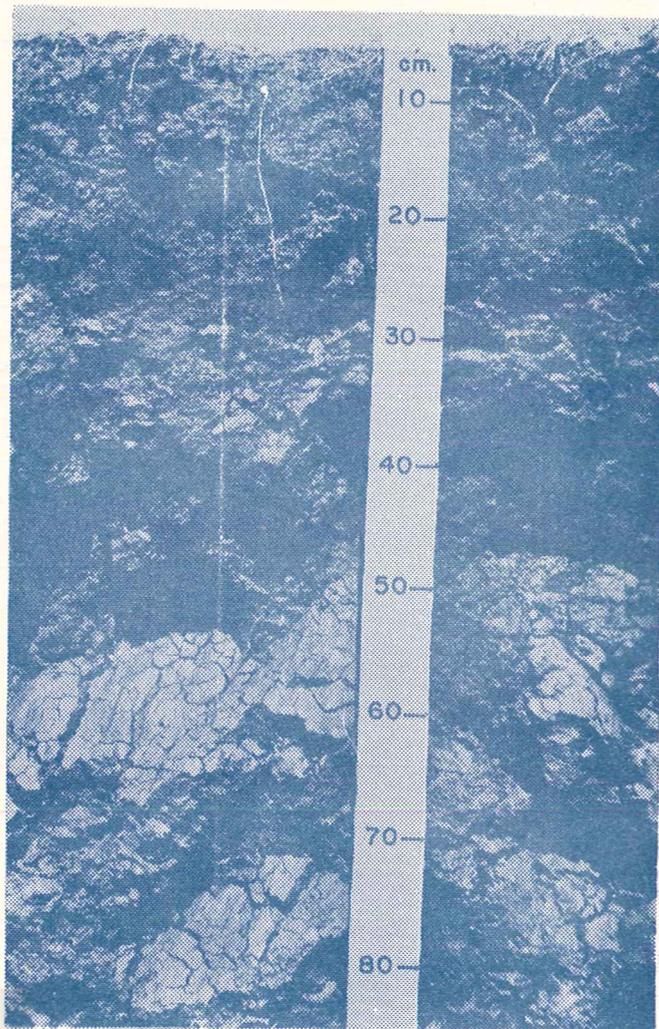


BENCHMARK SWELL-SHRINK SOILS OF INDIA

- morphology, characteristics
and classification

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**BENCHMARK
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Compiled by:

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Edited by:

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RESEARCH
SOIL SURVEY AND LAND USE PLANNING
- methodology, characteristics
and classification

Author
Editor
Reviewer
Printer
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OCTOBER 1988

FOREWORD

Benchmark soils is an emerging central concept in the transfer of agrotechnologies being developed by various research institutes and agricultural universities. This involves identification of Typical soils in different environmental setting; their extent learned through mapping; their characterisation resulting from detailed investigation and, collection of appropriate supporting data regarding their crop yield and performance. Once the Benchmark soils are identified, agronomic experiments and their results from the farms can be transferred to areas having similar soils through soil taxa which act as wheels of technology transfer.

It is heartening to note that the National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur is bringing out a publication 'Benchmark Swell-Shrink Soils of India - morphology, characteristics and classification'. Appropriately, the issue of this publication coincides with the International Workshop on Swell-Shrink Soils being held at Nagpur during October 24-31, 1988. I am sure the information contained in this publication will be utilised by agronomists, planners, students and extension workers for academic as well as applied use and most importantly for developing rational land use plans for the swell;shrink soils region of India.

N.S. Randhawa

N.S. RANDHAWA
Director General, ICAR &
Secretary, Govt. of India, DARE

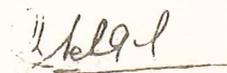
PREFACE

Ever since the publication of 'Benchmark Soils of India' by National Bureau of Soil Survey and Land Use Planning in 1982 there has been a strong desire to bring out similar publications for Benchmark soils of different regions of the country. Setting up of the Vertisol Network at the Bureau in 1987, gave a thrust to this idea and the scientists of the Bureau took up the challenge to bring out a publication on the Benchmark Swell-Shrink Soils of India.

This has been achieved through collection and compilation of data for 33 Benchmark Swell-Shrink soils, covering extensive areas and/or occupying key position in Soil Taxonomy/Classification to provide a scientific base for rational land use planning of this region, where the agricultural potential is yet to be fully realised. It may not be out of place to mention that this is not an exhaustive compilation of all kinds of swell-shrink soils of India, but the first attempt for some extensive soil types of the region.

The NBSS&LUP plans to bring out similar publications for each State through its network of Soil Resource Mapping programme being carried out in different states in the near future. I do realize that this publication might be suffering from certain shortcomings, like incomplete analytical data for some pedons, yet it is a step forward in as much as basic information has been compiled and brought out in the present form.

I take this opportunity to express deep sense of gratitude to all the Soil Survey Staff of State and Central Organizations and the Scientists of the NBSSLUP who were associated in bringing out this publication. It is hoped that this publication will be of great value to different land-user agencies and scientists engaged in soil studies and their field applications especially the areas of swell-shrink soils.



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We wish to place on record our sincere thanks to Shri S.C. Yadav and Shri W.V. Bankar for providing crop performance data on different series. Thanks are also due to Shri S.N. Deshmukh, Dr. K.S. Gajbhiye, Shri R.K. Batta, Dr. D.K. Pal and Dr. J.P. Sharma for their help and cooperation.

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Last but not the least, we are indebted to all others who have directly or indirectly cooperated to bring out this publication.

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INTRODUCTION

Swell-Shrink Soils are those soils that show striking swell-shrink phenomena in their morphology. In the array of these soils, Vertisols indicate the central concept showing the evidence of pedoturbation. The intergrades of Vertic Inceptisols and Entisols show aberrant characteristics of Vertisols.

The typical Vertisols in India are deep, usually calcareous, dark in colour with low chroma, high in clay content, low in organic matter content, high in cation exchange capacity, sticky and plastic and high in shrink-swell potential. They are relatively homogeneous in their morphology as compared to other soil groups ;they lack distinct or prominent horizonation (Dudal and Bramao, 1965). However, recent studies indicate that such soils have 3 distinct horizons based on their striking structural profile viz. self-mulching surface, blocky/prismatic subsurface and a typical wedge-shaped subsoil.

While the Vertisols occupy the lower topographic positions, their geographically associated soils occur on comparatively higher positions on slopes. The climatic setting of these soils ranges from semi-arid to sub-humid tropics characterised by hot and dry summer and fairly dry and mild winters intervened by short period of summer monsoon rainfall.

Vertisols and their geographically associated soils (Vertic intergrades of Inceptisols and Entisols) are widely distributed and occupy about 271.4 million hectares of land area in the world (Blokhuis, 1981; NBSS Staff, 1988). In India, such soils occur in the peninsular region and occupy about 70 m ha, constituting 21.4 per cent of the total geographic area of the country (NBSS Staff, 1988). The soils are very deep to shallow, dark coloured cracking clays; dominantly smectitic in clay mineralogy with a characteristics swell-shrink potential while Vertisols have unique structure profile (Sehgal and Bhattacharjee, 1988). They are generally fertile with high production potential and can contribute significantly in increasing the food production in the country.

A knowledge of the kinds and distribution of soils is necessary for proper appraisal of their productivity potential and their rational use. It is also necessary to relate the information on crop requirements to units delineated on the soil map for agrotechnology transfer. It is in this context, that the concept of Benchmark soils assumes added significance.

The Benchmark soil concept helps to provide a base for research on soils, water management and crop responses; design experiments to ascertain crop responses as per variables in the soil series - which may help in predicting crop performance and pinpoint the type location for such soil series and provide informations to classify these soils and carry out future studies.

The idea of the preparation of a Benchmark publication on the swell-shrink soils of India was conceived in the early part of 1988, in order to focus attention on the extent, location, limitations and the placement of such soils in the systems of Soil Taxonomy. It was thought appropriate to bring out this publication on the occasion of the International Workshop on Swell-Shrink Soils to be held in October, 1988 at Nagpur.

