined as a separation between gross polyhedrons. If the surface is strongly self-mulching or if the soil is cultivated while cracks are open, the cracks may be filled mainly by granular

material from the surface. A crack is regarded as open, if it controls the infiltration and percolation of water in a dry, clayey soil (Soil Survey Staff 1999). The presence of slickensides and cracks are not mandatory for grouping soils as intergrades of Vertisols (i.e., Inceptisols or Alfisols) if linear extensibility value is 6.0 or more (Soil Survey Staff 1999).

Gilgai microrelief is an important observation in undisturbed land, which is normally associated with the Vertisols in that landscape. With the introduction of agriculture, this surface feature disappears. Hence, such morphological features were not identified in the agricultural field from where the soils were collected. Alfisols are identified in the field by the presence of clay cutans (by 10x hand lens) in the illuvial B-horizons (Bt) of soils.

3.8.1 Black Soils

Slickensides are observed in all the soils in sub-humid (moist) bioclimatic system. Although pressure faces and weakly developed slickensides appear within 15-30 cm depth well developed and closely intersecting slickensides appear between 60 and 84 cm depth of soils with the exception of Boripani (P15) and Nabibagh soils under FM (P6). Since most of the areas are under irrigation, cracks are not easily identifiable, although 0.5 to 2.0 cm wide cracks limited up to 35 cm depth were observed in few locations.

Well-developed slickensides appear in Linga soils (P1, P2, P3) between 41 and 102 cm, although pressure faces and weakly-formed slickensides are common within 13 to 16 cm depth in the sub-humid (dry) bioclimatic system. In Sarol series, well-developed slickensides appear between a depth of 44 to 66 cm depth with the depth of occurrence of slickensides increasing from 44 cm in LM to about 60 cm in HM. Slickensides are, in general, weakly developed in soils of Adilabad district of Andhra Pradesh in Nipani (P48) and Pangidi (P49) soils. Except Sarol soils under HM (P7) and LM (P9), cracks are either not well pronounced or limited to 15-20 cm depth. In P7, 2.5 to 7.5 cm wide cracks extend up to 85 cm depth and in P9 such cracks are up to 120 cm puncturing the slickensides.

Well-developed slickensides appear in the soils of semi-arid (moist) bioclimatic system within a depth of 37 to 69 cm. The depth of occurrence of slickensides in Asra soils varies from 40 to 69 cm. In general, soils under HM show slickensides at lower depth than soils under LM. The cracks in these soils extend up to 107 to 125 cm. In the soils under HM (P12) the cracks are limited to 50 cm depth only.

Well-developed slickensides appear in the semi-arid (dry) bioclimatic system from 35 and 69 cm depth in Paral soils, i.e., HM (P14) and LM (P13), respectively. The slickenside formation is generally weak in Kovilpatti soils and appear between 20 and 55 cm depth.The Jhalipura soils show the appearance of slickensides at about 48 to 58 cm depth. Jajapur soils indicate weak to very weakly developed slickensides from 28 to 48 cm. Kasireddipalli soils under traditional management (TM) system show the appearance of slickensides at 30 cm depth whereas similar soils under HM show appearance of slickenside at 54 cm depth. Paddy soils of Teligi series show appearance of slickensides from 44 cm in LM and 54 cm in HM. Konheri soils show weak to very weakly developed slickensides. Kalwan soils show the appearance of slickensides within 50 cm depth.

Generally, the cracks present in Paral soils (P13, P14), Kasireddipalli soils (P40) and Teligi soils (P44) are wide (4 to 6 cm up to 60 to 70 cm depth) and extend up to 140 to 150 cm depth. However, in Teligi soils cracks extend only up to 54 cm depth. For other soils polygonal cracks in the surface are common. For a few soils such as P20, P21, P32, P33, P36, P43 and P47 cracks were not noticed at the time of profile examination.

Well-developed slickensides are observed in Nimone soils only at 55 cm depth under HM and at 84 cm under FM in the arid bioclimatic zone. In Sokhda soils (P31) slickensides appear at nearly 60 cm depth and cracks extend up to 60-90 cm depth. The cracks are more wide in Sokhda under FM2 (P31) than FM1 (P30). Cracks were not observed in Nimone soils (P51) due to moistness of the profile. In P52, cracks extend up to 25-30 cm depth.

3.8.2 Red Soils

In red soils, pressure faces, slickensides and cracks were not observed except in Kaukuntla (P34) and Patancheru (P41) soils which have pressure faces in 27-68 cm and 21-65 cm depth, respectively.

It may be mentioned that thin patchy argillans as shown by the Bt horizons are identified in all the red soils of Dadarghugri, Karkeli [sub-humid (moist)], Vijaypura [semi-arid (moist)], and Hayatnagar, Patancheru, Kaukuntla and Palathurai [semi-arid (dry)]. These thin and patchy clay cutans qualify for argillic horizon in these soils. These soils are accordingly grouped as Alfisols (Soil Survey Staff 1999).

Details of pressure faces, slickensides, cracks and cutans are given as other features in Appendix 1.

3.9 Soil Classification

The soils were classified following US Soil Taxonomy (Soil Survey Staff 1999).

3.9.1 Black Soils

In the sub-humid (moist) bioclimate system, all the soils are grouped as Typic Haplusterts. However, the Boripani soils are grouped as Vertic Haplusterts. Due to higher clay percentage (>60%), Panjri soils and Kheri soils (P27) are grouped under very fine textural class. Different textural class puts the soils of P28 as Kheri 1 series (Table 3.1).

Table 3.1. Classification of black soils in sub-humid (moist) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P4	Panjri	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P5	Nabibagh	Fine	Smectitic	Hyperthermic	Typic Haplusterts
P6	Nabibagh	Fine	Smectitic	Hyperthermic	Typic Haplusterts
P15	Boripani	Very fine	Smectitic	Hyperthermic	Vertic Haplustepts
P27	Kheri	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P28	Kheri 1	Fine	Smectitic	Hyperthermic	Typic Haplusterts

All the soils in sub-humid (dry) bioclimate system are grouped as Typic Haplusterts. The textural, mineralogy and temperature class of Linga and Sarol soils are very fine, smectitic and hyperthermic. P50 was grouped into Vertic Haplustepts as these soils have depth only up to 41 cm and thus are named as Pangidi 1 soil series (Table 3.2).

Table 3.2. Classification of black soils in sub-humid (dry) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P1	Linga	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P2	Linga	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P3	Linga	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P7	Sarol	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P8	Sarol	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P9	Sarol	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P48	Nipani	Fine	Smectitic	Hyperthermic	Typic Haplusterts
P49	Pangidi	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P50	Pangidi 1	Very fine	Smectitic	Hyperthermic	Vertic Haplustepts

The black soils in semi-arid (moist) bioclimate are Asra soils, which are grouped into Typic Haplusterts. The Bhatumbra soils are Udic Haplusterts and belong to isohyperthermic temperature class (Table 3.3).

Table 3.3. Classification of black soils in semi-arid (moist) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P10	Asra	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P11	Asra	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P12	Asra	Very fine	Smectitic	Hyperthermic	Typic Haplusterts
P42	Bhatumbra	Very fine	Smectitic	Isohyperthermic	Udic Haplusterts

In the semi-arid (dry) bioclimate, Semla (P29), Jhalipura (P32, P33), Kalwan (P47) and Kasireddipalli soils were classified into the same class of Typic Haplusterts. These soils have similar textural, mineralogical and temperature classes except Kasireddipalli, which is isohyperthermic (Table 3.4). The Paral soils belong to hyperthermic and were classified as Sodic Haplusterts. The Kovilpatti soils (P19 and P21) are Gypsic Haplusterts, whereas P20 belongs to Leptic Gypsiusterts due to depth limitation and are thus named as Kovilpatti 1 series. Though both the pedons (P35 and P36) of Jajapur series belong to Vertic Haplustepts, due to the difference in textural class (Table 3.4), P36 is named as Jajapur1. P43 and P44 soils are similar with respect to mineralogy, texture and subgroup classification, except textural class. Therefore, P43 with fine textural class, is named as Teligi series and P44 with very fine textural class as Teligi 1 series. Both the soils are classified as Sodic Haplusterts. On the basis of differences in subgroup level classification, P45 was named as Konheri series whereas P46 as Konheri 1 series. Out of 17 pedons 12 observations fall in isohyperthermic temperature class (Table 3.4).

The black soils in the arid bioclimatic system are grouped as Sodic Haplusterts. The pedon P30 is an exception (Table 3.5) because unlike P31 it is moderately deep and belongs to Leptic Haplusterts and therefore named as Sokhda 1.When the soil classification at subgroup level was compared with the bioclimatic system vis-à-vis MAR pattern it was found that up to about 800 mm annual rainfall cover sub-humid (moist), sub-humid (dry) and semi-arid (moist) bioclimatic systems. Typic Haplusterts are the dominant soils in all the benchmark soils. The Gypsic and Calcic Haplusterts are found only in semi-arid (dry) bioclimatic system experiencing MAR of 550-800 mm. The formation of Sodic Haplusterts, which show a beginning in semi-arid dry bioclimatic system gradually covered the entire arid bioclimatic system showing a corresponding decrease in SOC and increase in soil inorganic carbon. Figure 3.1 shows soil grouping in relation to annual rainfall.

Table 3.4. Classification of black soils in semi-arid (dry) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P13	Paral	Very fine	Smectitic	Hyperthermic	Sodic Haplusterts
P14	Paral	Very fine	Smectitic	Hyperthermic	Sodic Haplusterts
P19	Kovilpatti	Very fine	Smectitic	Isohyperthermic	Gypsic Haplusterts
P20	Kovilpatti 1	Fine	Smectitic	Isohyperthermic	Leptic Gypsiusterts
P21	Kovilpatti	Very fine	Smectitic	Isohyperthermic	Gypsic Haplusterts
P29	Semla	Fine	Smectitic	Hyperthermic	Typic Haplusterts
P32	Jhalipura	Fine	Smectitic	Hyperthermic	Typic Haplusterts
P33	Jhalipura	Fine	Smectitic	Hyperthermic	Typic Haplusterts
P35	Jajapur	Fine	Smectitic	Isohyperthermic	Vertic Haplustepts
P36	Jajapur 1	Fine-loamy	Smectitic	Isohyperthermic	Vertic Haplustepts
P39	Kasireddipalli	Fine	Smectitic	Isohyperthermic	Sodic Haplusterts
P40	Kasireddipalli	Fine	Smectitic	Isohyperthermic	Sodic Haplusterts
P43	Teligi	Fine	Smectitic	Isohyperthermic	Sodic Haplusterts
P44	Teligi 1	Very fine	Smectitic	Isohyperthermic	Sodic Haplusterts
P45	Konheri	Fine	Smectitic	Isohyperthermic	Vertic Haplustepts
P46	Konheri 1	Very fine	Smectitic	Isohyperthermic	Leptic Haplusterts
P47	Kalwan	Fine	Smectitic	Isohyperthermic	Typic Haplusterts

Table 3.5. Classification of black soils in arid bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P30	Sokhda	Fine	Smectitic	Hyperthermic	Leptic Haplusterts
P31	Sokhda 1	Fine	Smectitic	Hyperthermic	Sodic Haplusterts
P51	Nimone	Very fine	Smectitic	Isohyperthermic	Sodic Haplusterts
P52	Nimone	Fine	Smectitic	Isohyperthermic	Sodic Haplusterts

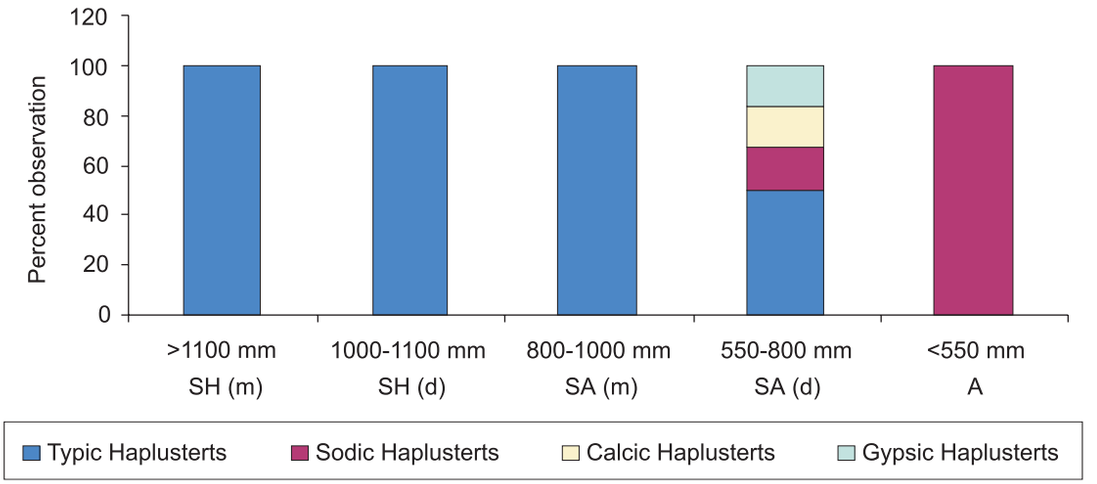

Figure 3.1. Soil taxonomy as influenced by rainfall in different bioclimatic systems (see note in Fig. 2.1).

3.9.2 Red Soils

The red soils in sub-humid moist bioclimatic system are grouped as Typic Haplustalfs (P23, P24) and Typic Paleustalfs (P25, P26). Due to difference in textural class, P25 and P26 are named as Karkeli and Karkeli 1, respectively (Table 3.6).

The Vijaypura 1 soils are similar (P17 and P18) and are grouped as fine-loamy, kaolinitic, isohyperthermic Typic Haplustalfs (Table 3.7), whereas P16 has fine textural class and therefore named as Vijaypura.

Red soils in the semi-arid (dry) bioclimatic system are Typic Haplustalfs (P22, P34) and Typic Rhodustalfs (P37, P38, P41) (Table 3.8).

Table 3.6. Classification of red soils in sub-humid (moist) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P23	Dadarghugri	Clayey-skeletal	Mixed	Hyperthermic	Typic Haplustalfs
P24	Dadarghugri	Clayey-skeletal	Mixed	Hyperthermic	Typic Haplustalfs
P25	Karkeli	Coarse-loamy	Mixed	Hyperthermic	Typic Paleustalfs
P26	Karkeli 1	Fine-loamy	Mixed	Hyperthermic	Typic Paleustalfs

Table 3.7. Classification of red soils in semi-arid (moist) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P16	Vijaypura	Fine	Kaolinitic	Isohyperthermic	Typic Haplustalfs
P17	Vijaypura 1	Fine-loamy	Kaolinitic	Isohyperthermic	Typic Haplustalfs
P18	Vijaypura 1	Fine-loamy	Kaolinitic	Isohyperthermic	Typic Haplustalfs

Table 3.8. Classification of red soils in semi-arid (dry) bioclimatic system.