Keeping this in view, information on the Benchmark Swell-Shrink Soils was collected from different sources, namely the Benchmark Soils of India (Murthy, et al. Ed., 1982), Soil Survey Reports of the National Bureau of Soil Survey and Land Use Planning and soil series identified and mapped by various State Soil Survey agencies and correlated by Soil Correlation Committees from different regions of the country. The criteria used for including a soil series in the Benchmark category are

- i) a soil occupying a key interpretative position in Soil Taxonomy,
- ii) a soil covering a large area, and
- iii) a soil typical of a particular area.

GEOGRAPHIC SETTING

2.1 CLIMATE

In the formation of Black Soils of India, among the other factors, the peculiar monsoonic climate of India giving rise to alternate aridity and humidity must have had a preponderate share. The climate of the black soil region ranges from hot and semi-arid parts of Rajasthan in west to hot and sub-humid in the southern tip of India (Raychaudhuri et al., 1963). The mean annual temperature ranges from 24 to 30^o C. The climate is generally hot and dry in summer and mild in winter. Table 1 shows the climatic data for a few selected stations in different climatic belts of this region. Monsoon showers are received mostly during June to September, which extend upto December in the southern part of the country. The distribution of rainfall is generally erratic, ranging from 500 to 600 mm in arid, 600 to less than 1000 mm in semi-arid and 1000 to 1500 mm in the sub-humid parts of the country (Murthy et al., 1982).

The main feature about the climate is the seasonality of rainfall allowing for annual wetting and drying of the solum leading to many unique physical properties typical of Vertisols. The seasonality also results in a particular weathering regime, associated with montmorillonite synthesis (Ahmad, 1983). The annual changes of precipitation and temperature should be such as to encourage weathering for some time of the year during the wet season, and for accumulation of basic cations in the dry seasons (Crompton, 1967).

In a nutshell, the climatic patterns for the Vertisols and associated soils are : the well expressed hot and dry summer, dry and mild winters and a well pronounced short duration monsoon rainfall period (June to September).

Table 1. Climatic data of some important stations

Climatic particulars	Arid		Semi-arid		Sub-humid (dry)		Sub-humid (moist)
	Anant-pur (14° 14'N)	Rajkot (22° 18'N)	Ahmed-nagar (19° 05'N)	Tiruchirapalli (10° 46'N)	Nizamabad (18° 40'N)	Bhopal (23° 17'N)	Jabalpur (23° 10'N)
Annual mean rainfall(mm)	562.3	673.8	677.3	867.6	1086.1	1208.9	1447.5
Annual mean temperature (°C)	27.6	26.8	25.3	28.9	27.0	25.0	25.2
Maximum summer temperature (°C)	38.39	39.41	39.40	37.0	39.4	38.4	39.42
Minimum winter temperature (°C)	17.18	19.20	131.14	21.0	14.15	10.11	9.10
Average minimum temperature (°C)	33.3	33.9	32.0	33.7	33.1	31.5	32.1
Percentage of evapotranspiration covered by rainfall	30	30	42	41	68	77	103
Number of dry months	11	10	6	9	4	4	3
Number of humid months	0	1	2	2	3	3	3
Humidity Index (Ih)	0	0	0	0	13.6	27.0	46.9
Aridity Index (Ia)	69.7	68.6	57.2	56.4	45.3	49.9	43.5
Moisture Index (Im)	-69.7	-68.6	-57.2	-56.4	-31.7	-22.1	3.3

Source : Murthy et al., 1982

2.2 VEGETATION

The vegetation of uncultivated dark clay soils is mostly grassland, both in the tropical and subtropical areas. It seems possible that the original climax vegetation in many areas was of forest which has been obliterated by man's activities (Dudal and Brama, 1965). Due to the relatively high temperature and a marked dry season in the Vertisol landscape, the present natural vegetation is tropical dry deciduous and tropical thorny forest interspersed with grasses. In general, there is an open type of vegetation in the higher topographic situations viz., table-land and pediment. Specific natural vegetation includes *Butea frondosa*, *Dalbergia latifolia*, *Azadirachta indica*, *Tectona grandis*, *Terminalia tomentosa* and *Acacia spp.* Piedmont plain and flood plain are mostly cultivated. However, thorny biotic species are not uncommon. The normal crop husbandry consists of dryland farming which includes crops such as sorghum, cotton, pearl millet, pigeon pea, groundnut, soybean and safflower. In the areas receiving irrigation, wheat, sugarcane and paddy are grown. Orchards of citrus, banana and mango are also common in these areas.

2.3 GEOLOGY

Parent materials which are basic in nature, containing high proportions of alkaline earths are responsible for the development of Vertisols and associated soils of Vertic subgroups. In the Indian context, Deccan trap, an extensive volcanic formation of basaltic rocks is the main parent material for the black soils. The term trap is applied to different kind of rocks but in this case, it is used as a Swedish word meaning stairs or slopes in view of the usual step-like aspect of the weathered hills of the basalt which are a common feature of the Deccan plateau. The Deccan basalts are singularly uniform. The most common rock is a normal augite-basalt of mean specific gravity 2.82. The most common colour of the rock is greyish-green with lighter or deeper shades. The bulk of the rock is composed of a fine-grained mixture or groundmass of feldspar and augite. The age of the Deccan trap

is considered to be from the Cretaceous Period (based on external evidence), the trap themselves being unfossiliferous and do not provide conclusive evidence of their age (Raychaudhuri et al., 1963).

Although the most characteristic Black Cotton Soils are found around the volcanic plateau of the Deccan trap, its area is not limited by the boundary of the Deccan trap formation. These soils are also observed over the surrounding granitic and gneissic formations, and Vindhyan or Cuddapah sandstones and slates. Large tracts of Black Soil are formed in alluvium derived from the Deccan trap.

Murthy et al. (1982) have reviewed the parent materials on which the Vertisols and associated soils of Vertic Subgroups could have possibly formed (Table 2).

2.4 LANDSCAPE

Vertisols occur at elevations ranging from the sea level to 2,200 m, above the mean sea level (MSL), with the majority occurring below 300 m (Dudal and Bramao, 1965). Most of the Black Cotton Soils, occurring in the Deccan plateau, are generally situated between 300 to 600 m above MSL (Raychaudhuri et al., 1963).

By and large, the Vertisols occur in the regions that have limited local differences in elevation. Generally the topography is undulating to level, though it may be rolling at places. Land surfaces in the Deccan plateau consist of low ridges with broad crests separated by wide shallow valleys. In such landscape, Vertisols blanket the region.

It has been observed that these soils rarely occur in hilly landscape and are generally observed on the smoothest and lowest positions of toposequences having slopes not exceeding 5 per cent. The Black Soils as a whole are characterised by gentle slopes and mild relief (Dudal and Bramao, 1965).

Table 2. *Parent materials for development of Vertisols*

Reference	Particulars of parent material	Inferences
Dudal and Bramao (1965)	Basalt, shales, limestone, volcanic rocks, tuffs, basic metamorphic rocks, alluvium (fluvial and marine) Colluvium basic in nature	Common parent materials develop black soils
Bal (1935); Wadia (1945); Basu and Sirur (1938)	Basalt (Deccan trap)	Dominant parent materials
Hosking (1935); Simonson (1954)	Limestone, shales, calcareous clay	Responsible for the formation of Vertisols
Ramaiah and Raghavendrachar (1936)	Materials rich in soda lime feldspar	Responsible for the formation of Vertisols and associated soils, while potash feldspar gives rise to red soils under similar climate and land form
Tamhane and Sen (1954)	Dharwar schists basalt and norites	Responsible for the formation on black soils
Parthasarathy (1959)	Calcium gneiss	Gives rise to black soils, while Orthoclase feldspar and hornblende give rise to red soils
Kalbande and Swamynatha (1976)	Hornblende granulite, calcic gneiss, granitised schist and chorite schist	Responsible for the formation of Vertisols and associated soils
Bhattacharjee, Landey and Kalbande (1979) (Unpublished)	Marine alluvium and coastal alluvium	Responsible for the development of Vertisols and associated soils

Source : Murthy et al., 1982

2.5 DISTRIBUTION

Vertisols and associated soils occur in all the five continents. They have very wide geographical distribution which ranges from 45° S to 45° N latitude (Dudal and Bromao, 1965). The largest expanses of such soils occur in Africa, Australia, Asia and Far East (mainly India) (Table 3, Fig. 1).

Table 3. *Global distribution of Vertisols and associated soils*

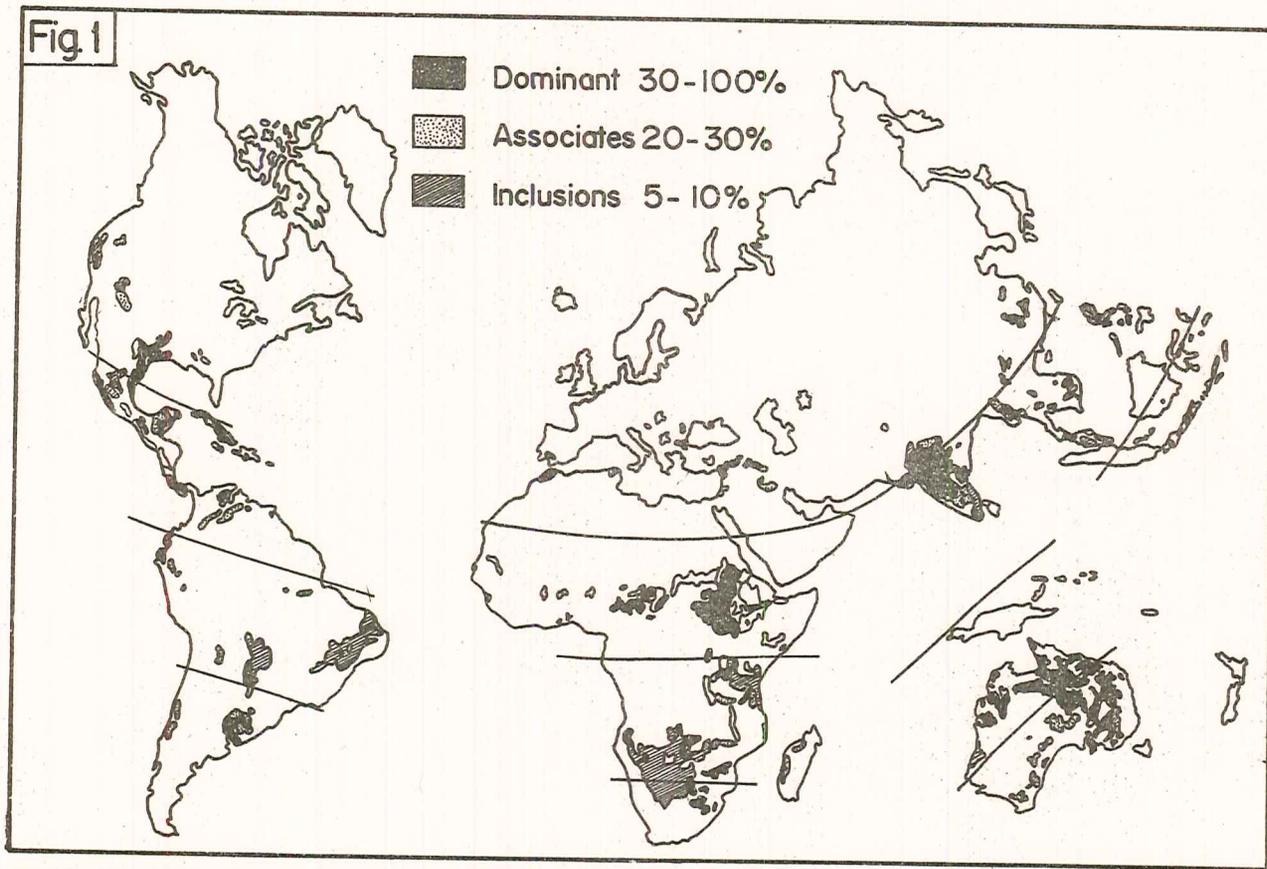
Region	Area in million ha
Africa (dominantly northern strip from west to east below Sahara desert)	105
Asia and Far East (mainly India)	58 (70.3)*
Australia	48
Latin America	27
North America (essentially southern USA)	10
Near and Middle East	5.7
Europe (widely scattered)	5.4
Total	259.1 (271.4)*

Source : Blokhuis, 1982

* Area in view of Latest Map (NBSS Staff, 1988)

In India, Vertisols and associated soils (Fig. 2) are mostly encountered in Peninsular region between 8° 45' and 26° 0' N latitude, and 68° 0' and 83° 45' E longitude, covering an area of about 70 million hectare, constituting approximately 21.4 per cent of the total geographical area of the country (NBSS Staff, 1988)**. They are dominantly observed in the states of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan, and Uttar Pradesh. The Statewise distribution of these soils is given in Table 4. Maharashtra and Madhya Pradesh share

**



Worldwide distribution of vertisols (adopted from FAO Unesco Soil Map of the world 1971-79) courtesy of ILRI

the major portion of such soils, which account for 7.4 and 6.4 per cent of the total geographical area of the country.

Table 4. *Distribution of Vertisols and associated soils in India*

State	Total area under Vertisols and associated soils (million ha.)	Area under Vertisols and associated soils expressed as	
		% of gross Vertisols & associated soils	% of total geographical area of the Country
Maharashtra	24.2	34.3	7.4
Madhya Pradesh	21.2	30.2	6.4
Gujarat	4.9	7.0	1.5
Andhra Pradesh	9.4	13.4	2.9
Karnataka	5.8	8.0	1.8
Tamil Nadu	2.6	4.0	0.8
Rajasthan	1.1	1.5	0.3
Uttar Pradesh	1.1	1.6	0.3

Source : NBSS Staff, 1988

Of the 21.4 per cent area under swell-shrink soils, the area under different soil orders is as follows :

● VERTISOLS	8.0 %) 21.4 % of the total geographical area of the country.
● INCEPTISOLS	8.6 %	
● ENTISOLS	4.4 %	
● ALFISOLS	0.4 %	

MORPHOLOGY AND CHARACTERIZATION

3.1 MORPHOLOGY

The Vertisols in India are dark in colour, generally calcareous, low in organic matter, high in clay content, high in cation exchange capacity and base saturation. They are sticky and plastic and have high swell-shrink potential. The soils are relatively homogeneous in their morphology. Although, horizonation is not distinct, yet 3 horizons may be identified namely self mulching surface, blocky subsurface and wedge shaped subsoil which are related to processes of soil development. Thus, the study of morphology provides an index for identifying the genetic processes attributing to unique properties of the soils.

These soils are characterised by the cyclic A1 horizon of varying thickness with micro-knolls and micro-depressions resulting in a typical micro-relief pattern which grade to a wedge-shaped structure horizons. The associated soils of Vertic subgroups generally show A-(B)-C profiles (Landey et al., 1982; Murthy et al., 1982). Based on the several pedons studied by the Soil Survey Staff of the Central, State and other agencies, the morphological characteristics of the Black Cotton (Swell-Shrink) soils are summarised as follows.

The depth of such soils vary from shallow to very deep. Raychaudhuri et al. (1963) and Srinivasan et al. (1969) have grouped the black soils into shallow (less than 30 cm), medium (30 to 100 cm) and deep (more than 100 cm); the depth of shallow soils has been modified to 50 cm (Sehgal et al., 1987). In Vertisols and associated vertic intergrades, the minimum depth requirement is more than 50 cm (Soil Survey Staff, 1975). In India, the Vertisols are not observed in soils having less than 80 cm depth; the Vertic intergrades are however, observed even in shallow profiles.

According to Simonson (1954) a slow and steady churning process within the pedon inhibits the process of horizon differentiation. The size of the pedon synchronizes with the linear frequency of micro-knoll (puff) and micro-depression (shelf) of gilgai microrelief (Bartelli, 1971; Bhattacharjee et al., 1977). The distinction between the adjacent horizons in swell-shrink soils, indicating contrast, has been generally recognised as clear and gradual with smooth and wavy boundary (Landey et al., 1982).

The swell-shrink soils, in general, have dark coloured surface horizons. The dark colour appears to be due to the organic matter, associated with the very fine clay (Dudus and Pawluk, 1969). Laboratory experiments have shown that the black colour formation is an intrinsic property of the specific clay mineral which fixes the humus in a certain proportion to form the clay-humus complex which imparts black colours to these soil. The difference in organic matter status, however, does not find any relation with soil colour. It is likely that the presence of iron and manganese oxide in combination with the organic complex may impart dark colour in these soils. Srinivasan et al. (1969) and Sehgal and Bhattacharjee (1988) proposed the designation of structural B horizon as Bv horizon to highlight the vertic properties of swell-shrink soils.