Pedon no.	Series name	Textural class	Mineralogy class	Temperature class	Subgroup classification
P22	Palathurai	Fine-loamy	Mixed	Isohyperthermic	Typic Haplustalfs
P34	Kaukuntala	Fine	Mixed	Isohyperthermic	Vertic Haplustalfs
P37	Hayatnagar	Loamy-skeletal	Mixed	Ioshyperthermic	Typic Rhodustalfs
P38	Hayatnagar	Loamy-skeletal	Mixed	Isohyperthermic	Typic Rhodustalfs
P41	Patancheru	Fine	Mixed	Isohyperthermic	Typic Rhodustalfs

4. Summary and Conclusions

4.1 Summary

Soil depth, color, texture, consistence, structure, roots, coarse fragments, nodules and effervescence, pressure faces, slickensides, cracks and clay cutans (or argillans) have both direct and indirect relation with SOC and soil inorganic carbon. Soil inorganic carbon is estimated from $CaCO_3$ equivalent of soils in <2 mm size. Relative proportion of SOC and soil inorganic carbon should therefore, reflect those morphological features mentioned above.

Generally, soil color and concentration of roots have a direct bearing on SOC content of soil. Since SOC content is again related to the level of management, therefore darker color in black soils (10YR3/2) might indicate higher level of soil management. Concentration of roots in agricultural fields is usually more within first 25-30 cm depth of soil. Although most of the roots may not fit into the overall calculation of Walkley and Black (1934) carbon nevertheless, it might indicate better soil environment for more root proliferation because better root proliferation requires more aeration and better supply of nutrients. Relatively high SOC content influences soil structure, which provides better soil aeration. Higher amount of SOC also might supply more nutrition for better root growth. Soil management changes soil environment. Therefore, increasing SOC is important in the SAT and arid environments. The red soils studied in the forest ecosystem are rich in SOC as compared to their counterparts utilized for cultivation.

It is, however, cautioned that the black soils contain relatively high amounts of manganese and titanium minerals present as a result of complex interaction of clay humus and other amorphous and crystalline sesquioxides. Hence, these soils perhaps show typical black color in spite of low inorganic matter.

It has earlier been reported that the depth of occurrence of slickenside is related with soil moisture regime, viz, udic and ustic (Vadivelu and Challa 1985). These authors reported that depth of slickensides increases in areas where the rainfall is high. These observations allowed developing a mathematical equation to calculate linear distance of cyclic horizon in Vertisols (Bhattacharyya et al. 1999). Our study from sub-humid (moist) to arid bioclimatic system generally agrees with the above observations (Fig. 4.1). It is interesting to find that slickensides appear in relatively deep layers in Nimone soils under arid ecosystem. The Nimone soils are under irrigation both in FM and HM. Hence slickensides appear at lower depths. The influence of irrigation is thus similar to that of humid climate experiencing more rainfall so far as depth of occurrence of slickensides is concerned. This demonstrates how management interventions can influence morphological properties of Vertisols. Table 4.1 gives an overall view of depth of occurrence of slickensides in Vertisols of the semi-arid areas.

Table 4.1. Depth of occurrence of pressure faces and slickensides in Indian SAT.

		Pressure faces		Slickensides*	
Bioclimate	Rainfall	HM	LM	HM	LM
Sub-humid (moist)	>1100 mm	13-15	23	60-69	42
Sub-humid (dry)	1000-1100	15	13-17	41-57	44-57
Semi-arid (moist)	800-1000	12	12-14	40	37-59
Semi-arid (dry)	550-800	8-13	9-20	31-35	35-58
Arid	<550	13	11-12	55	37-55

** Indicates only well developed slickensides close to intersect.*

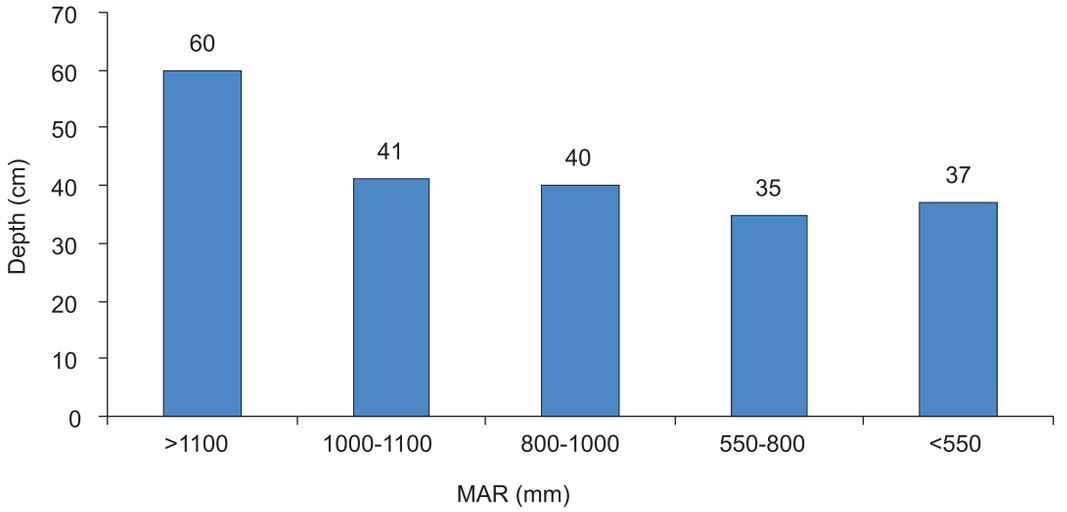

Figure 4.1. Mean annual rainfall (MAR) in relation to the depth of occurrence of slickensides in SAT Vertisols in India.

As indicated earlier, the 52 pedons are broadly identified with Inceptisols, Vertisols and Alfisols. These soils can again be broadly grouped into two temperature classes such as hyperthermic and isohyperthermic under family level of soil classification. Soils under hyperthermic classes have a difference in soil temperature of 6^0C or more between mean summer and mean winter, with a mean annual soil temperature of 22^0C or more. For isohyperthermic temperature class the mean summer and mean winter soil temperatures differ by less than 6^0C with a mean annual soil temperature of 22^0C (Soil Survey Staff 1999). In general, areas of isohyperthermic temperature class do not have a well pronounced winter season. Thus this temperature regime characterizes an area having similar temperature throughout the year.

In the study area, the western part of Maharashtra (Nasik, Solapur and Ahmednagar), Andhra Pradesh, Karnataka and Tamil Nadu have isohyperthermic temperature class. These areas represent arid, semi-arid (moist), semi-arid (dry) and sub-humid (dry) bioclimatic system. The hyperthermic temperature class in the study area covers entire sub-humid (moist) bioclimatic system, other than few observations in sub-humid (dry), semi-arid (moist), semi-arid (dry) and arid systems (Table 4.2). It was reported earlier that Vertisols under isohyperthermic temperature regime show better cropping performance than those under hyperthermic temperature regime (NBSS&LUP-ICRISAT 1991). To find out the difference in morphological properties of soils under these two regimes, the following observations were made. In the sub-humid (dry) bioclimate, the effervescence in soils under isohyperthermic regime is *slight* except for P48. In hyperthermic temperature regime almost all the soils show *slight* effervescence up to a depth of 100-130 cm, beyond which effervescence is *strong*.

In the semi-arid (moist) bioclimatic system under hyperthermic temperature regime, effervescence is generally *slight* in P12, *slight* up to a depth of 90 cm in P10 and *strong* in P11, throughout the profile. In contrast, Bhatumbra soils under isohyperthermic temperature regime indicate *slight* effervescence. In semi-arid (dry) bioclimatic system, the effervescence is *strong* to *violent* throughout the depth of the profile in contrast to *slight* effervescence at least up to 75 to 100 cm in Kovilpatti (P19, P21, P21); 35-53 cm in Jajapur (P35, P36) and 59-84 cm depths in Kasireddipalli (P39, P40) soils.

In arid bioclimatic system, soils under hyperthermic temperature regime indicate *violent* effervescence throughout the profile depth. In isohyperthermic temperature regime *strong* to *violent* effervescence was observed throughout the profile depth. Influence of temperature regime on effervescence is given in Table 4.3.

Table 4.2. Distribution of pedons under different temperature regimes in the study area.

	Temperature regime			
	Hyperthermic		Isohyperthermic	
Bioclimate	HM	LM	HM	LM
Sub-humid (moist)	P4, P5, P27	P6, P15, P28	-	-
Sub-humid (dry)	P1, P7	P2, P3, P8, P9	P50	P48, P49
Semi-arid (moist)	P12	P10, P11	-	P42
Semi-arid (dry)	P14	P13, P29, P32, P33	P19, P21, P39, P44	P20, P35, P36, P30, P43, P45, P46, P47
Arid	-	P30, P31, P51	P52	P50, P51, P52, P53, P54, P55, P56, P57

Table 4.3. Effervescence as influenced by temperature regime in the study area.

Bioclimatic	Hyperthermic*	Isohyperthermic*
Sub-humid (dry)	e (100-130 cm); es (>130 cm)	e
Semi-arid (moist)	e (90 cm); es (>90 cm)	e
Semi-arid (dry)	es-ev (throughout the depth)	e (35-100 cm)
Arid	ev	es-ev

** Values in parentheses indicate soil depth. See Appendix 2 for abbreviations.*

4.2 Conclusions

- Soils under HM are darker in color indicating more SOC content. Black soils under waterlogged condition show very dark gray color, which is related to higher SOC content.
- Wet consistence such as *very sticky* and *very plastic* correspond with those horizons in black soils showing well developed slickensides. Firm moist consistence may indicate development of sodicity problems, provided there are no or very less amount of soil modifiers such as zeolites and gypsum.
- The black soils under HM in sub-humid (moist) bioclimatic system show moderate structure throughout the profile depth. This is in contrast to common observations of strong structure in other black soils under LM.
- Higher concentration of roots in soils corresponds with lower degree of $CaCO_3$ concentration, as indicated by *slight* effervescence with dil HCl in the field.
- Black soils contain coarse fragments of 3-8%, 1-10%, 1-10% and 5-15% in sub-humid (moist), semi-arid (moist), semi-arid (dry) and arid bioclimatic system, respectively. In general, the degree of effervescence is in line with size and quantity of coarse fragment and calcium concretions observed in the field.
- In general black soils under HM show slickensides at lower depth in the profile. With the decrease in MAR, the depth of occurrence of slickensides decreases from 60 cm in sub-humid (moist) to 30 cm semi-arid (dry) bioclimate. Management intervention including irrigation in drier tracts push the slickensides further down in the profile.
- The formation of Sodic Haplusterts indicate poor organic carbon accumulation but a very high inorganic carbon sequestration in soils of dry part of the arid bioclimatic system. It manifests natural chemical degradation under MAR of <550 mm.

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Appendix 1

Morphological Propertites 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)

(See Appendix 2 for Abbreviations.)

Series: PANJRI BM Spot: 2 (Black Soils)

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

CLIMATE: SUB-HUMID (MOIST) Classification: Very fine, smectitic, Analysis at: Division of Soil Resource
RAINFALL: 1127 mm hyperthermic, Typic Haplusterts Studies, NBSS&LUP, Nagpur.

Location: Panjri, CICR farm, Nagpur, Maharashtra Sampling Date: 30.11.2000

Morphological properties of Profile No. 4 (Panjri, Katol, Nagpur)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-13	c	s	10YR3.5/2	10YR3/2	c	fg 3-5	m	2	sbk
Bw1	13-38	c	s	-	10YR3/2	c	3-5	m	3	sbk
Bss1	38-60	g	w	-	10YR4/2	c	5-8	m	3	abk (weak)
Bss2	60-89	g	w	-	10YR3/2	c	3-5	c	3	abk
Bss3	89-131	c	w	-	10YR4/3* 10YR3.5/2	c	1-3	c	3	abk
Bss4	131-150	-	-	-	10YR4/3.5	c	5-8	m	3	abk

** The first colour dominates and is about 80% by area, the other one is about 20%.*

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-13	h	fr	sp	vf, f	m	vf, f, m	c, f	vf, f	c, f	e	-	1-2 cm
13-38	-	fr	sp	-	-	vf, f, m	c	vf, f	f	e	Pressure faces	
38-60	-	fr	sp	-	-	vf, m	m, c	vf, f	f	e	Slickensides (weak)	
60-89	-	fr	vs, vp	-	-	vf, f	c	vf, f	f	e	Slickensides	
89-131	-	fr	vs, vp	-	-	vf, f	f	vf, f	f	e	Slickensides	
131-150	-	fr	vs, vp	-	-	vf, f, m	m, c	vf	f	e	Slickensides	

Series: NABIBAGH BM Spot: 3 (Black Soils)

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

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

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-13	c	s	10YR3.5/2	10YR3/2	c	fg 3-5	m	2	sbk
Bw1	13-38	c	s	-	10YR3/2	c	3-5	m	3	sbk
Bss1	38-60	g	w	-	10YR4/2	c	5-8	m	3	abk (weak)
Bss2	60-89	g	w	-	10YR3/2	c	3-5	c	3	abk
Bss3	89-131	c	w	-	10YR4/3 10YR3.5/2	c	1-3	c	3	abk
Bss4	131-150	-	-	-	10YR4/3.5	c	5-8	m	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks*
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-13	h	fr	sp	vf, f	m	vf, f, m	c, f	vf, f	c, f	e	-	1-2 cm
13-38	-	fr	sp	-	-	vf, f, m	c	vf, f	f	e	Pressure faces	
38-60	-	fr	sp	-	-	vf, m	m, c	vf, f	f	e	Slickensides (weak)	
60-89	-	fr	vs, vp	-	-	vf, f	c	vf, f	f	e	Slickensides	
89-131	-	fr	vs, vp	-	-	vf, f	f	vf, f	f	e	Slickensides	
131-150	-	fr	vs, vp	-	-	vf, f, m	m, c	vf	f	e	Slickensides	

** Cracks 1-2 cm wide up to 15 cm and <0.5 mm cracks up to 35 cm.*

Series: NABIBAGH BM Spot: 3 (Black Soils)

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

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

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-23	c	s	10YR5/2	10YR4/2	c	3-5	m	2	sbk
Bw1	23-42	g	s	-	10YR3.5/2	c	3-5	c	2	abk
Bss1	42-81	g	s	-	10YR3.5/2	c	3-5	c	2	abk
Bss2	81-122	c	s	-	10YR3/2	c	3-5	c	2	abk
Bss3	122-150	-	-	-	10YR3/2	c	3-5	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-23	h	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	c, f	e	-	0.5 cm
23-42	-	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	c, f	e	Pressure faces	
42-81	-	fr	sp	-	-	vf, f, m	m, f	vf, f	c, f	e	Slickensides	
81-122	-	fr	sp	-	-	vf, f, m	c, f	vf, f	c, f	e	Slickensides	
122-150	-	fr	sp	-	-	f, vf	c	-	-	e	Slickensides	

** Matrix effervescence observed in 42-150 cm.*
*** Cracks ~ 0.5 mm wide up to 20 cm.*

Series: BORIPANI BM Spot: 7 (Black Soils)

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

CLIMATE: SUB-HUMID (MOIST) Classification: Very fine, smectitic, Analysis at: Division of Soil Resource
RAINFALL: 1279 mm hyperthermic, Vertic Haplustepts Studies, NBSS&LUP, Nagpur