The swell-shrink soils are in general, black or dark in colour. According to Annet (1910), the black colour in these soils is largely due to the presence of titaniferous magnetite mineral(s) and soluble humus. Joshi (1950) however, indicated that the colour was due to the clay humus complex. The formation of clay-organic matter complex favouring anaerobic condition during wet season was considered essential to the formation of dark colour (Singh, 1956; Maignien, 1961; Johnson et al., 1962). In situations where the soil is developing in recent alluvium, the soil colours may vary from shades of grey to brown/reddish brown (Ahmad, 1983).

The clay content is most of these soils, remains uniformly high throughout the profile, (upto a depth of 1 m or more) which suggests non-translocation of clay in these soils.

The swell-shrink soils usually show cloddy structure; but occasionally one may notice crumb or aggregated surface horizon. In view of their hard but not massive surface soils, dark colours, and high base status, and organic matter content that is high enough to qualify for a mollic epipedon, some such vertic intergrades may qualify for Mollisols instead of Inceptisols. In very deep soils however, one may observe a characteristic wedge-shaped structure which is typical of type Vertisols. Krishna and Perumal (1948) described the subsoil peds, occurring at 90 to 200 cm depth with dimensions of 10 to 20 cm in the Black Soils of Hyderabad State, India, as 'Lentils' after its close resemblance to the lentil seed. Such soils are also observed in Tamil Nadu near Madurai.

The surface soils show a self-mulching horizon. The mulch, if destroyed by cultivation, may reform after a drying cycle. At the other extreme, the surface horizons of other Vertisols are both massive and very hard (when dry) which pose difficulty in preparing the seedbed.

The swell-shrink soils on wetting develop a characteristic microrelief consisting of low mounds and shallow depressions.

The distribution of lime concretions (and pebbles) in profiles of black soils may be uniform throughout the profile. It may be probably due to the localised movement of the sub-soil. Range of important morphological features of the Vertisols and their Vertic intergrades, as described by Murthy et al. (1982) are given in Table 5.

3.2 PHYSICAL AND CHEMICAL CHARACTERISTICS

The clay content generally ranges from 40 to 60 per cent but it may be as high as 80 per cent in some soils. The percentage of fine to total clay content in some of the Benchmark Soils of western and central India ranges from 45 to 77 (Pal and Deshpande, 1987). Clay is uniformly distributed within the solum. The proportion of sand and silt in these soils is related to the parent material in which the soils develop. The soils developed in coastal and deltaic alluvia have low sand contents and most

Table 5. Ranges in characteristics of Vertisols and vertic subgroups in India

Horizon	Moist colour	Texture	Structure	Special features compound structure	Width of cracking (cm)	General remarks
1	2	3	4	5	6	7
<i>Typic Chromusterts/Typic Pellusterts</i>						
Ap/A11-A12	10YR-2.5Y 4/2-3/2,3/3 10YR-2.5Y 3/1-2/1	c	1f/1m sbk - 2c/3c abk	1c/2c pr-3c pr	2-5	Gilgai relief; 2-3 cm thick mulch layer at places; peds with shiny pressure faces; accretionary lime nodules may not be present; A11 horizons may or may not be present at places
A13-A14	10YR-2.5Y 3/3-3/2 10YR-2.5Y 3/1-2/1	c	2m/2c abk - 3c abk	Intersecting slickensides or parallelepipeds with long axes tilted 35 to 55° from horizontal	2-1.5	
AC	10YR-2.5Y 4/4-3/4 10YR-2.5Y 5/1.2-3/1 Mottles: 10YR-2.5Y 3/2-2/2 10YR-2.5Y 7/2-6/3	c	2c abk - 3c abk	Intersecting slickensides or parallelepipeds with long axes tilted 35 to 55° from horizontal	1-0.5	
C	10YR-2.5Y 4/4, 5/4-4/3 10YR-2.5Y 7/2, 7/1-5/4	c-gc	2m sbk - 3 abk/ massive	Intersecting slickensides/ massive/blocky		
<i>Vertic Ustochnepts/Vertic Ustropepts</i>						
Ap/A1	10YR 5/2-4/3 10YR-7.5YR 4/2-3/2, 3/3	l-cl, scl	1m sbk - 2m sbk	1 cpr - 2 cpr	2-2.5	Peds with shiny pressure faces; accretionary lime nodules or lime in soft powdery or hard mass may not be present in subsoil layers
B1-B2	10YR 4/3-3/3,2/2 10YR- 7.5YR 3/2-3/2,4/6	cl-c	2m sbk - 3m/3c abk	2 cpr - 3 cpr or slickensides tilted at an angle from horizontal	1.5	
B3	10YR 6/3-3/2 10YR-7.5YR 3/3-3/2/3/4,4/4	gscl/cl gc/gl	1m/2m sbk 3m/2c abk	---	---	
C	10YR 7/6-4/4 10YR-7.5YR 5/2-3/2,4/4	gsl/gl gscl	1f, sbk - 1m abk	---	---	

Source : Murthy et al., 1982

of the non-clay material is of silt size. On the other hand, the soils developed mainly in alluvium of weathering basalt have comparatively lower content of same fraction than those developed in alluvium derived from both basalt and metamorphic rocks.

The soils show bulk density ranging from 1.2 to 1.5 (33 kPa) to 1.5 to 2.0 Mg m^{-3} (1500 kPa) depending on the swell-shrink potential. The bulk density of the soils is an index of workability of the soils with respect to tillage operations.

The pH in the surface layers of swell-shrink soils usually ranges between 6.5 and 7.5 (in non-calcareous soils) and between 7.5 and 8.3 (in calcareous soils).

In general a relatively narrow range of pH occurs in most of the swell-shrink soils, but soils with higher pH are also observed where parent materials are rich in alkaline earths or where these have been rendered sodic.

The CaCO_3 is invariably observed in most of the swell-shrink soils. Their amount varies from 0.5 to 8 per cent with extremes of 0.1 to 20 per cent. The lime carbonates may be distributed throughout the profile or occur in concentrated form in some part of the profile, depending on the rainfall and topographic position. The distribution of calcium carbonate in these soils can be used to establish a nice climo-sequence of soils from Akola (rainfall~500 mm) to Jabalpur (having~1400 mm rainfall).

The soils are generally low in organic matter. The amount of organic matter decreases with depth. The magnitude of variation is, however, small. The organic matter of the surface soil in general ranges from 0.5 to 1.5 per cent with a mean value of \approx 1 per cent which remains practically unaltered upto a depth of about 1 metre and then decreases markedly in the C-horizon. The organic matter content seems to be strongly related to grassland vegetation, cropping history, and prevailing environments.

The cation exchange capacity (CEC) of swell-shrink soils is generally high (35 to 60 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$) as compared with other minerals soils. It is due to the dominance of smectitic clay mineral in the fine clay fractions (Pal and Deshpande, 1987).

Soils are saturated with bases, especially Ca and Mg while calcium constitutes 60 to 80 per cent, magnesium may constitute 10 to 30 per cent of the exchange complex. The exchangeable K and Na are observed in horizons where Mg exceeds or equals the Ca saturation. The base saturation, in general increases with depth.

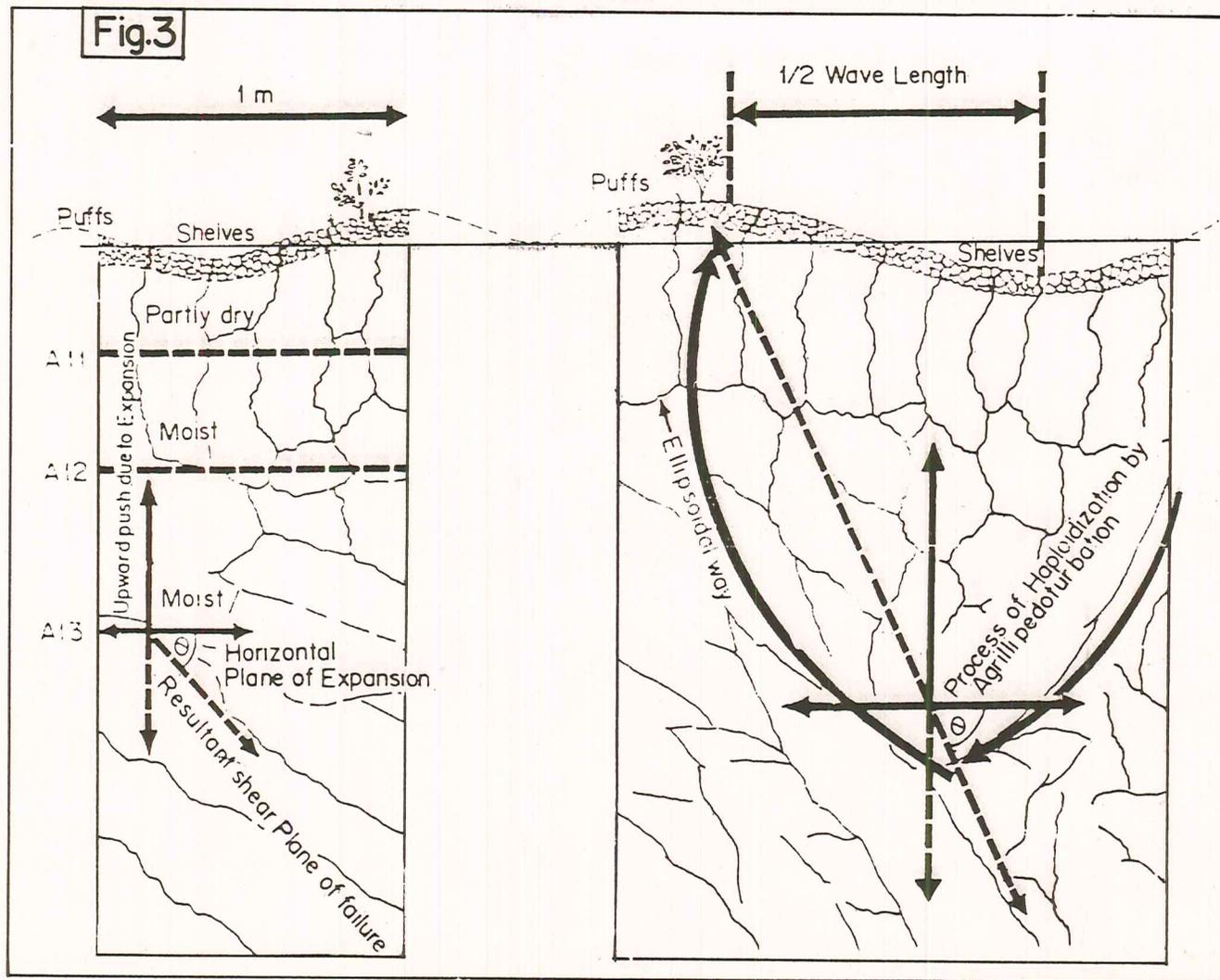
The swell-shrink soils, in general, are deficient in available nitrogen but have high available potassium content. As such they do not respond to the application of K fertilization (Pal and Durge, 1987). These soils have been found to contain small amount of gypsum in the finely divided state or as gypsum crystals in the sub-soil, especially in the arid climatic environments. But the amount does not qualify for a gypsic horizon.

PEDOGENESIS AND CLASSIFICATION-CONSIDERATIONS

4.1 PEDOGENESIS

The parent material - basalt - of these soils is primarily basic in nature, containing a high proportion of the alkaline-earths, which weathers to smectite as its first weathering product (Pal and Deshpande, 1987). This is an essential pre-requisite for the genesis of Vertisols and Vertic associates. The high coefficient of expansion and contraction of these minerals results in three-dimensional volume changes of the soil mass during alternate wet and dry cycles, as conditioned by climatic environments and topography. This sets up a cyclic movement of soil materials (auto-inversion) to cause vertical mixing (pedoturbation) of soil material. Such phenomena cause one mass to slip over another resulting in the formation of slickensides in the lower part of the pedon. The slickensides intersect or are close enough to intersect, resulting in wedge-shaped structural aggregates which constitute the most characteristic features of Vertisols (Fig.3). The slipping occurs when shear strength is surpassed by shear stress acting upon a soil mass. The shear stress is a major force caused by swelling and develops when volume expansion results during the wet cycle and tensile stress develops upon soil shrinkage during the dry cycle (Blokhuis, 1982). Simultaneously, deep and wide cracks and/or gilgai micro-relief develop. The deep wide cracks separate the soil into strong and massive prism-like blocks in the upper part of the pedon that break into angular blocky peds of hard and firm consistence. In the subsoil, wedge-shaped structural aggregates develop with their longitudinal axes inclined at 30 to 60° from horizontal (Sehgal and Bhattacharjee, 1988).

In most swell-shrink soils, the temperature being high, the potential evapo-transpiration exceeds the total precipitation, suggesting incomplete leaching and inducing the process of calcification in these soils.



Mechanism of pedoturbation forming gilgai micro-relief and slickensides in Vertisols.

4.2 CLASSIFICATION

The unique properties common to Vertisols are the limited horizon differentiation due to argilli-pedoturbation, high content of clay; pronounced changes in volume with changes in moisture; deep wide cracks (at least 1 cm wide at a depth of 50 cm) at some season; evidence of soil movement in the form of slickensides, gilgai micro-relief, and tilted wedge-shaped structure peds.

It may be remarked that not all swell-shrink soils qualify for Vertisol. Murthy et al. (1982) observed that deep Black (Cotton) Soils generally satisfy the diagnostic criteria for Vertisols while the moderately - deep to shallow soils qualify for Vertic Ustropepts, Ustochrepts or Ustorhents.

The water-balance data of the swell-shrink soils region of India indicate dominance of ustic moisture regime. As such the soils qualify for Usterts. Further based on the differences in colour chroma, these soils are differentiated into two Great Groups of Pellusterts and Chromusterts.

Sehgal and Bhattacharjee (1988) have discussed in detail the taxonomic problems of swell-shrink soils, especially Vertisols. The authors believe that

- a minimum depth of 100 cm (or least 80 cm) must be there to qualify a soil as Vertisol;
- the concept of Pell and Chrom based on chroma (moist) of 1.5 need to be deemphasised as it has little relationship with drainage under Indian conditions;
- the well-expressed structural B horizon should be recognized and designated as vertic - B horizon like argillic - B, calcic - B horizon to highlight vertic properties;
- diagnostic horizon such as salic, natric, calcic be introduced to differentiate Great Groups; and
- the Ustic moisture regime be sub divided, as aridic, typic and udic-ustic for defining subgroups.

Further the occurrence of aquic moisture regime in Vertisols has not been observed to-date and hence the proposal to introduce AQUERT subgroup does not find support from this part of the world. It is also realised that a precise soil rather than climatic criteria may need to be searched to separate ustic soil moisture regime from the aridic or udic under Indian conditions.

In view of the above observations, the classification of Vertisols may need revision. But before it is undertaken and accepted, the studied Benchmark soils have been classified using the prevailing class criteria.

SOILS

5.1 GENERAL

Thirty three soil series representing the Vertisols and Vertic Inceptisols have been selected as Benchmark soils. The location of these soils is shown in Fig. 4. Twenty six series belong to Vertisols and seven to Inceptisols (Table 6). These soils occur in four climatic regions viz., semiarid subtropical, subhumid subtropical, subhumid tropical and semi-arid tropical.

Brief descriptions of the soils series are given in Table 7. Detailed description of the series and their setting are given in the succeeding pages under 5.2

- *Soils of semiarid subtropical region*

This region receives mean annual rainfall of 800 mm mostly during monsoon period July to October. The mean annual temperature is about 25° C. The black soils in this region represented by Chambal series are deep, moderately well drained and calcareous in nature. The striking feature of these soils is the crumb structure on the surface which minimises the moisture loss.

- *Soils of subhumid subtropical region*

The mean annual rainfall in this region varies from 1200 to 1400 mm. The mean annual temperature is about 25° C. The black soils representing Vertisols in this region are of Marha, Jamra and Sundra series. These soils are very deep exhibiting wide and deep cracks. They are moderately well drained.