Location: Boripani-Sirajpur, Umred, Nagpur, Maharashtra Sampling Date: 24.01.2001

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

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
A1	0-16	g	s	10YR4/2	10YR3/2	c	2-3	c, m	2/1 2	pr, sbk
Bw1	16-44	g	s	10YR4/2	10YR3/2	c	2-3	m	2/1 2	sbk
Bw2	44-57	c	w	10YR4/2	10YR3/2	c	3-5	m	2/1	sbk-abk
Ck1	57-94	-	-	-	10YR4/6 (R)	c	45-50		Massive	

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence (dil HCl)	Other features*	Cracks
0-16	h	fr	sp	vf, f	f	f, m, c	c	f, m	m	e	-	1 cm
16-44	-	fr	sp	vf, f	f	f, m, c	c	f, m, c	c, m	e	Pressure faces	1 cm
44-57	-	fr	sp	vf, f	f	vf, f, m, c	c	f, m, c,	m	e	Pressure faces	1 cm
57-94	-	vfr	spo	-	-	vf, c	m	f, m	c	ev	-	1 cm

** Soil matrix is non-calcareous. Polygonal cracks 10-15 cm in diameter.*

Series: KHERI BM Spot: 13 (Black Soils)

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, Madhya Pradesh		Sampling Date: 17.10.2001

Morphological properties of Profile No. 27 (Kheri, Jabalpur)

Horizon	Depth (cm)	Boundary		Matrix color		Mottle color	Texture	Coarse fragments (%) (fg)	Structure		
		D	T	Dry	Moist				Size	Grade	Type
Ap	0-20	c	s	-	2.5Y5/2	Very faint	c	-	m	2	sbk
Bw1	20-42	c	s	-	10YR3/2	Roots mottles	c	-	m	2	sbk
Bw2	42-63	g	s	-	10YR3/2	7.5YR5/6	c	-	m	2	abk
Bss1	63-84	g	s	-	10YR3/2	-	c	-	m	2	abk
Bss2	84-115	g	s	-	10YR3/2	-	c	-	m	2	abk
Bss3	115-160	-	-	-	10YR3/2	-	c	3-5	m	2	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-20	h	fr	sp	f, m	m	-	-	f	c	e	-	1-2 cm
20-42	-	fr	sp	-	-	-	-	f	f	e	-	1-2 cm
42-63	-	fr	sp	-	-	-	-	-	-	e	Pressure faces	1 m
63-84	-	fr	sp	-	-	vf, f	f	-	-	e	Slickensides	
84-115	-	fi	vs, vp	-	-	vf, f	f	-	-	e	Slickensides*	
115-160	-	fi	vs, vp	-	-	vf, f	f	-	-	e	Slickensides*	

** Intersecting slickensides which increase down the depth.*

Series: KHERI BM Spot: 13 (Black Soils)

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), Madhya Pradesh

Sampling Date: 17.10.2001

Morphological properties of Profile No. 28 (Kheri, Jabalpur)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (% v/v)	(fg and cg)	Structure		
		D	T	Dry	Moist				Size	Grade	Type
Ap	0-14	c	s	2.5Y5/2	2.5Y4.5/3	c	5-6		m	2	sbk
Bw1	14-32	c	s	-	10YR3/2	c	5-6		m	2	sbk
Bw2	32-61	g	s	-	10YR3/2	c	5-6		m	2	abk
Bss1	61-82	g	s	-	10YR3/2	c	5-6		m	3	abk
Bss2	82-112	g	s	-	10YR3/2	c	5-6		m	3	abk
Bss3	112-133	g	s	-	10YR3/2	c	5-6		m	3	sbk
Bss4	133-156	-	-	-	10YR3/2	c	5-6		m	3	sbk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity		
0-14	h	fr	sp	f	c	vf, f	m	f, m	m	es	-
14-32	-	fr	sp	-	-	vf, f	m	f	c	es	Pressure faces
32-61	-	fr	sp	-	-	vf, f	m	f	c	es	Pressure faces
61-82	-	fr	sp	-	-	vf, f	m	f	c	es	Slickensides
82-112	-	fr	sp	-	-	vf, f	m	f	f	ev	Slickensides
112-133	-	fr	sp	-	-	vf, f	m	vf	f	ev	Slickensides
133-156	-	fr	sp	-	-	vf, f	m	vf	f	ev	Slickensides

BLACK SOILS

Sub-humid (dry)

(MAR 1000->1100 mm)

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

(See Appendix 2 for Abbreviations.)

Series: LINGA BM Spot: 1 (Black Soils)

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

Morphological properties of Profile No. 1 (Linga, Katol, Nagpur)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-15	c	s	10YR4/2	10YR3/2	c	5-8	m	2	sbk
Bw	15-41	c	s	-	10YR3/2	c	5-8	m	3	sbk
Bss1	41-70	c	s	-	10YR3/2	c	3-5	c to m	3	abk
Bss2	70-95	g	s	-	10YR3.5/2	c	3-5	c	3	abk
Bss3	95-135	c	w	-	10YR4/2	c	1-2	c	3	abk
Bss4	135-155+	-	-	-	10YR4/3	c	1-2	m	2	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-15	h	fr	sp	vf, f	m	vf, f, c	c, f	f, m, c	f	e	-	1-2 cm
15-41	h	fr	sp	-	-	vf, f, c	c, f	f, m, c	f	e	Pressure faces	1 cm
41-70	-	fr	vs, vp	-	-	vf, f, c	c, f	f, m, c	f	e	Slickensides	
70-95	-	fr	vs, vp	-	-	vf , c	f, f	vf, f	f	e	Slickensides	
95-135	-	fr	vs, vp	-	-	vf, f	c, f	vf	f	e	Slickensides	
135-155+	-	fr	vs, vp	-	-	vf, f	f, c	nil	nil	es	Slickensides	

Series: LINGA BM Spot: 1 (Black Soils)

Profile No. P2 ***System: Horticulture (Soybean-Chickpea/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

Morphological properties of Profile No. 2 (Linga, Katol, Nagpur)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-13	c	s	10YR3.5/2	10YR3/2	c	3-5	m	2	sbk
Bw	13-33	g	s	-	10YR3/2	c	3-5	m	3	sbk
Bw1	33-55	g	s	-	10YR3/2	c	3-5	m	3	sbk-abk
Bss1	55-81	g	s	-	10YR3/2	c	2-3	m	3	abk
Bss2	81-119	c	s	-	10YR3/1.5	c	2-3	c	3	abk
Bss3	119-150+	-	-	-	10YR4/2.5	c	2-3	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-13	sh	fr	sp	vf, f	m	f, vf, m	m, c	vf, f	m, f	e	-	0.5 cm
13-33	-	fr	sp	-	-	f, vf, m	m, f	vf, f	c, f	e	Pressure faces	
33-55	-	fr	sp	-	-	vf, f	m, c	vf	c	e	Slickensides (weak)	
55-81	-	fr	vs, vp	-	-	vf, f	m, c	vf	f	e	Slickensides	
81-119	-	fr	vs, vp	-	-	vf, f, m	m, c, f	vf	f	e	Slickensides	
119-150+	-	fr	vs, vp	-	-	vf, f, m	m, c, f	-	-	e	Slickensides	

** Matrix effervescence was also observed.*

Series: LINGA BM Spot: 1 (Black Soils)

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

Morphological properties of Profile No. 3 (Linga, Katol, Nagpur)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-16	c	s	10YR3.5/2	10YR3/2	c	3-5	m	2	sbk
Bw1	16-44	g	s	-	10YR3/1.5	c	3-5	m	3	sbk
Bw2	44-69	g	s	-	10YR3/1.5	c	2-3	m	3	sbk-abk
Bss1	69-102	g	s	-	10YR3/1.5	c	2-3	m	3	abk (weak)
Bss2	102-128	g	s	-	10YR3.5/2.5	c	2-5	m	3	abk
Bss3	128-150	c	s	-	10YR4/3	c	5-8	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescenc* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-16	sh	fr	sp	vf, f	m	vf, f	m	vf, f, m	m, f	e	-	0.5 cm
16-44	-	fr	sp	vf, f	m, c	vf, f, m	m, f	vf, f, m	c, f	e	Pressure faces	0.5 cm
44-69	-	fr	sp	-	-	vf, f, m	m, f	vf, f	c	e	Slickensides (weak)	
69-102	-	fr	vs, vp	-	-	vf, f, m	f, c	vf, f	f	e	Slickensides (weak)	
102-128	-	fr	vs, vp	-	-	vf, f, c	m, f	vf	f	es	Slickensides	
128-150	-	fr	vs, vp	-	-	vf, f, m, c	c, f	-		es	Slickensides	

** Matrix effervescence was also observed.*
*** Cracks ~ 0.5 mm wide up to 35 cm depth.*

Series: SAROL BM Spot: 4 (Black Soils)

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 Farm, Bhavarkuan, Indore, Madhya Pradesh

Sampling Date: 7.12.2000

Morphological properties of Profile No. 7 (Sarol, Bhavarkuan, Indore)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-14	c	s	2.5Y3/2	2.5Y3/2	c	3-5	m	2	sbk
Bw1	14-28	g	s	-	2.5Y3/2	c	5-8	m	3	sbk
Bss1	28-57	g	w	-	2.5Y3/2	c	2-3	c	3	abk
Bss2	57-85	g	s	-	2.5Y3/2	c	5-8	c	3	abk
Bss3	85-109	g	w	-	2.5Y3/2	c	5-8	c	3	abk
Bss4	109-130	g	w	-	2.5Y4/3 & 3/2	c	8-10	c m	3 2	abk sbk
Bss5	130-155	-	-	-	2.5Y4/4 & 3/2	c	8-10	c m	3 2	abk sbk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-14	sh, h	fr	sp	vf, f	m	m, c	c	f, m	m, c	e	-	2.5–7.5 cm
14-28	vh	fr	sp	vf, f	m	m, c	c	f, m	m, f	**e	-	2.5–7.5 cm
28-57	-	fr	sp	-	-	m, c	c	f, m	m, f	**e	Slickensides /Pressure faces	2.5–7.5 cm
57-85	-	fr	sp	-	-	m, c	c	f	c	**e	Slickensides	2.5–7.5 cm
85-109	-	fr	sp	-	-	m, c	c	f	f	*e	Slickensides	
109-130	-	fr	sp	-	-	vf, f	m	-	-	*e-es	Slickensides	
130-155	-	fr	sp	-	-	vf, f	m			*e-es	Slickensides	

** Matrix effervescence observed in 85-135 cm.*
*** Matrix does not show any effervescence.*

Series: SAROL BM Spot: 4 (Black Soils)

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

Morphological properties of Profile No. 8 (Sarol, Limbodi, Indore)

		Boundary		Matrix color				Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	Coarse fragments (%) (fg and cg)	Size	Grade	Type
Ap	0-18	g	s	10YR4/2	10YR3/2	c	3-5	m	3	sbk
Bw1	18-45	g	s	-	10YR3.5/2	c	3-5	m	3	sbk
Bw2	45-66	c	s	-	10YR3/2	c	3-5	m	3	abk (weak)
Bss1	66-90	c	s	-	10YR3.5/2	c	3-5	m	3	abk
Bss2	90-124	d	s	-	10YR3.5/2	c	3-5	c	3	abk
Bss3	124-159+	-	-	-	10YR4/3 (R)	c	3-5	c	3	abk

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence*** (dil HCl)	Other features	Cracks
0-18	vh	fr	sp	vf, f	c	vf, f, m	c	vf, f	c	nil to e	-	0.5 cm
18-45	-	fr	sp	vf, f	c	vf, f	c	vf	f	e	-	0.5 cm
45-66	-	fr	sp	-	-	vf, f, m	c, m, f	vf	f	e	Pressure faces/ Slickensides (weak)	25 cm
66-90	-	fr	sp	-	-	vf, f, m	c, m	vf	f	e	Slickensides**	
90-124	-	fr	sp	-	-	vf, f, m	c, f	vf	f	e	Slickensides	
124-159	-	fr	sp	-	-	vf, f, m	c, f	-	-	e*	Slickensides	

** Many vertical cracks ≅ 0.5 cm wide up to 25 cm depth.*
*** Well developed sides about 3 feet wide at an angle 35° to 40°.*
**** Matrix effervescence was also observed.*

Series: SAROL BM Spot: 4 (Black Soils)

Profile No. P9 ***System: Agriculture (Soybean-Chickpea in mango orchard) (LM)***

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 Farm, Bhavarkuan, Indore, Madhya Pradesh

Sampling Date: 7.12.2000

Morphological properties of Profile No. 9 (Sarol, Limbodi, Indore)

		Boundary		Matrix color				Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	Coarse fragments (%) (fg and cg)	Size	Grade	Type
Ap	0-17	c	s	10YR4/2	10YR3.5/2	c	8-10	m	3	sbk
Bw	17-44	g	s	-	10YR3/2	c	5-8	m	3	sbk
Bss1	44-79	g	s	-	10YR3/2	c	5-8	m	3	sbk-abk
Bss2	79-102	g	s	-	10YR3/2	c	8-15	c	3	abk
Bss3	102-127	c	s	-	10YR3/2,4/3	c	8-15	c	3	abk
Bss4	127-152	-	-	-	10YR4/3.5	c	15-20	c	3	abk

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence* (dil HCl)	Other features	Cracks**
0-17	vh	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	m	e	-	10-20 cm
17-44	-	fi	sp	-	-	vf, f, m	m, f	vf, f	c	e	Pressure faces	0.5 cm
44-79	-	sfi	vs, vp	-	-	vf, f, m	m, f	vf, f	c, f	e	Slickensides	
79-102	-	fi	vs, vp	-	-	vf, f, m	m, f	vf	f	e	Slickensides	
102-127	-	fi	vs, vp	-	-	vf, f, m	m, c	vf	f	e	Slickensides	
127-152	-	sfi	vs, vp	-	-	vf, f, m	m, c	-	-	e	Slickensides	120 cm

** Matrix effervescence also observed in 102 to 152 cm.*
*** Cracks 10-20 cm wide up to 20 cm depth; <5 mm wide up to 120 cm penetrating the slickensides.*

Series: NIPANI BM Spot: 26 (Black Soils)

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

Morphological properties of Profile No. 48 (Nipani, Adilabad)

		Boundary		Matrix color			Coarse fragments (%)*		Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(fg, cg)	(st)	Size	Grade	Type
Ap	0-13	c	s	-	10YR3/1.5	sic	3-5	1-3	m	2	sbk
Bw1	13-35	g	s	-	10YR3/2	sic	3-5	-	m	2	sbk
Bw2	35-62	g	s	-	10YR3/2	sic	3-5	-	m	3	sbk-abk (weak)
Bss1	62-88	g	s	-	10YR3/2	sic	3-5	-	m	3	abk
Bss2	88-127	c	w	-	10YR3.5/2	sic	5-8	-	m	3	abk
Bss3	127-155+	-	-	-	10YR3.5/2	sic	8-10	-	m	3	abk