- *Soils of subhumid tropical region*

The mean annual rainfall in this region varies from about 1000 to 1500 mm and the mean annual temperature is about 26° C. Of the

Table 6. *Distribution of Benchmark swell-shrink, soils in different agroclimatic regions in India*

Subgroup	Semiarid sub-tropical	Subhumid sub-tropical	Subhumid tropical	Semiarid tropical
<i>Soil Series</i>				
Typic Chromusterts	--	--	Halдар, Jalalpur, Sarol, Kheri, Jambha, Aroli	Otur, Nimone, Barsi, Kagalgomb, Hugaluru, Hungund,
Entic Chromusterts	--	Marha, Jamra, Sundra	Arang, Kirnapur	Kadirabad
Udic Chromusterts	--	--	Linga	Semla
Udorthentic Pellusterts	--	--	--	Kalathur
Typic Pellusterts	--	--	--	Kasireddipalli, Achmatti, Teligi
Entic Pellusterts	Chambal	--	--	Raichur
Vertic Halaquepts	--	--	Golana	--
Vertic Ustropepts	--	--	--	Dholwad, Coimbatore
Vertic Ustochrepts	--	--	Saunther, Sisodara, Karla	Bhola

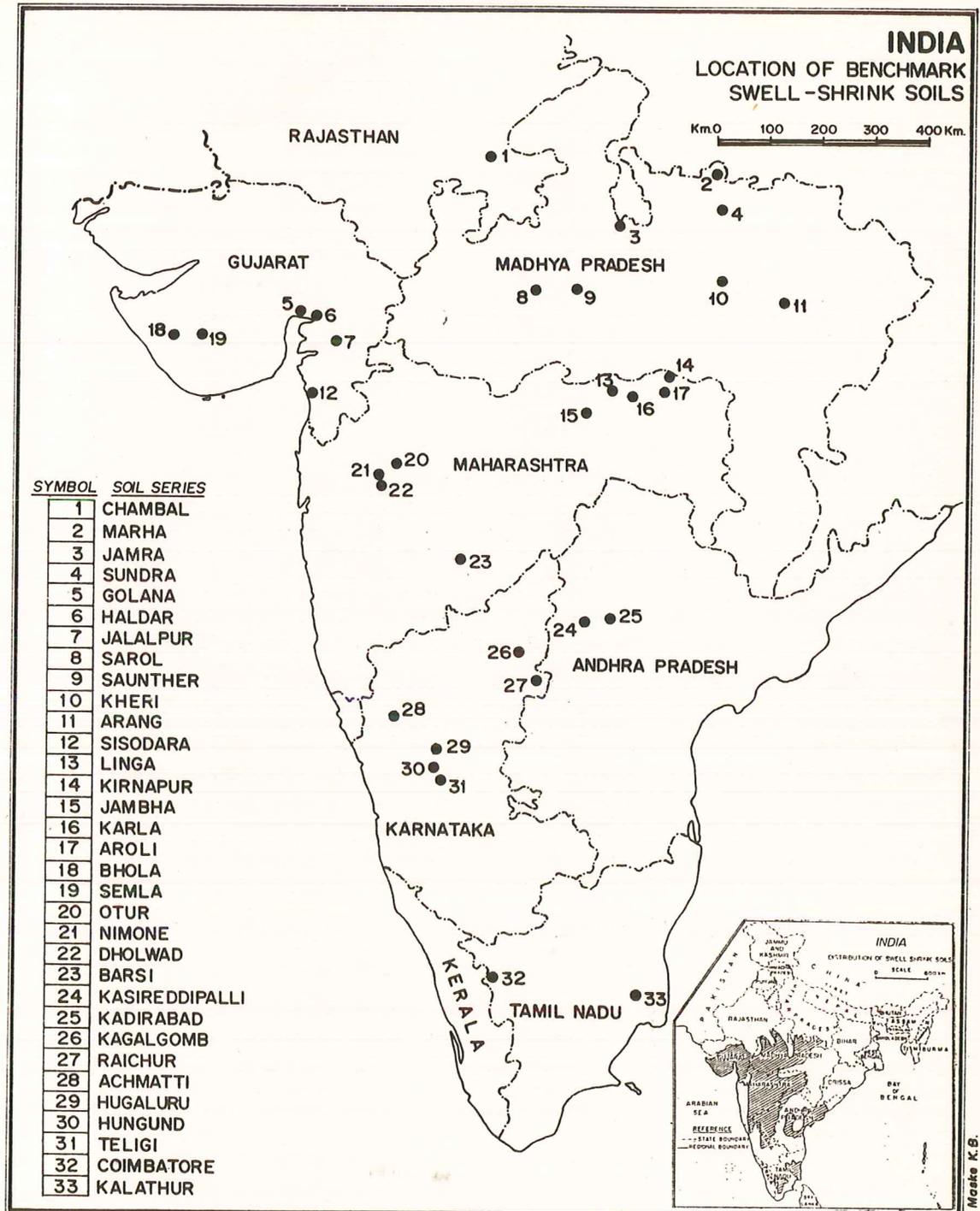


Fig. 4

Table 7. Some salient characteristics of the soil series

Soil series	Depth (cm)	Drainage	Colour (moist)	Clay (%)	Structure	Depth of slickensides (cm)	Organic carbon (%)	CaCO ₃ (%)	pH (1:2.5 H ₂ O)	CEC (c mol (p ⁺)/kg ⁻¹)	Other features
1	2	3	4	5	6	7	8	9	10	11	12
<i>Soils of semiarid subtropical region</i>											
Chambal	131	MWD	10YR 4/1	48-56	2,m,abk	27-131	0.33	6-7	8.1-8.4	40-57	Crumb structure in upper 6 cm; 1-2 cm wide cracks
<i>Soils of subhumid subtropical region</i>											
Marha	180	MWD	2.5Y 4/2, 3/2	44-51	3,c,abk	70-180	0.48	--	8.0-8.1	46-54	2-4 cm wide cracks upto 125 cm; ESP 10-12% in subsoil
Jamra	140	MWD	10YR 4/2	51-58	2,m,abk	45-102	0.78	8-9	8.1-8.4	40-44	1-2 cm wide cracks upto 102 cm
Sundra	140	MWD	2.5Y 4/2	54-64	2,m,sbk-abk	40-140	0.70	0.5-0.8	7.9-8.9	31-37	1/cm wide cracks upto 70 cm

contd.....

- Col. 2 Depth of A and AC horizons or solum depth
 Col. 3 Drainage : WD - Well drained, MWD - Moderately well drained, ID - Imperfectly drained, PD - Poorly drained
 Col. 4 Munsell colour of upper 30 cm
 Col. 5 Clay percentage range
 Col. 6 Structure grade 1 - weak, 2 - moderate, 3 - strong; size f - fine, m - medium, c - coarse; shape gr - granular
 sbk - sub-angular blocky, abk - angular blocky
 Col. 7 Depth at which slickensides/wedge shape peds occur
 Col. 8 Organic carbon content in the surface
 Col. 9 CaCO₃)
 Col.10 pH) Range
 Col.11 CEC)

1	2	3	4	5	6	7	8	9	10	11	12
<i>Soils of subhumid tropical region</i>											
Golana	125	PD	10YR 3/2	65-66	1-2,m, sbk-abk	--	0.58	12-15	8.8-9.3	27-29	2-4 cm wide cracks upto 60 cm
Haldar	130	ID	10YR 3/2, 3/3	55-60	2-3,m-c, sbk-abk	39 -102	0.27	1-2	7.4-8.0	44-46	5-7 cm wide cracks
Jalalpur	150	MWD	10YR 3/2	60-61	2,m, sbk-abk	65-100	0.49	3-23	8.3-9.4	25-47	Crack during dry season; surface horizon has moderate salinity
Sarol	160	MWD	2.5Y 3/2	52-59	2-3, m-c, sbk-abk	29-160	0.40	1-15	8.0-8.2	43-58	2-3 cm wide cracks; prominent gilgai; loose granular mulch on surface
Saunther	77	MWD	10YR 3/1.5	54-75	2-3,m, sbk-abk	27-77	0.84		6.8-7.2	51-54	1-2 cm wide cracks upto 60 cm
Kheri	150	MWD ID	2.5Y 3/2 10YR 3/2	62-66	2-3, m-c, sbk-abk	37-150	0.52	5-8	7.1-8.1	54-60	Surface crusting 2-3 cm wide cracks
Arang	152	MWD	10YR 4/3	44-60	2-3, m-c, sbk-abk	36-152	0.57	--	6.9-7.9	22-29	Wide cracks, prominent gilgai relief
Sisodara	127	MWD	10YR 3/2	44-56	2, m sbk-abk	--	--	--	8.0-8.1	39-42	1-2 cm wide cracks
Linga	140	ID-PD	10YR 3/2	71-75	2,c,abk	16-140	0,51	2-9	8.1-8.3	56-69	3-5 cm wide cracks upto 100 cm; gilgai relief prominent
Kirnapur	142	WD	2.5Y 3.5/2	51-64	2-3,m-c sbk-abk	40-142	0.41	--	7.7-7.8	31-48	1-2 cm wide cracks upto 100 cm
Jambha	190	PD	10YR 3/2	57-73	3,c, sbk-abk	65-190	0.46	1-3	8.3-8.7	44-55	1-2 cm wide cracks upto 65 cm; prominent gilgai
Karla	66	MWD	10YR 3/2	61-66	3,m-c, sbk	--	0.59	4-6	7.7-7.9	57-59	1-2 cm wide cracks upto 66 cm
Aroli	163	MWD	10YR 3/2	58-64	2-3,m-c, sbk-abk	42-163	0.43	5-14	8.4-8.5	53-58	3-4 cm wide cracks; gilgai relief
<i>Soils of semiarid tropical region</i>											
Bhola	96	MWD	10YR 3/3	41-51	2-3,m-c,	--	0.70	14-27	8.1-8.7	37-44	1-2 cm wide cracks upto 56 cm

%	1	2	3	4	5	6	7	8	9	10	11	12
Semla	156	ID	10YR 3/2	58-62	2-3,m-c, sbk-abk	23-156	0.72	21-25	8.8-9.0	48-59	2-4 cm wide cracks; gilgai relief	
Otur	110	MWD	10YR 3/3	42-56	2-3,m-c, abk	18-110	0.62	2-5	8.4-8.5	46-59	4-6 cm wide cracks upto 65 cm	
Nimone	125	ID	10YR 3/2, 2/2	54-59	2-3,m-c, sbk-abk	18-125	0.60	3-10	8.1-8.5	56-60	Deep wide cracks; gilgai micro relief; loose granular mulch	
Dholwad	64	WD	10YR 4/3, 3/3	34-46	2,m,sbk	--	0.70	7-20	7.4-8.1	32-43	1-2 cm wide cracks upto 64 cm	
Barsi	147	MWD	10YR 3/2	64-76	2-3,m-c, sbk-abk	36-147	0.53	0.5-5	8.3-8.5	57-70	2-3 cm wide cracks; sodicity in subsoil	
Kasireddipalli	130	ID	10YR 3/1	54-67	2-3,m-c, sbk-abk	40-130	0.73	5-7	8.8-9.4	56-63	Deep wide cracks	
Kadirabad	103	MWD	10YR 4/2, 2.5Y 3/2	37-49	2-3,m-c, sbk-abk	38-103	0.71	2-8	8.0-8.3	40-48	Deep wide cracks; upto 66 cm	
Kagalgomb	200	MWD	10YR 3/2	52-72	2-3,m-c, sbk-abk	50-200	0.63	5-9	8.5-9.3	60-68	Deep wide cracks; prominent gilgai relief, ∞ sodicity in subsoil	
Raichur	150	MWD	10YR 3/1, 3.5/1	65-69	2-3,m-c, sbk-abk	60-150	0.97	3	8.0	71-72	1-2 cm wide cracks upto 60 cm	
Achmatti	170	ID	10YR 3/1	55-70	2-3,m-c, sbk-abk	22-170	1.25	12-15	8.3-8.9	59-72	2-5 cm wide cracks; sodicity in subsoil	
Hugaluru	183	MWD	10YR 3/2	32-47	2-3,m-c, sbk-abk	53-183	0.60	--	8.2-9.0	--	Deep wide cracks	
Hungund	81	MWD	10YR 3/2	35-65	3, m-c, sbk-abk	28-70	0.62	10-12	8.7-8.9	57-60	2-6 cm wide cracks; sodicity in subsoil	
Teligi	122	MWD	10YR 3/1, 2/1	33-44	2-3,m-c, sbk-abk	30-122	0.40	--	8.7-9.4	--	Deep wide cracks	
Coimbatore	75	ID	10YR 5/2	43-55	2-3, f-c, gr-sbk	--	0.35	7-12	8.5-8.9	40-52	Deep wide cracks	
Kalathur	104	MWD	10YR 3.5/1	39-59	3, c, sbk-abk	49-104	0.90	8-9	9.1-9.7	39-58	Deep wide cracks; sodicity in subsoil	

13 Benchmark soils identified in this region, 9 belong to Vertisols and 4 belong to Inceptisols. The soils are very deep, moderately well to imperfectly drained depending upon the topographic situation. These soils are relatively high in clay content. Some of these soils have tendency to become sodic either due to poor drainage or lower situations.

● *Soils of semiarid tropical region*

This region receives mean annual rainfall from 500 to 850 mm and experiences mean annual temperature of 27 C. Of the 16 Benchmark soils identified in this region, 13 qualify for Vertisols and 3 for Inceptisols. The soils are deep to very deep and fine to very fine. In some soils, the slickensides occur below the surface at about 20 cm. As in the subhumid tropical region, some soils occurring in the low lying area have a tendency to develop sodicity. Most of the soils are highly calcareous and pH ranges from 8.0 to 9.5.

5.2 BENCHMARK SOILS - DESCRIPTION

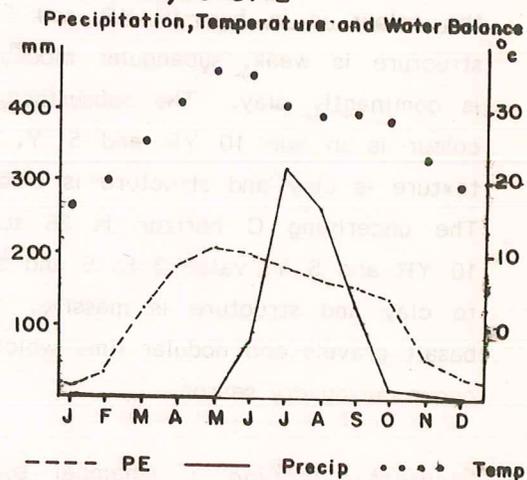
The detailed morphological description, and physical and chemical characteristics alongwith the interpretative grouping of the 33 Benchmark Swell-Shrink Soils are given below.

1. CHAMBAL SERIES (ESTABLISHED)

The Chambal series is a member of the fine, montmorillonitic, hyperthermic family of Entic Pellusterts. Chambal soils have grey to very dark grey, moderately alkaline, clayey A horizons, greyish brown to very dark greyish brown, moderately alkaline, clayey AC horizons, and yellowish brown to very dark greyish brown, moderately alkaline, clayey C horizons.

Typifying pedon : Chambal clay cultivated

Kota (Rajasthan) 25° 11' N, 75° 51' E



- Ap 0-6 cm --- Dark grey (10 YR 4/1 M) clay; weak, fine, crumb; firm, very sticky and plastic; few, fine and very fine roots; many, fine pores; strongly effervescent; few basalt gravels of 2 to 5 mm; moderately alkaline (pH 8.3); clear, smooth boundary.
- A12 6-27 cm --- Dark grey (10 YR 4/1 M) clay; moderate, medium, angular blocky peds with shiny pressure faces; firm, very sticky and plastic; few, very fine roots; many, very fine pores; strongly effervescent; few, 2 to 5 mm basalt gravels and lime nodules; moderately alkaline (pH 8.2); gradual, wavy boundary.
- A13 27-78 cm --- Grey (5 Y 5/1 M) clay; moderate, medium, angular blocky peds with prominent slickensides; firm, very sticky and plastic; common, very fine pores; strongly effervescent; few, 2 to 10 mm basalt gravels and lime nodules; moderately alkaline (pH 8.1); gradual, smooth boundary.
- AC 78-131 cm --- Olive grey (5 Y 5/2 M) silty clay; moderate, medium, angular blocky with prominent slickensides; firm, very sticky and plastic; few, very fine roots; strongly effervescent; moderately alkaline (pH 8.4); gradual smooth boundary.
- C 131-188 cm --- Olive grey (5 Y 5/2 M) clay; moderate, medium, angular blocky; very firm, sticky and plastic; violent effervescent; few, 2 to 5 mm basalt gravels and lime nodules; moderately alkaline (pH 8.4).