** Few limestone fragments.*

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence* (dil HCl)	Other features	Cracks
0-13	-	vfr	sp	vf, f, m	m, c	vf, f, m	m, f	vf, f, m	f	ev	-	Not observed
13-35	-	fr	sp	vf, f, m	m, c	vf, f	c	vf, f, m	f	ev	Pressure faces	
35-62	-	fr	sp	vf, f, m	m, c	vf, f	c	vf	f	ev	Slicken-sides (weak)	
62-88	-	fr	sp	vf, f	m	vf, f	m	vf	f	ev	Slicken-sides (weak)	
88-127	-	fr	sp	-	-	vf, f, m	m, f	vf	f	ev	Slicken-sides (weak)	
127-155+	-	fr	sp	-	-	vf, f, m, c	m, f	vf	f	ev	Slicken-sides (weak)	

** Matrix effervescence was also observed.*

Series: PANGIDI BM Spot: 27 (Black Soils)

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

Morphological properties of Profile No. 49 (Pangidi, Adilabad)

		Boundary		Matrix color			Coarse fragments (%)		Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(fg, cg)	(st)	Size	Grade	Type
Ap	0-14	c	s	10YR3/2	10YR3/2	c	2-3	1-3	m	2	sbk
Bw1	14-36	g	s	-	10YR3/1.5	c	2-3	-	m	3	sbk
Bw2	36-62	g	s	-	10YR3/2	c	2-3	-	m	3	sbk-abk
Bss1	62-87	c	w	-	10YR3/1.5	c	3-5	-	m	3	abk
Bss2	87-110	-	-	-	10YR4/3; 10YR3.5/2(R)	c	5-8	-	m	3	abk

Depth	Consistence			Porosity		Nodules (conca)		Roots		Effervescence	Other	
(cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	(dil HCl)	features	Cracks
0-14	h	fr	sp	vf, f	m	vf, f, m	m, c	vf, f	c, f	e	-	0.5 to 1 cm
14-36	-	fr	sp	vf, f	m	vf, f,,m	m, c	vf, f	c, f	e	-	
36-62	-	fr	vs, vp	vf, f	m	vf, f, m	m, f	vf, f	c, f	e	Pressure faces	
62-87	-	fr	vs, vp	vf, f, m	m, f	vf, f, m, c	m, f	vf	c	e	Slickensides*	
87-110	-	fr	vs, vp	-	-	vf, f, m, c	m, f	vf	f	e	Slickensides*	

** In patches. Earthworm activity is concentrated throughout the profile.*

Series: PANGIDI BM Spot: 27 (Black Soils)

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

Morphological properties of Profile No. 50 (Pangidi, Adilabad)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg %)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-11	c	s	10YR3/1	10YR3/1.5	c	2-3	m	2	sbk
Bw1	11-27	c	s	-	10YR3/1.5	c	2-3	m	2	sbk
Bw2	27-41	c	w	-	10YR3/2	c	3-5	m	3	sbk
Crk	41-55	-	-	-	10YR4/1(R)	c	45-50	Massive		

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)*	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-11	sh	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	c, f	e	-	Not observed
11-27	-	fr	sp	vf, f	m	vf, f, m	c, f	vf, f	c, f	e	-	
27-41	-	fr	sp	vf, f	m	vf, f, m	m, f	vf	f	e	Pressure faces	
41-55	-	fr	sp	-	-	-	-	vf	f	ev	-	

* *Calcareous parent material (lime stone).*

BLACK SOILS

Sub-arid (moist)

(MAR 850->1000 mm)

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

(See Appendix 2 for Abbreviations.)

Series: ASRA BM Spot: 5 (Black Soils)

Profile No. P10 ***System: Agriculture (Cotton/Mung bean + 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

Morphological properties of Profile No. 10 (Asra, Amravati)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-14	c	s	-	10YR2.5/2	c	3-5	m	2	sbk
Bw1	14-40	g	s	-	10YR2.5/2	c	3-5	m	3	sbk
Bw2	40-59	c	s	-	10YR2/2	c	3-5	m	3	sbk
Bss1	59-91	g	s	-	10YR2.5/2	c	3-5	m	3	abk
Bss2	91-125	g	s	-	10YR3/2.5	c	5-8	c	3	abk
Bss3	125-150	-	-	-	10YR3/2.5	c	5-8	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-14	-	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	m, c	e	-	2 cm
14-40	-	fr	sp	-	-	vf, f, m	m, f	vf, f	m, c	e	Pressure faces	
40-59	-	fr	sp	-	-	vf, f	m, f	vf, f	c, f	e	Pressure faces	1 cm
59-91	-	fi	sp	-	-	vf, f	m, f	vf, f	c, f	e	Slickensides	0.5 cm
91-125	-	fi	vs, vp	-	-	vf, f, m	m, f	vf, f	c, f	es	Slickensides	0.2 cm
125-150	-	fi	vs, vp	-	-	vf, f, m	m, f	vf	c	es	Slickensides	

** Matrix effervescence was also observed.*
*** Cracks 2 cm wide up to 40 cm and 1 cm wide cracks up to 60 cm, 0.5 cm wide up to 91 cm and 0.2 cm wide up to 125 cm.*

Series: ASRA BM Spot: 5 (Black Soils)

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

CLIMATE: SEMI-ARID (MOIST) Classification: Very fine, smectitic, Analysis at: Division of Soil Resource
RAINFALL: 975 mm hyperthermic, Typic Haplusterts Studies, NBSS&LUP, Nagpur

Location: Asra, Bahtkuli, Amravati, Maharashtra Sampling Date: 16.01.2001

Morphological properties of Profile No. 11 (Asra, Amravati)

		Boundary		Matrix color				Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	Coarse fragments (%) (fg and cg)	Size	Grade	Type
Ap	0-14	-	-	-	10YR2/2	c	1-3	m	3	sbk
Bw1	14-35	c	s	-	10YR2/2	c	1-3	m	2	sbk
Bss1	35-69	g	s	-	10YR2/2	c	1-3	m	3	abk (weak)
Bss2	69-107	g	w	-	10YR2/2	c	<1	m	3	abk
Bss3	107-150	g	w	-	10YR2/2	c	<1	m	3	abk

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence* (dil HCl)	Other features	Cracks**
0-14	-	fr	sp	vf, f	m	vf, f	m, f	vf, f	c, f	es	-	1-2 cm
14-35	-	fr	sp	-	-	vf, f	m, f	vf, f	c, f	es	Pressure faces	0.5 cm
35-69	-	fi	sp	-	-	vf, f	m, f	vf	c	es	Slickensides (weak)	0.5 cm
69-107	-	sfi	vs, vp	-	-	vf, f	c, f	vf	f	es	Slickensides	0.5 cm
107-150	-	sfi	vs, vp	-	-	vf, f	c, f	vf	f	es	Slickensides	

** Matrix effervescence was also observed.*
*** Cracks 1-2 cm wide up to 18 cm and 0.5 cm up to 107 cm.*

Series: ASRA BM Spot: 5 (Black Soils)

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, Amravati, Maharashtra

Sampling Date: 17.01.2001

Morphological properties of Profile No. 12 (Asra, Walgaon, Amravati)

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
Ap	0-12	c	s	-	10YR3/2	c	1-2	m	2	sbk
Bw1	12-40	g	s	-	10YR2.5/2	c	1-2	m	3	sbk
Bss1	40-79	g	s	-	10YR2.5/2	c	1-2	m	3	abk
Bss2	79-116	g	s	-	10YR2.5/2	c	1-2	c	3	abk
Bss3	116-150	-	-	-	10YR2.5/2	c	5-8	m	3-2	abk

Depth	Consistence			Porosity		Nodules (conca)		Roots		Effervescence*	Other	
(cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	(dil HCl)	features	Cracks**
0-12	-	fr	sp	vf, f	m	vf, f	c	vf, f, m	m, c	e	-	1 cm
12-40	-	fr	sp	-	-	vf, f	c	vf, f, m	c, f	e	Pressure faces	<0.5 cm
40-79	-	fr	vs, vp	-	-	vf, f	c	vf, f	c	e	Slickensides	<0.5 cm
79-116	-	fr	vs, vp	-	-	vf, f	c	vf, f	c, f	e	Slickensides	
116-150	-	fr	vs, vp	-	-	vf, f, m	m, c	vf	f	e	Slickensides (weak)	

** Matrix effervescence was observed.*
*** Cracks <1 cm wide up to 35 cm and <0.5 cm wide up to 50 cm.*

Series: BHATUMBRA BM Spot: 22 (Black Soils)

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

Morphological properties of Profile No. 42 (Bhatumbra, Bhakli, Bidar)

		Boundary		Matrix color			Coarse fragments (%)	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(fg and cg)	Size	Grade	Type
Ap	0-12	c	s	-	2.5Y3/2	c	2-3*	m	2	sbk
Bw	12-37	c	s	-	2.5Y3.5/2	c	2-3	m	3	sbk
Bss1	37-79	g	s	-	2.5Y3/2	c	3-5	m	3	abk
Bss2	79-110+	a	s	-	2.5Y3/1.5	c	3-5	m	3	abk

** Mainly basaltic gravel and stones.*

Depth	Consistence			Porosity		Nodules (conca)		Roots		Effervescence	Other	
(cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	(dil HCl)	features	Cracks
0-12	-	fr	sp	vf, f	m	vf, f, m	f	vf, f	m	es-e*	-	Not observed
12-37	-	fr	sp	vf, f	m	vf, f, m	f	vf, f	m	e	Pressure faces	
37-79	-	fr	vs, vp	vf, f	m	vf, f, m	f, c	-	-	e	Slickensides	
79-110+	-	fr	vs, vp	-	-	vf, f, m	f, c	-	-	e	Slickenssides	

** Matrix effervescence was also observed. Salt encrustations at the surface.*

BLACK SOILS

Sub-arid (dry)

(MAR 550-850 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)

(See Appendix 2 for Abbreviations.)

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

Morphological properties of Profile No. 13 (Paral, Akola)

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
Ap	0-9	c	s	-	7.5YR3/2	c	5-8	m	2	sbk
Bw1	9-35	g	s	-	7.5YR2.5/2	c	5-8	m	3	sbk
Bss1	35-69	g	s	-	7.5YR2.5/2	c	5-8	m	3	abk
Bss2	69-105	g	w	-	7.5YR2.5/2	c	5-8	c	3	abk
Bss3	105-132	g	w	-	7.5YR2.5/2	c	5-8	c	3	abk
Bss4	132-150	-	-	-	7.5YR2.5/2	c	8-10	c	3	abk

Depth	Consistence			Porosity		Nodules (conca)		Roots		Effervescence*	Other	
(cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	(dil HCl)	features	Cracks**
0-9	-	fr	sp	vf, f	m	vf, f	c	vf, f, m, c	c, f	es	-	6 cm
9-35	-	fr	sp	-	-	vf, f	c	vf, f, m	c, f	es	Pressure faces	4 cm
35-69	-	fi	s, vp	-	-	vf, f	c	vf, f, m	c, f	es	Slickensides (weak)	4 cm
69-105	-	fi	vs, vp	-	-	vf, f	c	vf, f	c	es	Slickensides	0.5-1 cm
105-132	-	fi	vs, vp	-	-	vf, f	c	vf, f	c	es	Slickensides	0.5-1 cm
132-150	-	fi	vs, vp	-	-	vf, f	m	vf, f	f	es	Slickensides	<0.5 cm

** Matrix effervescence was observed.*

*** Cracks 6 cm wide up to 15 cm depth, 4 cm wide up to 70 cm, 0.5-1 cm wide up to 130 cm and <0.5 cm up to 145 cm depth.*

Series: PARAL BM Spot: 6 (Black Soils)

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

Morphological properties of Profile No. 14 (Paral, Akola)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-8	c	s	-	7.5YR3/1	c	5-8	m	2	sbk
Bw	8-35	g	s	-	7.5YR3/1.5	c	5-8	m	3	sbk
Bss1	35-68	g	s	-	7.5YR3/1.5	c	5-8	m	3	abk
Bss2	68-97	g	w	-	7.5YR3/1.5	c	5-8	c	3	abk
Bss3	97-129	g	w	-	7.5YR3/2	c	5-8	c	3	abk
Bss4	129-150	-	-	-	7.5YR3/2	c	8-10	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-8	-	fr	sp	vf, f	m	vf, f	c	vf, f, m	c, f	es	-	5-6 cm
8-35	-	fr	sp	-	-	vf, f	c	vf, f, m	c, f	es	Pressure faces	5-6 cm
35-68	-	fi	vs, vp	-	-	vf, f	c	vf, f	c	es	Slickensides	2-3 cm
68-97	-	fi	vs, vp	-	-	vf, f	c	vf, f	c	es	Slickensides	1-2 cm
97-129	-	fi	vs, vp	-	-	vf, f	c	vf, f	f	es	Slickensides	<1 cm
129-150	-	fi	sp	-	-	vf, f	m	vf, f	f	es	Slickensides	<1 cm

** Matrix effervescence was observed.*
*** Cracks 5-6 cm wide up to 40 cm, 2-3 cm wide up to 70 cm, 1-2 cm wide up to 100 cm and <1 cm wide up to 148 cm depth.*

Series: KOVILPATTI BM Spot: 9 (Black Soils)

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, Thoothukodi, Tamil Nadu

Sampling Date: 14.02.2001

Morphological properties of Profile No. 19 (Kovilpatti, Thoothukodi)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap1	0-6	c	s		10YR3/2 (R)	c	3-5	f	0	gr
Ap2	6-20	c	s	-	10YR3/2	c	3-5	f	2	sbk
Bw1	20-41	c	s	-	10YR3/1.5	c	3-5	m	1	sbk
Bw2	41-74	g	s	-	10YR3/1.5	c	3-5	m	2	sbk
Bss1	74-104	c	s	-	10YR3/1	c	1-3	m	3	abk
Bss2	104-118	c	s	-	10YR3/1.5	c	5-8	m	3	abk
BC	118-128	a	s	-	10YR4.5/2 (R)	c	5-8	m	1	sbk
2C	128-140	Gypsum + Carbonate			10YR4.6/2 (R)	-	-		Massive	

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-6	-	vfr	sp	vf, f, m	m, c	vf, f	c, f	vf, f, m	m, f	e	-	0.1-0.2 cm
6-20	-	fr	sp	-	-	vf, f	c, f	vf, f, m	m, f	e	-	0.1 cm
20-41	-	fr	sp	-	-	vf, f	c, f	vf, f, m	c, f	e	Pressure faces	
41-74	-	fr	vs, vp	-	-	vf, f	c	vf, f	c	e	Slickensides (weak)	
74-104	-	fr	vs, vp	-	-	vf, f, m	c, f	vf, f, m	f	es	Slickensides	
104-118	-	fr	sp	-	-	vf, f, m	c	vf	f	ev	-	
118-128	-	-	-	-	-	-	-	-	-	ev	-	
128-140	Layer of gypsum and lime with very little soil											

** Effervescence in the soil matrix.*
*** Very fine polygonal cracks on the surface and few vertical cracks.*

Series: KOVILPATTI BM Spot: 9 (Black Soils)

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, Thoothukodi, Tamil Nadu

Sampling Date: 14.02.2001

Morphological properties of Profile No. 20 (Kovilpatti, Thoothukodi)

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
Ap	0-11	c	s	-	10YR3/2	c	3-5	m	1	sbk
Bw1	11-31	c	s	-	10YR3/1.5	c	3-5	m	1	sbk
Bw2	31-55	g	s	-	10YR3/1.5	c	3-5	m	2	sbk
Bss	55-79	c	s	-	10YR3/1.5	c	5-10	m	2	sbk
2C1	79-91	a	s	-	10YR3/1	c	60-80		Massive	
2C2	91-105	-	-	-	10YR5/2	c	85-90		Massive	

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence* (dil HCl)	Other features	Cracks
0-11	s	vfr	sp	vf, f, m	m, f	vf, f, m	m, c	vf, f, m, c	c, f	e	-	Not observed
11-31	-	vfr	sp	-	-	vf, f, m	m, c	vf, f	c	e	-	
31-55	-	fr	vs, vp	-	-	vf, f, m, c	m, c, f	vf, f	c	es	Pressure faces	
55-79	-	fr	vs, vp	-	-	vf, f m, c	m, c, f	vf	f	es	Slickensides (weak)	
79-91	-	fr	vs, vp	-	-	m, c	m	vf	f	es	-	
91-105	-	-	s, po	-	-	m, c	m	-	-	e	-	

**Matrix effervescence was also observed.*

Series: KOVILPATTI BM Spot: 9 (Black Soils)

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), Thoothukodi, Tamil Nadu

Sampling Date: 15.02.2001

Morphological properties of Profile No. 21 (Kovilpatti, Thoothukodi)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap1	0-9	g	s	-	10YR3/2	c	3-5	f f	2 1	gr sbk
Ap2	9-20	c	s	-	10YR3/2	c	3-5	f m	2 1	sbk sbk
Bw1	20-58	g	s	-	10YR3/1.5	c	3-5	m c	2 1	sbk abk
Bss1	58-100	a	w	-	10YR3/1.5	c	3-5	c	2	abk
2Cky1	100-126	g	s	-	10YR5/2.5 (R)	sic	80	-	-	-
2Cky2	126-155	-	-	-	10YR5/2.5 (R)	c	90	-	-	-

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks***
	Dry	Moist	Wet	S	Q*	Size	Quantity	Size	Quantity			
0-9	-	vfr	sp	-	-	vf, f	m	vf, f	c	e**	-	Not observed
9-20	-	vfr	sp	-	-	vf, f	m	vf, f	c	e**	Pressure faces	
20-58	-	fr	sp	-	-	vf, f, m	m, c	vf, f	f, c	e**	Pressure faces; Slickensides	
58-100	-	fr	vs, vp	-	-	vf, f, m	m, c	vf, f	f, c	e	Slickensides	
100-126		fr	sp	-	-	vf, f, m, c	m	vf	f	ev	-	
126-155		fr	sp	-	-	vf, f, m, c	m	vf	f	ev	-	

** Soil was moist; porosity not seen; soils are relatively porous.*
*** Soil matrix is non-calcareous.*
**** Cracks are not visible due to moist profile.*

Series: SEMLA BM Spot: 14 (Black Soils)

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

Morphological properties of Profile No. 29 (Semla, Rajkot)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Texture	Coarse fragments (%) (fg and cg)	Structure Size	Structure Grade	Structure Type
Ap	0-17	c	s	10YR4/2.5	10YR2/2	c	5-8	m	2	sbk
Bw1	17-42	g	s	-	10YR2/2; 3/2(R)	c	3-5	m	2	sbk
Bw2	42-57	g	s	-	10YR2/2	c	5-10	m	2	abk (weak)
Bss1	57-86	g	w	-	10YR2/2	c	1-2	m-c	3	abk
Bss2	86-115	g	w	-	10YR2/2	c	1-2	c	3	abk
Bss3	115-144	c	s	-	10YR2/2	c	2-3	c-m	3	abk
BC	144-155	c	s	-	10YR4.5/2(R)	cl	2-3	m	1	sbk

Depth (cm)	Consistence Dry	Consistence Moist	Consistence Wet	Porosity S	Porosity Q	Nodules (conca) Size	Nodules (conca) Quantity	Roots Size	Roots Quantity	Effervescence* (dil HCl)	Other features	Cracks**
0-17	sh	fr	sp	vf, f, m	m, f	vf, f, m	m, f	vf, f	m	es	-	1-2 cm
17-42	-	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	c	ev	Pressure faces	
42-57	-	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	f	ev	Pressure faces	1 cm
57-86	-	fr	vs, vp	vf, f	m	vf, f, m	m, f	vf, f	f	es	Slickensides	
86-115	-	fr	vs, vp	vf, f	m	vf, f, m	m, f	vf	f	ev	Slickensides	
115-144	-	fr	vs,vp	vf, f	m	vf, f, m	m, f	vf	f	ev	Slickensides	
144-155	-	fr	sp	-	-	vf, f	m, f	-	-	ev	Slickensides	

** Matrix effervescence was also observed.*
*** Cracks 1-2cm wide up to 40 cm and <1 cm up to 60 cm.*

Series: JHALIPURA BM Spot: 16 (Black Soils)

Profile No. P32 ***System: Agriculture (Soybean-Wheat) (FM1)***

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), Rajasthan

Sampling Date: 10.11.2001

Morphological properties of Profile No. 32 (Jhalipura, Kota)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-12	c	s	10YR4.5/1	10YR4/1	c	2-5	m	2	sbk
Bw1	12-31	g	s	-	10YR3/1	c	2-5	m	3	sbk
Bw2	31-48	c	w	-	10YR3/2	c	2-5	m	3	sbk
Bss1	48-74	g	s	-	10YR3/1	c	2-5	m	3	abk
Bss2	74-110	g	s	-	10YR3/2	c	2-5	m	3	abk
Bss3	110-148	g	s	-	10YR3/2	c	2-5	c	3	abk
Bss4	148-165	-	-	-	10YR3/2	c	2-5	c	3	abk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-12	h	fr	sp	vf, f, m	m	vf, f	m, f	vf, f	m, c	e	-	Not observed
12-31	-	fr	sp	vf, f	m	vf, f	m, f	vf, f	c	e	Pressure faces	
31-48	-	fr	vs, vp	vf, f	m	vf, f	m, f	vf, f	f	e to nil	Pressure faces	
48-74	-	fr	vs, vp	vf, f	m	vf, f	c, f	vf, f	f	e**	Slickensides	
74-110	-	fr	vs, vp	vf, f	m	vf, f	c, f	vf	f	es	Slickensides	
110-148	-	fr	vs,vp	vf, f	m	vf, f	c, f	vf	f	es	Slickensides	
148-165	-	fr	vs,vp	vf, f	m	vf, f	m, f	-	-	es	Slickensides	

** Matrix effervescence was also observed.*

*** Salt (including $CaCO_3$) encrustation in the form of channels is found branching on the surface of peds.*

Series: JHALIPURA BM Spot: 16 (Black Soils)

Profile No. P33 ***System: Agriculture (Paddy-Wheat) (FM2)***

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

Morphological properties of Profile No. 33 (Jhalipura, Kota)

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
Ap	0-13	c	s	-	2.5Y3/1	c	3-5	m	2	sbk
Bw1	13-36	g	s	-	2.5Y3/2	c	3-5	m	3	sbk
Bw2	36-58	g	w	-	2.5Y3/2	c	3-5	m	3	sbk-abk
Bss1	58-82	g	s	-	2.5Y4/2 (R)	c	3-5	c	3	abk
Bss2	82-107	c	s	-	10YR4/3 (R)	c	3-5	c	3	abk
Bss3	107-132	c	s	-	10YR5/4 (R)	sicl	5-8	m	3	abk
Bss4	132-156	-	-	-	10YR4/1	sicl	5-8	m	3	abk

Depth	Consistence			Porosity		Nodules (conca)		Roots		Effervescence*		
(cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	(dil HCl)	Other features	Cracks
0-13	vh	fi	sp	vf, f, m	m	vf, f	m, c	vf, m	f, c	e	-	Not observed
13-36	-	fr	sp	vf, f	m	vf, f	m, c	vf, m	f, c	es	Pressure faces	
36-58	-	fr	sp	vf, f	m	vf, f	m, c	vf, m	f	es	Pressure faces	
58-82	-	fr	vs, vp	vf, f	m	vf, f	m, c	vf	c	es	Slickensides**	
82-107	-	fr	vs, vp	vf, f	m	vf, f	m, c	vf	f	es	Slickensides	
107-132	-	fr	vs, vp	vf, f	m	vf, f, m	m, c	vf	f	es	Slickensides	
132-156	-	fr	sp	vf, f	m	vf, f, m	m, f	vf	f	es	Slickensides	

** Matrix effervescence was also observed*
*** Slickensides well developed and as wide as 1 m.*

Series: JAJAPUR BM Spot: 18 (Black Soils)

Profile No. P35 ***System: Agriculture (Sorghum/Pigeonpea + Mung bean) (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, Mahbubnagar, Andhra Pradesh

Sampling Date: 15.12.2001

Morphological properties of Profile No. 35 (Jajapur, Mahbubnagar)

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
Ap	0-12	c	s	-	2.5Y3/2	scl	5-8	m	2	sbk
Bw1	12-35	c	s	-	2.5Y3/2	sc	5-8	m	2	sbk
Bw2	35-48	c	s	-	2.5Y3/3	sc	5-8	m	3	sbk
Bw3	48-76	g	s	-	2.5Y4/3	sc	3-5	m	2	sbk
Bwk1	76-96	c	s	-	2.5Y4.5/3	c	3-5	m	2	sbk
Bwk2	96-126	g	s	-	2.5Y5/3	c	5-8	m	2	sbk
BCk	126-155	-	-		10YR5/3 (m&R)	c	5-8	m	2-3	sbk

	Consistence			Porosity		Nodules (conca)		Roots				
Depth (cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity	Effervescence* (dil HCl)	Other features	Cracks**
0-12	h	fr	sp	vf, f	m	vf, f	c, f	vf, f, m, c	c, f	e	-	2 cm
12-35	-	fr	sp	vf, f	m	vf, f	c, f	vf, f, m, c	f	e	Pressure faces	
35-48	-	fr	sp	-	-	vf, f	c, f	vf	f	es	Thick pressure faces	
48-76	-	fr	sp	-	-	vf, f, m	f	vf	f	es	Slicken-sides weak)	
76-96	-	fr	s, sp	-	-	vf, f, m	f, c	vf	f	ev	Slicken-sides weak)	
96-126	-	fr	s, sp	-	-	vf, f, m, c	f, c	vf	f	ev	-	
126-155	-	fr	s, sp	-	-	vf, f, m, c	f, c	-	-	ev	-	

** Matrix effervescence was observed.*
*** Cracks of about 2 cm wide on the surface.*

Series: JAJAPUR BM Spot: 18 (Black Soils)

Profile No. P36 ***System: Agriculture (Paddy-Paddy) (FM2)***

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, Mahbubnagar, Andhra Pradesh

Sampling Date: 15.12.2001

Morphological properties of Profile No. 36 (Jajapur, Mahbubnagar)

		Boundary		Matrix color		Mottle color*				Coarse	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	A	S	C	Texture	fragments (%) (fg and cg)**	Size	Grade	Type
Ap	0-10	c	s	10YR4/1	10YR3/2		-		scl	3-5	c	3	sbk
Bw1	10-28	c	s	-	10YR3/1.5		-		scl	3-5	c	3	sbk
Bw2	28-53	c	s	-	2.5Y4/1 (R)		-		scl	5-8	m	2	sbk
Bw3	53-76	a	s	-	2.5Y4.5/2	f	10YR5/6 1	d	scl	8-10	m	1	sbk
BCK1	76-98	c	s	-	2.5Y6/2 (R)	f	10YR4/6 1	d	sc	10-15	m	1	sbk
BCK2	98-128	c	s	-	2.5Y6/2.5 (R)	c	10YR4/6 2	d	scl	10-15	m	1	sbk
BCK3	128-150	c	s	-	2.5Y6/3 (R)	c	10YR4/6 2	d	scl	15-20	m	1	sbk
BCK4	150+	-	-	-	2.5Y5/4 (R)	m	10YR4/6 2	d	scl	15-20	m	1	sbk (weak)

** **A** = Abundance, **S** = Size, **C** = Contrast of mottles.*
*** Mainly calcareous nodules with few stones of gneissic material.*

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-10	h	fr	s, sp	f, vf	m	vf, f	c	vf, m	f, c	e	-	Not observed
10-28	-	fr	s, sp	f, vf	m	vf, f	m	vf, c	f	e	Pressure faces (weak)	
28-53	-	fr	s, sp	f, vf	m	vf, f	m	vf, f	f	e	Slickensides (very weak)	
53-76	-	fr	s, sp	f, vf	m	vf, f	m	vf	f	es	Slickensides (very weak)	
76-98	-	fr	s, sp	-	-	vf, f, m	m, c	vf	f	ev	-	
98-128	-	fr	s, sp	-	-	vf, f, m	m	vf	f	ev	-	
128-150	-	fr	s, sp	-	-	vf, f, m	m	-	-	ev	-	
150+	-	fr	s, sp	-	-	-	-	-	-	ev	-	

** Matrix effervescence was observed.*

Series: KASIREDDYPALLI BM Spot: 20 (Black Soils)

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, Medak, Andhra Pradesh

Sampling Date: 18.12.2001

Morphological properties of Profile No. 39 (Kasireddypalli, Medak)

Horizon	Depth (cm)	Boundary		Matrix color		Mottle color	Texture	Coarse fragments (%) (fg %)	Structure		
		D	T	Dry	Moist				Size	Grade	Type
Ap	0-12	c	s	10YR3.5/1	10YR3/2	-	c	5-8	m	1	sbk
BW1	12-31	c	s	-	10YR3/1	-	c	5-8	m	2	sbk
Bss1	31-54	g	w	-	10YR3/1	-	c	5-8	m	3	abk
Bss2	54-84	g	w	-	10YR3/2	-	c	5-8	m	3	abk
Bss3	84-118	c	s	-	10YR3/2	10YR 3/1	c	5-8	m	3	abk
Bss4	118-146	c	s	-	2.5Y4/3,4/2 (R)	10YR 3/1	c	8-10	m	3	abk (weak)
BssK5	146-157	-	-	-	2.5Y5/4	10YR 3/1	c	8-10	m	3	sbk

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-12	s	vfr	s, p	f, m	m	vf, f	c	vf, f, m, c	c, f	e	-	0.3 cm
12-31	-	vf	s, p	vf, f, m	m, f	vf, f, m	c, f	vf, f, m	c, f	e	Pressure faces	
31-54	-	vf	s, p	vf, f	m	vf, f, m	c, f	vf, f, m	f	e	Slickensides (mod. well)	60 m
54-84	-	sfi	vs, vp	vf, f	m	vf, f, m	c, f	vf, f	f	e	Slickensides	
84-118	-	sfi	vs, vp	-	-	vf, f, m, c	c, f	vf, f	f	es	Slickensides	
118-146	-	sfi	vs, vp	-	-	vf, f, m, c	m, f	vf	f	es	Slickensides	
146-157	-	fi	s, p	-	-	vf, f, m, c	m, c	vf	f	es	Slickensides (weak)	

** Matrix effervescence was also observed.*
*** Cracks do not reach continuously vertically downward. Polygonal cracks on the surface of slickensides only even after exposure for 3-4 days.*

Series: KASIREDDYPALLI BM Spot: 20 (Black Soils)

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, Kasireddypalli, Patancheru, Medak, Andhra Pradesh

Sampling Date: 18.12.2001

Morphological properties of Profile No. 40 (Kasireddypalli, Medak)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-12	c	s	10YR4/2	10YR3.5/2	c	8-10	m	2	sbk
Bw1	12-30	c	s	-	10YR3/2	c	5-8	m	3	sbk
Bss1	30-59	g	w	-	10YR3/2	c	3-5	m	3	abk
Bss2	59-101	g	w	-	10YR3/1.5	c	3-5	c	3	abk
Bss3	101-130	c	s	-	2.5Y3/1.5, 4/2.5(R)	c	8-10*	c	3	abk
BCK	130-160	-	-	-	2.5Y5/4 (M & R)	c	20-25*	m	2	sbk

** These are mainly calcareous nodules of medium and coarse sizes and small fine basaltic gravel.*

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-12	vh	fr	sp	vf, f	m	vf, f, m	m, f	vf, f, m	m, f	e	-	3-4 cm
12-30	-	fr	sp	vf, f	m	vf, f, m	m, f	vf, f	m, f	e	Pressure faces	
30-59	-	sfi	vs, vp	vf, f	m	vf, f, m	m, c	vf, f	m, f	e	Slickensides	2-3 cm
59-101	-	fi	vs, vp	vf, f	m	vf, f, m	m, f	vf	m	es	Slickensides	1-2 cm
101-130	-	fi	vs, vp	-	-	vf, m, c	c	vf	c	es	Slickensides	0.5 cm
130-160	-	sfi	sp	-	-	vf, f, m, c	f, m	vf	f	es-ev	-	

Series: TELIGI BM Spot: 23 (Black Soils)

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

Morphological properties of Profile No. 43 (Teligi, Bellary)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Texture	Coarse fragments* (%) (fg and cg %)	Structure Size	Structure Grade	Structure Type
Apk	0-10	c	s	10YR3/1	10YR3/1	c	8-10	m	2	sbk
Bw1	10-25	g	s	-	10YR2.5/1	c	8-10	m	3	sbk
Bw2	25-44	c	s	-	10YR3/1	c	8-10	m	3	sbk
Bss1	44-69	g	s	-	10YR3/1	c	8-10	m	3	sbk
Bss2	69-97	g	s	-	10YR3/1	c	8-10	m	3	abk
Bss3	97-123	g	s	-	10YR3/1	c	10-12**	m	3	abk
Bss4	123-150	c	s	-	10YR4/1(R)	c	10-12	m	3	abk

** Coarse fragments consists mainly of very fine gravels of calcarious nodules, some gravels of granite gneiss and quartz.*
*** This layer has nodules which are very soft and powdery.*

Depth (cm)	Consistence+ Dry	Consistence+ Moist	Consistence+ Wet	Porosity S	Porosity Q	Nodules (conca) Size	Nodules (conca) Quantity	Roots Size	Roots Quantity	Effervescence (dil HCl)	Other features	Cracks
0-10	h	fr	sp	vf, f, m	m, c	vf, f	m, f	vf, f	m	es	-	Not observed
10-25	-	fr	sp	vf, f	m	vf, f	m, f	vf, f	m, c	es	Pressure faces	
25-44	-	fr	sp	vf, f	m	vf, f	m, f	vf, f	m, c	es	Pressure faces	
44-69	-	fr	vs, vp	vf, f	m	vf, f	m, f	vf, f	m, f	es	Slickensides	
69-97	-	fr	vs, vp	-	-	vf, f	m, f	vf, f	c, f	es	Slickensides	
97-123	-	fr	vs, vp	-	-	vf, f	m, f	vf	f	ev	Slickensides	
123-150	-	fr	vs, vp	-	-	vf, f, m	m	vf	f	ev	Slickensides	

+ The soil peds are lighter in weight may be due to pressure of higher amounts of $CaCO_3$ throughout the profile as well as relatively lesser amount of clay content.

Series: TELIGI BM Spot: 23 (Black Soils)

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

Morphological properties of Profile No. 44 (Teligi, Bellary)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Texture	Coarse fragments (%) (fg and cg)	Structure Size	Structure Grade	Structure Type
Ap	0-10	c	s	10 YR 2/1	10 YR 2/1	cl	8-10*	m	3	sbk
Bw1	10-34	c	s	-	10 YR 3/1	c	8-10*	m	3	sbk
Bss1	34-54	g	w	-	10 YR 3/1	c	8-10	m	3	abk
Bss2	54-89	g	w	-	10 YR 3/1	c	8-10	m	3	abk
Bss3	89-119	g	s	-	10 YR 3/1	c	8-10**	m	3	abk
Bss4	119-142	c	s	-	10YR 3/1.5(m); 10 YR 3.5/1(R)	c	10-15**	m	2	abk
BCK	142-150	-	-	-	10YR4/1.5(m & R)	c	30-35**	m	2	sbk

** Calcareous nodules + quartz + granite gneiss.*
*** Medium to coarse-sized soft powdery calcareous nodules.*

Depth (cm)	Consistence Dry	Consistence Moist	Consistence Wet	Porosity S	Porosity Q	Nodules (conca) Size	Nodules (conca) Quantity	Roots Size	Roots Quantity	Effervescence (dil HCl)	Other features	Cracks*
0-10	vh	fi	s, p	vf, f	m	vf, f	m, f	vf, f	m	es	-	4-7 cm
10-34	vh	fi	s, p	vf, f	m	vf, f	m, f	vf, f	m, c	es	Pressure faces	2-4 cm
34-54	-	fr	vs, vp	vf, f	m	vf, f	m, f	vf, f	m, c	es	Slickensides (slight)	1-2 cm
54-89	-	fr	vs, vp	-	-	vf, f, m	m, f	vf, f	m, c	es	Slickensides (well)	0.5-1 cm
89-119	-	fr	vs, vp	-	-	vf, f, m	m, c	vf, f	c, f	es	Slickensides (well)	
119-142	-	vfr	vs, vp	-	-	vf, f, m, c	m	vf, f	f	ev	Slickensides (well)	
142-150	-	vfr	s, p	-	-	vf, f, m, c	m	vf	f	ev	-	

** Cracks 4-7 cm wide up to 14 cm, 2-4 cm wide up to 24 cm., 1-2cm wide up to 34 cm, and <1 cm wide up to 48 cm.*

Series: KONHERI BM Spot: 24 (Black Soils)

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

Morphological properties of Profile No. 45 (Konheri, Solapur)

		Boundary		Matrix color			Coarse fragments	Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	(%) (fg and cg)	Size	Grade	Type
Ap	0-13	c	s	7.5YR4/3	7.5YR3/3	c	1-2	m	1	sbk
Bwk1	13-33	g	s	-	7.5YR2.5/2	c	1-2	m	2	sbk
Bwk2	33-69	c	s	-	7.5YR2.5/2	c	1-2	m	2	sbk
Bwk3	69-93	g	s	-	7.5YR3/3	c	1-2	m	2	sbk
Bwk4	93-113	a	s	-	7.5YR2.5/3	sic	1-2	m	2	sbk
BCk	113-129	c	s	-	7.5YR2.5/2	sic	40-45*	f	1	gr
Bssk	129-160	-	-	-	7.5YR2.5/2	c	3-5	m	2	abk

** Calcareous nodules and rock fragments (rounded).*

Depth	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
(cm)	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-13	sh	fr	s, p	vf, f	m	vf	f	vf, f, m	m, f	es	-	2-3 cm
13-33	-	fr	s, p	vf, f	m	vf	f	vf, f, m	c, f	es	-	1-2 cm
33-69	-	vfr	s, p	vf, f	m	vf, f	f	vf, f, m	c, f	es	-	0.5 cm
69-93	-	vfr	s, p	vf, f	m	vf, f	f	vf, f, m	c, f	es	Pressure faces (very weak)	
93-113	-	vfr	s, p	-	-	vf, f	c	vf, f, m	c, f	es	Pressure faces (very weak)	
113-129	-	vfr	ss, po	-	-	vf, f	m	vf, f, m	f, c	ev	-	
129-160	-	fr	s, p	-	-	-	-	vf, f, m, c	c, f	es	Slicken-sides (weak)	

** Matrix effervescence was also observed.*
*** Cracks 2-3 cm wide up to 13 cm; 1-2 cm wide and <0.5 mm up to 35cm.*

Series: KONHERI BM Spot: 24 (Black Soils)

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

Morphological properties of Profile No. 46 (Konheri, Solapur)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Apk	0-13	c	s	10YR3/1	10 YR 2.5/2	c	2-3	m	2	sbk (weak)*
Bwk	13-34	c	s	-	10 YR 2.5/2	c	2-3	m	2	sbk (weak)
Bssk1	34-53	c	s	-	10 YR 2.5/2	c	1-2	m	2	abk
Bssk2	53-83	a	s	-	10 YR 3/2	c	1-2	m	3	abk
Ck1	83-117	c	s	-	7.5 YR 4/3(R)	c	10-15**		Massive	
Ck2	117-155	-	-	-	7.5 YR 4/4(R)	c	35-40**		Massive	

** Mainly quartz gravel and unweathered basalt gravel as well as some hard nodules.*
*** Most of the nodules are soft and powdery.*

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Efferve-scence* (dil HCl)	Other features	Cracks
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-13	sh	fr	s, p	vf, f, m	m	vf, f, m	m, c, f	vf, f, m	c, f	ev	-	0.5 cm
13-34	-	fr	s, p	vf	m, c	vf, f	m, c	vf, f, m	c, f	ev	Pressure faces (few)	
34-53	-	fr	s, p	vf	m, c	vf, f	c	vf, f, m	c, f	ev	Slickensides (weak)	
53-83	-	fr	s, p	vf	m, c	vf, f	c	vf, f, m	c, f	ev	Slickensides	
83-117	-	l	s, po	-	-	vf, f, m, c	m	vf, f	f	ev	-	
117-155	-	l	s, po	-	-	vf, f, m, c	m	vf, f	f	ev	-	

** Matrix effervescence was also observed.*

Series: KALWAN BM Spot: 25 (Black Soils)

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, Nasik, Maharashtra

Sampling Date: 20.02.2002

Morphological properties of Profile No. 47 (Kalwan, Nasik)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Texture	Coarse fragments (%) (fg and cg)	Structure Size	Structure Grade	Structure Type
Ap	0-20	c	s	10YR4/2	10YR3/2	c	3-5	vc, m-c	1 2	pr, sbk
Bw1	20-48	c	w	-	10YR2.5/2	c	3-5	c, m	1 3	pr, sbk
Bss1	48-70	g	s	-	10YR3/1.5	c	3-5	c	3	abk
Bssk1	70-88	c	s	-	10YR3/2	c	5-8	m	2	sbk
2BCk1	88-133	c	s	-	7.5YR5/5(R)	l	8-10*	m	1	sbk
2BCk2	133-154	-	-	-	7.5YR4/4(R)	l	10-12*	m	1	sbk

* *fg and cg are* $CaCO_3$ *nodules.*

Depth (cm)	Consistence Dry	Consistence Moist	Consistence Wet	Porosity S	Porosity Q	Nodules (conca) Size	Nodules (conca) Quantity	Roots Size	Roots Quantity	Effervescence* (dil HCl)	Other features	Cracks
0-20	h	fr	sp	vf, f	c	f, m	m, f	f, m	m, c	e	-	5-7.5cm
20-48	-	fi	vs, vp	vf, f	c	f, m	m, f	f, m	m, c	e	Pressure faces	5-7.5cm
48-70	-	vfi	vs, vp	vf, f	c	f, m	m, f	f, m	m, f	es	Slickensides	~5cm
70-88	-	fr	sp	vf, f	c	m, c	c	f, m	f	es	Slickensides	~1cm
88-133	-	vfr	ss, sp	vf, m	m	m, c	m	f	f	ev	Pressure faces	~0.5cm
133-154	-	vfr	ss, po	vf, m, c	m	m, c	m	Nil	Nil	ev	-	-

* *Matrix effervescence was also observed.*

BLACK SOILS

(Arid)

(MAR >550 mm)

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

(See Appendix 2 for Abbreviations.)

Series: SOKHDA BM Spot: 15 (Black Soils)

Profile No. P30 ***System: Agriculture (Cotton-Pearl millet) (FMI)***

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

Morphological properties of Profile No. 30 (Sokhda, Rajkot)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Texture	Coarse fragments (%) (fg and cg)	Structure Size	Structure Grade	Structure Type
Ap	0-11	c	s	10YR4.5/2	10YR4/2	c	8-10	m	1	sbk
Bwk1	11-32	g	s	-	10YR3/2	c	8-10	m	2	sbk
Bwk2	32-57	g	s	-	10YR3/2	c	8-10	m	2	sbk
Bssk	57-91	a	s	-	10YR3/2	c	8-10	m	3	sbk-abk (weak)
Ck1	91-107	c	s	7.5YR4/6 (R)	10YR 4/3(R) 10YR 8/2 (M)	l	60-70	m	1	sbk
Ck2	107-135	-	-	5YR4/4 (M)	7.5YR 4/4 (M) 10YR 4/4 (M) 7.5YR 4/4 (M) 5YR 4/4 (M)	sil	30-35	m, f	1 2	sbk sbk

Depth (cm)	Consistence Dry	Consistence Moist	Consistence Wet	Porosity S	Porosity Q	Nodules (conca) Size	Nodules (conca) Quantity	Roots Size	Roots Quantity	Effervescence* (dil HCl)	Other features	Cracks**
0-11	sh	fr	sp	vf, f, m	m	vf, f, m, c	c, f	vf, f	c, f	ev	-	1.5 cm
11-32	-	fr	sp	vf, f	m	vf, f, m, c	c, f	vf, f	c, f	ev	Pressure faces	
32-57	-	fr	sp	vf, f	m	vf, f	c	vf, f	c, f	ev	Pressure faces	0.5-1 cm
57-91	-	fr	sp	vf, f	m	vf, f	c	vf	f	ev	Slickensides (weak)	
91-107	-	vfr	sp	-	-	vf, f, m	m, f	vf	f	ev	-	
107-135	-	fr	sp	-	-	powdery lime		-	-	-	-	

** Matrix effervescence was also observed.*
*** Cracks 1-1.5 cm wide up to 20 cm and 0.5-1 cm up to 60 cm.*

Series: SOKHDA BM Spot: 15 (Black Soils)

Profile No. P31 ***System: Agriculture (Cotton-Pearl millet/Linseed) (FM2)***

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

Morphological properties of Profile No. 31 (Sokhda, Rajkot)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)*	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-11	c	s	10YR4/2.5	10 YR 4/2	c	8-10	m	1	sbk
Bw1	11-37	g	s	-	10YR3/2.5	c	8-10	m	2	sbk
Bw2	37-63	g	w	-	10YR3/3	c	8-10	m	3	sbk-abk
Bss1	63-98	g	w	-	10YR3/3	c	8-10	m	3	abk
Bss2	98-145	a	s	-	7.5YR3/2	c	8-10	m	3	abk
BC	145-160	-	-	-	5YR3/3 (R)	c	10-15	m	2	sbk

** cg: Powdery lime.*

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence* (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-11	sh	fr	sp	vf, f, m	m	vf, f, m	m, f	vf, f	c	ev	-	2-3 cm
11-37	-	fr	sp	vf, f	m	vf, f, m	c, f	vf, f	c	ev	Pressure faces	1-1.5 cm
37-63	-	fr	sp	vf, f	m	vf, f, m	c, f	vf, f	c, f	ev	Slicken sides (weak)	
63-98	-	fr	vs, vp	vf, f	m	vf, f	c	vf	f	ev	Slicken-sides	0.5 cm
98-145	-	fr	vs, vp	vf, f	m	vf, f	c	vf	f	ev	Slicken-sides	
145-160	-	fr	sp	-	-	vf, f, m	m, c	-	-	ev	-	

** Matrix effervescence was also observed.*
*** Cracks 2-3 cm wide up to 30 cm, 1-1.5 cm up to 75 cm and 0.5 cm up to 125 cm.*

Series: NIMONE BM Spot: 28 (Black Soils)

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, Ahmadnagar, Maharashtra

Sampling Date: 18.12.2002

Morphological properties of Profile No. 51 (Nimone, Rahuri)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg)*	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-13	c	s	7.5YR3/2	7.5YR2.5/2	c	5-8	m	1-2	sbk
Bwk1	13-38	g	s	-	7.5YR 2.5/2(m)/3/ 2(R)	c	5-8	m	2	sbk
Bwk2	38-55	g	w	-	7.5YR 2.5/2(m)/3/ 2(R)	c	5-8	m	2	sbk
Bssk1	55-94	g	w	-	7.5YR 2.5/2(m)/3/ 2(R)	c	5-8	m	3	sbk-abk
Bssk2	94-128	c	s	-	7.5YR 2.5/2(m)/3/ 2(R)	c	8-10	m	3	abk
Bwk3	128-150+	-	-	-	7.5YR2.5/2(R)** 5YR3/4m	c	10-15	m	2	sbk

** fg - Few quartz/zeolite gravels (fg/cg).*
*** 80-90% of colors are in 5YR lime and 10-20% are in hue of 7.5 YR.*

Depth (cm)	Consistence			Porosity		Nodules (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-13	h	fr	sp	vf, f	m	vf, f	c, f	vf, f	c, f	es	-	Not
13-38	-	fr	sp	vf, f	m	vf, f	c, f	vf, f	c, f	es	Pressure faces	observed
38-55	-	fr	sp	vf, f	m	vf, f	c, f	vf, f	f	es	Pressure faces	
55-94	-	fr	vs, vp	-	-	vf, f	c	vf	f	es	Slickensides (well)	
94-128	-	fr	vs, vp	-	-	vf, f, m	m, c*	vf	f	es	Slickensides	
128-150+	-	fr	sp	-	-	vf, f, c	m, c*	vf	f	ev	Pressure faces	

** The medium and coarse nodules are brittle and soft in nature; more soft in the last layer.*
*** Cracks are not observed under irrigation in this sugarcane belt. The soils do not remain dry for >90 consecutive days. Therefore the soils are grouped under Udic subgroup though the annual rainfall is 500 mm.*

Series: NIMONE BM Spot: 28 (Black Soils)

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), Ahmadnagar, Maharashtra

Sampling Date: 18.12.2002

Morphological properties of Profile No. 52 (Nimone, Ahmadnagar)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Texture	Coarse fragments (%)* (fg)	Structure Size	Structure Grade	Structure Type
Apk	0-12	c	s	10YR4/1	10YR4/1.5	c	10-12	m	2/1	sbk
Bwk1	12-29	g	s	-	10YR2/2 7.5YR3/2(R)	c	10-12	m	2	sbk
Bwk2	29-50	g	w	-	7.5YR3/2(R)	c	10-15	m	3	abk (weak)
Bssk1	50-84	a	w	-	7.5YR3/2(R)	c	10-15	m	3/1	sbk
Bssk2	84-113	a	w	7.5YR7/3	7.5YR3/2, 4/3(R)	c	10-15	m	3/1	sbk
Bssk3	113-148	c	w	7.5YR7/3	7.5YR3/1, 4/3(R)	c	10-15	m	3/1	sbk
BCk	148-165	-	-	7.5YR7/1	7.5YR 3.5/3 7.5YR 6/2, 4/3	c	10-15	m	2/1	sbk

**Few fg/cg gravels of quartz and zeolite also found in the pedon.*

Depth (cm)	Consistence			Porosity		Nodules* (conca)		Roots		Effervescence (dil HCl)	Other features	Cracks**
	Dry	Moist	Wet	S	Q	Size	Quantity	Size	Quantity			
0-12	-	fr	sp	vf, f	m	vf, f	c, f	vf, f	c	ev	-	1-2 cm
12-29	-	fr	sp	vf, f	m	vf, f	c, f	vf, f	c	ev	Pressure faces (weak)	0.5 cm
29-50	-	sfi	vs, vp	vf, f	m	vf, f	c, f	vf, f	c	ev	Pressure faces	
50-84	-	fi	vs, vp	vf, m	m	vf, c	c, f	vf, f	f	ev	Slickensides (weak)	
84-113	-	fr	sp	-	-	vf, f, m, c	c, m	vf, f, m	f	ev	Slickensides	
113-148	-	fr	sp	-	-	vf, f, m, c	c, m	f, m	f	ev	Slickensides (weak)	
148-165+	-	fr	sp	-	-	vf, f, m, c	c, m	vf	f	ev	Slickensides (weak)	

**Medium and coarse nodules of last three layers are brittle and break into fine and very fine particles.*
*** Cracks of 1-2 cm wide up to 15 cm and 0.5 cm wide up to 29 cm.*

RED SOILS

Sub-humid (moist)

(MAR >1100 mm)

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

(See Appendix 2 for Abbreviations.)

Series: DADARGHUGRI BM Spot: 11 (Red Soils)

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

Morphological properties of Profile No. 23 (Dadarghugri, Dindori)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-11	c	s	7.5YR4/4	7.5YR2.5/3	sicl	10-15	m	1	sbk
Bt1	11-29	c	s	-	5YR3/2	c	25-30	f	1	sbk
Bt2	29-55	c	w	-	5YR3/3	c	+st 60-70	f	1	sbk
C1	55-74	c	w	-	5YR3/4	-	+st 65-90		Massive	
C2	74-100	-	-	-	5YR3/4	-	+st 90-95		Massive	

Depth (cm)	Consistence			Porosity		Cutans			Roots		Effervescence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity		
0-11	s	vfr	sp	vf, f	m	-	-	-	vf, f	m	-	-
11-29	-	vfr	s, p	-	-	T	tn	p	vf, f	m	-	-
29-55	-	vfr	s, sp	-	-	T	tn	p	vf	c	-	-
55-74	-	-	-	-	-	-	-	-	vf	f	-	-
74-100	-	-	-	-	-	-	-	-	vf	f	-	-

Series: DADARGHUGRI BM Spot: 11 (Red Soils)

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

CLIMATE: SUB-HUMID (MOIST) Classification: Clayey-skeletal, mixed, Analysis at: Division of Soil Resource
RAINFALL: 1420 mm hyperthermic, Typic Haplustalfs Studies, NBSS&LUP, Nagpur

Location: Dadarghugri, Sehapura, Dindori, Madhya Pradesh Sampling Date: 11.06.2001

Morphological properties of Profile No. 24 (Dadarghugri, Dindori)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%)	(fg and cg)	Structure		
		D	T	Dry	Moist				Size	Grade	Type
A1	0-10	c	s	7.5YR3/2	-	sic	10-15		f	1	sbk
Bt1	10-26	c	w	7.5YR2.5/2	-	c	35-40		f	1	sbk (weak)
C1	26-50	c	w	7.5YR2.5/3	-	c	80-85			Massive	
C2	50-85	-	-	Partially weathered basalt		c	90-95			Massive	

Depth (cm)	Consistence			Porosity		Cutans			Roots		Effervescence (dil HCl)
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity	
0-10	-	vfr	sp	vf, f	m	-	-	-	vf, f, m, c	m, c	-
10-26	-	vfr	s, sp	-	-	T	tn	p	vf, f, m, c	m, c	-
26-50	-	l	s, po	-	-	-	-	-	vf, f, m	m, f	-
50-85	-	-	-	-	-	-	-	-	vf, f, m	m, f	-

Series: KARKELI BM Spot: 12 (Red Soils)

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

Morphological properties of Profile No. 25 (Karkeli, Umeria)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
A	0-11	c	s	-	7.5YR3.5/3	ls	fg 2.5	m	1	sbk
Bt1	11-23	c	s	-	7.5YR3.5/4	ls	fg 2.5	m	1	sbk (weak)
Bt2	23-47	c	s	7.5YR6/4	5YR 5/7	ls	2.5	m	1	sbk
Bt3	47-77	g	s	5YR6/6	2.5YR5/8	sl	2.5	m	1	sbk
Bt4	77-101	g	s	2.5YR6/8	2.5YR4/8	sl	5-10	m	1	sbk
Bt5	101-123	c	s	2.5YR5.5/8	2.5YR4/8	sl	5-10	m	1	sbk
Bt6	123-137	c	w	2.5YR5.5/8	2.5YR4/8	sl	20-25	f	1	sbk
BC	137-152	-	-	-	2.5YR5/8	sl	35-40*	-	-	sg

** Partially weathered and unweathered sandstone gravels present in some parts of the profile.*

Depth (cm)	Consistence			Porosity		Cutans			Roots		Effervescence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity		
0-11	-	vfr	so, po	f, m	m	-	-	-	vf, f, m	m, f	-	-
11-23	-	vfr	so, po	f, m	m	-	-	-	vf, f, m	m, c	-	-
23-47	sh	vfr	so, po	f	m	-	-	-	vf, f, m, c	f	-	-
47-77	sh	vfr	ss, sp	f, m, c	m	T	tn	p	vf, f, m, c	f	-	-
77-101	sh	vfr	ss, sp	f, m	m	T	tn	p	f, c, m	f	-	-
101-123	sh	vfr	ss, sp	f, m, c	c, f	T	tn	p	f, c, m	f	-	-
123-137	sh	vfr	ss, sp	f, m, c	c, f	T	tn	p	f, c, m	f	-	-
137-152	l	l	ss, sp	f, m	m	-	-	-	f, c, m	f	-	-

Series: KARKELI BM Spot: 12 (Red Soils)

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

Morphological properties of Profile No. 26 (Karkeli, Umeria)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-15	g	s	-	7.5YR4.5/6	ls	1-2	m	1	sbk
Bt1	15-39	c	w	-	7.5YR4./3.5	sl	1-2	m	2	sbk
Bt2	39-62	g	s	-	10YR5/6	scl	2-3	m	2	sbk
Bt3	62-84	c	w	-	7.5YR5/6	cl	3-5*	m	2	sbk
Bt4	84-127	g	s	-	5YR4.5/6 (R)	cl	5-8	m	2	sbk
Bt5	127-155	-	-	-	5YR5/6 (R)	scl	8-10	m	2	sbk

** Fe/Mn concretions also present.*

Depth (cm)	Consistence			Porosity		Cutans			Nodules (conir)		Roots		Effervescence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity	Size	Quantity		
0-15	-	vfr	so, po	f, m	m	-	-	-	-	-	vf, f, m	m, f	-	-
15-39	-	vfr	ss, ps	f, m	m	T	tn	p	-	-	vf, f, m	c, f	-	-
39-62	-	vfr	s, p	vf, f	m	T	tn	p	-	-	vf, f, m, c	c, f	-	-
62-84	-	vfr	s, p	vf, f	m	T	tn	p	vf, f, m, c	m, c	vf, c	c, f	-	-
84-127	-	vfr	s, p	vf, f	m	T	tn	p	vf, f, m, c	m, c	vf, f, m, c	c, f	-	-
127-155	-	vfr	s, p	vf, f	m	T	tn	p	-	-	vf, m	f, c	-	-

RED SOILS

Semi-arid (moist)

(MAR 850->1000 mm)

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

(See Appendix 2 for Abbreviations.)

Series: VIJAYPURA BM Spot: 8 (Red Soils)

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

Morphological properties of Profile No. 16 (Vijaypura, Bangalore)

Horizon	Depth (cm)	Boundary D	Boundary T	Matrix color Dry	Matrix color Moist	Mottle color	Texture	Coarse fragments (%) (fg and cg)	Structure Size	Structure Grade	Structure Type
Ap	0-9	c	s	5YR4/6	5YR3/4	-	scl	<2	m	1	sbk
Bt1	9-22	c	s	2.5YR4/6	2.5YR4/6	-	sc	<2	m	2	sbk
Bt2	22-42	g	s	2.5YR3.5/6	2.5YR3.5/6	-	c	<2	m	2	sbk
Bt3	42-69	g	s	2.5YR4/6	2.5YR4/6	-	c	<2	m	1	sbk
Bt4	69-98	g	s	-	5YR 5/6(R), 5YR 4/4	5YR4/4	c	30-35	m	1	sbk
Bt5	98-120	g	s	-	5YR5/6 (R), 7.5YR 6/1, 5/8	7.5YR6/1	c	10-15	f	2	sbk
BC1	120-150	-	-	-	7.5YR6/1, 5/8, 5YR 5/6	7.5YR6/1	c	10-15	f	2	sbk

Depth (cm)	Consistence Dry	Consistence Moist	Consistence Wet	Porosity S	Porosity Q	Cutans* Thickness	Cutans* Quantity	Roots Size	Roots Quantity	Effervescence (dil HCl)	Other features**
0-9	sh	fr	sp	f	m	-	-	vf, f	c	-	-
9-22	sh	fr	sp	f	m	tn	p	vf, f	c	-	-
22-42	-	fr	sp	vf, f	m	tn	p	vf, f	f	-	-
42-69	-	fr	sp	-	-	tn	p	vf	f	-	Laterite gravels & plinthites
69-98	-	fr	s, po	-	-	tn	p	vf	f	-	Laterite gravels & plinthites
98-120	-	fr	sp	-	-	tn	p	-	-	-	Laterite gravels & plinthites
120-150	-	fr	sp	-	-	-	-	-	-	-	Laterite gravels & plinthites

** Cutans are not observable in the last horizon due to disturbance.*

*** All the horizons become hard when dry except 69-98 cm horizon. Laterite gravel (dark coloured) and plinthites also in last two horizons.*

Series: VIJAYPURA BM Spot: 8 (Red Soils)

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

CLIMATE: SEMI-ARID (MOIST) Classification: Fine-loamy, kaolinitic, Analysis at: Division of Soil Resource
RAINFALL: 924 mm isohyperthermic, Typic Haplustalfs Studies, NBSS&LUP, Nagpur

Location: Plot no. 16, GKVK farm, Bangalore, Karnataka Sampling Date: 9.02.2001

Morphological properties of Profile No. 17 (Vijaypura, Bangalore)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-12	c	s	5YR6/8	5YR4/6	sl	<1*	f	1	gr
Bt1	12-37	c	s	2.5YR6/8	5YR4/6	scl	<1	f	1	sbk
Bt2	37-62	g	s	2.5YR6/8	5YR4/6	scl	<1	m	1	sbk
Bt3	62-92	a	s	2.5YR5/8	5YR4/6	sc	<1	m	2	sbk
Bt4	92-116	c	s	-	2.5YR4/7	scl	60-70	f	0	gr
Bt5	116-143	c	s	-	2.5YR4/6	scl	35-40	f	1	sbk
Bt6	143-155	-	-	-	2.5YR4/8	scl	20-25	m	1	sbk

** Gravel includes mainly quartz/feldspar and small laterite gravel.*

Depth (cm)	Consistence			Porosity		Cutans		Roots		Effervescence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Thickness	Quantity	Size	Quantity		
0-12	sh	vfr	so, po	f	m	-	-	vf, f	c	-	-
12-37	sh	vfr	sp	f	m	tn	p	vf	c	-	-
37-62	sh	vfr	sp	f	m	tn	p	vf, f	f, c	-	-
62-92	sh	vfr	sp	f	m	tn	p	vf	f	-	-
92-116	-	vfr	s, po	-	-	tn	p	vf	f	-	-
116-143	-	vfr	s, po	-	-	tn	p	vf	f	-	-
143-155	-	vfr	s, sp	-	-	tn	p	vf	f	-	-

Series: VIJAYPURA BM Spot: 8 (Red Soils)

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

CLIMATE: SEMI-ARID (MOIST) Classification: Fine-loamy, kaolinitic, Analysis at: Division of Soil Resource
RAINFALL: 924 mm isohyperthermic, Typic Haplustalfs Studies, NBSS&LUP, Nagpur

Location: Opp. to Plot no. 16, GKVK farm, Bangalore, Karnataka Sampling Date: 10.02.2001

Morphological properties of Profile No. 18 (Vijaypura, Bangalore)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-11	c	s	5YR 5/6	5YR 4/6	sl	<1	m	1	sbk
Bt1	11-32	g	s	5YR 5/8	5YR 4/6	scl	<1	m	2	sbk
Bt2	32-64	g	s	5YR 4.5/6	5YR 4/6	sc	<1	m	2	sbk
Bt3	64-100	a	s	5YR 4.5/6	5YR 4/6	scl	<2	m	2	sbk
Bt4	100-130	c	s	2.5YR 5.5/8	5YR 4/8	scl	60-70*	f	1	gr
Bt5	130-150	-	-	2.5YR5/8	5YR 4/8	scl	20-25	m	2	sbk

** Mainly fine gravels 75 to 80% and coarse gravels 20 to 25%; gravels are of quartz, feldspar and laterite.*

Depth (cm)	Consistence			Porosity		Cutans		Roots		Effervescence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Thickness	Quantity	Size	Quantity		
0-11	sh	vfr	so, po	f, m	m, f	-	-	vf, f, m	c, f	-	-
11-32	sh	vfr	sp	f	m	tn	p	vf, f, m	c, f	-	-
32-64	sh	vfr	sp	f	m	tn	p	vf, f	c	-	-
64-100	sh	vfr	sp	f	m	tn	p	vf, f	c	-	-
100-130	-	vfr	s, po	-	-	tn	p	vf	c	-	-
130-150	-	vfr	s, sp	-	-	tn	p	vf	f	-	-

RED SOILS

Semi-arid (dry)

(MAR 550-850 mm)

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

(See Appendix 2 for Abbreviations.)

Series: PALATHURAI BM Spot: 10 (Red Soils)

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

Morphological properties of Profile No. 22 (Palathurai, Coimbatore)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-16	c	s	5YR3.5/3	5YR3/2	sl	3-10	f m	2 1	gr sbk
Bt1	16-33	g	s	-	5YR3/2	scl	15	f m	2 2	sbk sbk
Bt2	33-46	c	i	-	5YR3/3	sl	15-25	f	1	sbk
Ck1	46-73	g	w	-	7.5YR4/3.5	sl	90	Hard & massive		
Ck2	73-95	-	-	-	7.5YR4/4	ls	15-45	Loose		

Depth (cm)	Consistence			Porosity		Cutans			Nodules (conca)		Roots		Efferve-scence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity	Size	Quantity		
0-16	sh	vfr	so, po	vf, f	c	-	-	-	vf, f, m	c	vf, f	c	e*	-
16-33	-	vfr	s, sp	vf, f	c	-	-	-	vf, f, m	c	vf	c	e*	-
33-46	l	vfr	ss, po	-	-	T	tn	p	m, c	c	vf	f	es	-
46-73	-	-	-	-	-	-	-	-	-	-	-	-	ev	-
73-95	-	-	-	-	-	-	-	-	-	-	-	-	ev	-

** No reaction in matrix; 46-73 cm layer is impervious - kind of calcrete layer.*

Series: KAUKUNTLA BM Spot: 17 (Red Soils)

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), Mahbubnagar, Andhra Pradesh

Sampling Date: 14.12.2001

Morphological properties of Profile No. 34 (Kaukuntla, Mahbubnagar)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-8	c	s	7.5YR6/6	7.5YR4/6	ls	3-5	m	1	sbk
Bt1	8-27	c	s	-	2.5YR4/6	c	5-8	m	2	sbk
Bt2	27-43	c	s	-	2.5YR3/6	c	5-8	m	3	sbk
Bt3	43-68	c	s	-	5YR4/6(R)	c	5-8	m	3	sbk
Bt4	68-98	c	s	-	5YR4/4(R)	c	8-10	m	3	sbk
Bt5	98-121	c	s	-	5YR4/6(R)	c	30-35*	m	1	sbk
Bt6	121-156	c	s	-	7.5YR4/6	c	20-25	m	2	sbk
BC	156-+	-	-	-	7.5YR5/6	sc	25-30	m	1	sbk

** On one face gravels are about 60-65%.*

Depth (cm)	Consistence			Porosity		Cutans			Nodules (conir)*		Roots		Other features**
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity	Size	Quantity	
0-8	sh	fr	so, po	f, m	m	-	-	-	-	-	vf, f	c	-
8-27	-	fr	sp	f, m	m	T	tn	p	vf	f	vf, f	f	-
27-43	-	sfi	sp	vf, f	m	T	mtk	p	vf, f	f	vf	f	Slight pressure faces
43-68	-	sfi	sp	-	-	T	mtk	p	vf, f	c	vf	f	Slight pressure faces
68-98	-	sfi	sp	-	-	T	tn	p	vf, f	f	vf	f	-
98-121	-	fr	s, po	-	-	T	tn	p	f	f	-	-	-
121-156	-	fr	s, po	-	-	T	tn	p	f	f	-	-	-
156-+	-	fr	s, po	-	-	T	tn	p	-	-	-	-	-

** Soft iron and manganese concretions.*
*** No effervescence with dil HCl.*

Series: HAYATNAGAR BM Spot: 19 (Red Soils)

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

Morphological properties of Profile No. 37 (Hayatnagar, Rangareddy)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
Ap	0-12	c	s	2.5Yr 4/6	2.5YR3/6	scl	27-35	m	2	sbk
Bt1	12-29	a	s	-	2.5YR3/4	scl	35-45	m	2	sbk
Bt2	29-67	c	s	-	2.5YR3/4	scl	80-90	f	1	gr
Bt3	67-101	-	-	-	2.5YR3/4	scl	-	m, f	1	sbk, gr
C	101+	Highly weathered gneissic material which is soft, mixed with stone and rock fragments. The material has some clay and also has few patchy and thin clay cutans. It is moist and seems to retain some moisture.								

Depth (cm)	Consistence			Porosity		Cutans			Roots		Effervescence* (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity		
0-12	h	fr	ss, po	vf, f, m, c	c, f	-	-	-	vf, f, m, c	m, f	-	-
12-29	h	fr	s, sp	m, c, vf	c, f	T	tn	p	vf, f, c	c, f	-	-
29-67	-	fr	s, po	m, c	c	T	tn	p	vf, f	c	-	-
67-101	-	fr	s, po	m, c	c	T	tn	p	vf, f	f	-	-
101+	-											

** Throughout the profile is slightly calcareous, though not observable by dilute HCl; chemical analysis data confirmed its presence. The profile is truncated at the surface and thus eluvial horizon(s) does not exist.*

Series: HAYATNAGAR BM Spot: 19 (Red Soils)

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

Morphological properties of Profile No. 38 (Hayatnagar, Rangareddy)

		Boundary		Matrix color			Coarse fragments (%)		Structure		
Horizon	Depth (cm)	D	T	Dry	Moist	Texture	fg, cg	st	Size	Grade	Type
Ap	0-16	c	s	5YR4/6	5YR3/4	sl	5-8	3-5	m	1	sbk
Bt1	16-41	a	s	-	2.5YR3/4	scl	60-65	3-5	f	1	gr
Bt2	41-62	g	s	-	2.5YR3/6	c	50-55	3-5	f	1	sbk
Bt3	62-89	c	s	-	2.5YR3/6	scl	50-55	3-5	f	1	sbk
CrK	89-115	-	-	-	5YR3/4 (R)	scl	5-10	20-30	Massive		

Depth	Consistence			Porosity		Cutans			Roots		Effervescence	Other
(cm)	Dry	Moist	Wet	S	Q	Type	Thickness	Quantity	Size	Quantity	(dil HCl)	features
0-16	h	fr	ss, sp	f, m	c	-	-	-	vf, f, m	c, f	-	-
16-41	-	vfr	s, po	m, c	c	T	tn	p (w)	vf, f, m	c, f	-	-
41-62	-	vfr	s, po	m, c	c	T	tn	p	vf, f	c	-	-
62-89	-	vfr	s, po	m, c	c	T	tn	p	vf, f	f	-	-
89-115	-	vfr	s, sp	-	-	-	-	-	vf, f	f	ev	-

Series: PATANCHERU BM Spot: 21 (Black Soils)

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

Morphological properties of Profile No. 41 (Patancheru, Medak)

Horizon	Depth (cm)	Boundary		Matrix color		Texture	Coarse fragments (%) (fg and cg)	Structure		
		D	T	Dry	Moist			Size	Grade	Type
A1	0-4	c	s	7.5YR4/6	7.5YR3/4(M&R)	sl	3-5 (70-80)*	-	-	gr
A2	4-11	a	s	5YR3/6	5YR5/4	sl	3-5	m	2	sbk
Bt1	11-38	c	s	-	2.5YR3/6	sc	3-5	m	3	sbk
Bt2	38-65	g	s	-	2.5YR3/3.5	c	8-10	m	3	sbk
Bt3	65-79	c	s	-	2.5YR3/3.5	c	cg,st 80-85	m	2	sbk
BC	79-109	c	s	-	2.5YR3/3.5	scl	30-35	m	1	sbk
C	109-163	-	-	-	7.5YR4/6	scl	40-45	f	1	sbk

** Mainly consists of termite activity up to 60 cm and earthworm cast.*

Depth (cm)	Consistence			Porosity		Cutans			Nodules (conca)		Roots		Efferve-scence (dil HCl)	Other features
	Dry	Moist	Wet	S	Q	Type	Thick-ness	Quantity	Size	Quantity	Size	Quantity		
0-4	h	fr	ss, sp	-	-	-	-	-	-	-	vf, f	m, c	-	-
4-11	sh	fr	ss, sp	vf, f, m	m, c	-	-	-	-	-	vf, f	m, c	-	-
11-38	-	fr	sp	vf, f, c	m, f	T	tn	p	-	-	vf, f	m, f	-	Slight pressure faces
38-65	-	fr	sp	vf, f	c	T	tn	p	-	-	vf	c	-	Slight pressure faces
65-79	-	fr	s, po	vf, f	c	T	tn	p	-	-	vf	c	-	-
79-109	-	fr	s, sp	vf, f	c	T	tn	p (w)	-	-	vf	c	-	-
109-163	-	vfr	ss, po	-	-	-	-	-	f	f	vf	f	e-es*	-

** Few soft calcareous modules are present which effervesce with HCl.*

Key to Abbreviations

Appendix 2

Boundary	
D - Distinctness	T – Topography
a – abrupt c – clear g – gradual d – diffuse	s – smooth w – wavy i – irregular b – broken

Color
D – dry M – moist R – rubbed

Texture	
s – sand lfs – loamy fine sand ls – loamy sand sl – sandy loam l – loam	sil – silty loam si – silt sic – silty clay c – clay scl – sandy clay loam cl – clay loam sc – sandy clay sicl – silty clay loam

Structure		
Size	Grade	Type
vf – very fine f – fine m – medium c – coarse vc – very coarse	0 structureless 1 weak 2 medium 3 strong	abk – angular blocky sbk – subangular blocky gr – granular m – massive sg – single grain cpr – columnar pr – prismatic pl – platy cr - crumb

Coarse fragments
fg – fine gravel (<2.5 cm) cg – coarse gravel (2.5-7.5 cm) st – stone (7.5-25 cm) b – boulders (>25 cm)

Consistence		
Dry	Moist	Wet
l – loose s – soft sh – slightly hard h – hard vh – very hard eh – extremely hard	l – loose vfr – very friable fr – friable fi – firm vfi – very firm efi – extremely firm	so – non-sticky ss – slightly sticky s – sticky vs – very sticky po – non-plastic sp – slightly plastic p – plastic vp – very plastic

Porosity, Nodules and Roots	
S = Size	Q = Quantity
vf – very fine f – fine m – medium c – coarse	f – few c – common m – many

Effervescence
e – slight es – strong ev – violent

Cutans		
Type	Thickness	Quantity
T – Argillan Fe – Ferran Mn – Mangan O – Organ	tn – thin mtk – moderately thick tk – thick	p – patches b – broken c – continuous

About NBSS&LUP

The National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur, a premier Institute of the Indian Council of Agricultural Research (ICAR), was set up in the year 1976 with the objective to prepare soil resource maps at state and district level and to provide research inputs in soil resource mapping, and its applications, land evaluation, land use planning, land resource management, and database management using GIS for optimising land use on different kinds of soils in the country. The Bureau has been engaged in carrying out agro-ecological and soil degradation mapping at the country, state and district level for qualitative assessment and monitoring the soil health towards viable land use planning. The research activities have resulted in identifying the soil potentials and problems, and the various applications of the soil surveys with the ultimate objective of sustainable agricultural development. The Bureau has the mandate to correlate and classify soils of the country and maintain a National Register of all the established soil series. The Institute is also imparting in-service training to staff of the soil survey agencies in the area of soil survey and land evaluation, soil survey interpretations for land use planning. The Bureau in collaboration with Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola is running post-graduate, teaching and research programme in land resource management, leading to M.Sc. & Ph.D. degrees. Recently the Bureau has been actively engaged in the research work under National Agricultural Technology Project (NATP).

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About ICRISAT®

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR).

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