Type location : $25^{\circ}11'$ N, $76^{\circ}05'$ E; 200 m west of Meteorological Station, Govt. Agricultural Farm, Digod, Kota, Rajasthan.

Range in characteristics : The thickness of Ap horizon is 6 to 34 cm; the colour is in hue 10 YR and 5 Y, value 3 to 5 and chroma 1. The structure is weak, subangular blocky to coarse, angular blocky, and texture is dominantly clay. The subsurface A horizon is 59 to 126 cm thick; the colour is in hue 10 YR and 5 Y, value 3 to 5 and chroma 1 to 2. The texture is clay and structure is moderate to strong, medium, angular blocky. The underlying C horizon is 36 to 110 cm thick. The colour is in hue 10 YR and 5 Y, value 3 to 5 and chroma 2 to 4. The texture is clay loam to clay and structure is massive. The C horizon is highly calcareous with basalt gravels and nodular lime which increase with depth. Deep, wide cracks occur during dry season.

Geographic setting : Chambal soils are formed in basaltic alluvium of Chambal river and its tributaries on nearly level land at an elevation of 260 m above MSL. The climate is semi-arid subtropical with mean annual temperature of 25.2°C and mean annual rainfall of 813 mm. The estimated MAST is 26.2°C . MSST is 31.2°C and MWST is 18.7°C .

Geographically associated soils : Chambal soils are associated with Kota soils; both are clayey but differ in colour chroma. The Kota soils have chroma of more than 2 in the upper 30 cm, and qualify as Typic Chromusterts.

Drainage and permeability : Moderately well drained with slow to very slow permeability.

Use and vegetation : Most of the area is under irrigated agriculture. Common crops grown are rice, sorghum, wheat, sugarcane, mustard and vegetables.

Natural vegetation comprises of *Acacia arabica*, *Butea frondosa* and *Zizyphus jujuba*; and grasses *Cynodon dactylon* and *Saccharum spontaneum*.

Distribution and extent : The Chambal series is extensive in Chambal command area covering Kota, Bundi and Jhalawar districts of Rajasthan and in adjoining areas of Madhya Pradesh.

Series proposed : Soil Survey Organization, Department of Agriculture, Rajasthan.

Interpretation : Chambal soils are very deep, calcareous and clayey. These soils have high nutrient and moisture retentivity. Due to cracking nature, they conserve most of the initial rainfall received but once saturated they are susceptible to runoff and erosion.

Slow permeability and susceptibility to water erosion are major problems. Canal irrigation will pose problems of water stagnation and hence land shaping and provision of drainage are necessary.

In the Chambal command area, saline, alkali and water-logged phases of the series are mapped indicating nature and intensity of problems due to irrigation. Provision of effective drainage is necessary in the management of these soils. Leaching of salts and using amendments to replace sodium in the exchange complex by calcium are necessary. Green manuring may help in improving the physical condition of the soil.

Interpretative grouping :

i) Land capability sub-class	IIs, IIIs, } and IIIw }	According to phases of soil series
ii) Land irrigability sub-class	2d and 3d	
iii) Productivity potential	Medium to high	

Note : The soil texture is based on International particle size classification.

Soil Series : CHAMBAL

Classification : Entic Pellustert

Location : District Kota,
RajasthanAnalysis at ; Soil Survey Unit,
Kota, Dept. of Agri.,
Rajasthan

Horizon	Depth (cm)	Size class and particle diameter (mm)		
		Sand (2.0-0.02)	Silt (0.02-0.002)	Clay (< 0.002)
		← % of < 2 mm →		
Ap	0-6	24.0	20.0	56.0
A12	6-27	25.0	25.0	50.0
A13	27-78	25.0	23.0	52.0
AC	78-131	25.0	27.0	48.0
C	131-188	23.0	25.0	52.0

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (Saturation extract)	E _{Ce} dSm ⁻¹	Bulk density Mg m ⁻³	Water holding capacity %
0-6	0.33	7.0	8.3	0.2	1.45	41.6
6-27	0.33	6.0	8.2	1.6	1.57	45.7
27-78	0.33	6.0	8.1	2.1	1.58	43.9
78-131	0.33	6.0	8.4	1.4	1.54	31.4
131-188	0.30	5.0	8.4	1.4	1.50	41.2

Depth (cm)	CEC c mol(p ⁺) Kg ⁻¹	Exchangeable Sodium %
0-6	41.8	8.1
6-27	39.6	15.1
27-78	57.0	6.5
78-131	53.0	9.7
131-188	42.8	14.0

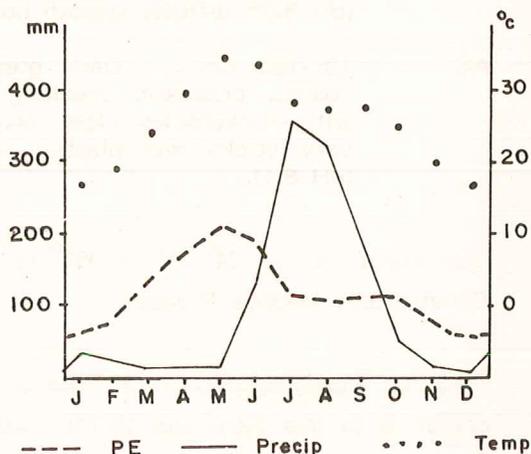
2. MARHA SERIES (ESTABLISHED)

The Marha series is a member of the fine, montmorillonitic hyperthermic, family of Entic Chromusterts. Marha soils have very dark greyish brown to dark greyish brown, moderately alkaline, silty clay A horizons, and dark greyish brown, moderately alkaline, silty clay loam to silty clay AC horizons.

Typifying pedon : Marha silty clay
-- cultivated

Satna (M.P.)
24° 34' N, 80° 50'

Precipitation, Temperature and Water Balance



- Ap 0-12 cm --- Dark greyish brown to greyish brown (2.5Y 4.5/2 D) silty clay, dark greyish brown (2.5Y 4/2 M); moderate, medium, subangular blocky; soft, friable, sticky and plastic; common, fine roots inside peds; fine, interstitial pores; moderately alkaline (pH 8.0); clear, wavy boundary.
- A12 12-44 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D) silty clay, very dark greyish brown (2.5Y 3/2 M); strong, coarse, angular blocky; slightly hard, friable, sticky and plastic; many, fine roots inside peds; fine, interstitial pores; moderately alkaline (pH 8.0); gradual, wavy boundary.
- A13 44-70 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D&M) silty clay; coarse, prismatic breaking to strong, coarse, angular blocky peds with prominent pressure faces; hard, firm, sticky and plastic; few, fine roots inside peds; fine, interstitial pores; moderately alkaline (pH 8.0); gradual, smooth boundary.
- A14 70-105 cm --- Dark greyish brown (2.5Y 4/2 D&M) silty clay; coarse, prismatic breaking to strong, coarse, angular blocky peds with prominent slickensides close enough to intersect; hard, firm,

Pedon described by the core group J.C. Bhattacharjee, S.G. Pandey and H.P. Choudhary; G.V. Patel, R.J. Landey, S.N. Deshmukh and G.S. Kaushal associated. December 9, 1979.

sticky and plastic; few, fine roots inside peds; fine, interstitial pores; moderately alkaline (pH 8.0); diffuse, smooth boundary.

A15 105-137 cm --- Dark greyish brown to greyish brown (2.5Y 4.5/2 D) silty clay, greyish brown (2.5Y 5/2 M); coarse, prismatic breaking to strong, coarse, angular blocky peds with slickensides close enough intersect; very hard, very firm, very sticky and plastic; few, fine roots inside peds; fine, interstitial pores; moderately alkaline (pH 8.0); diffuse, smooth boundary.

AC 137-180 cm --- Dark greyish brown (2.5Y 4/2 D&M) silty clay; coarse, prismatic breaking to strong, coarse, angular blocky peds with slickensides close enough to intersect; very hard, very firm, very sticky and plastic; slightly effervescent; moderately alkaline (pH 8.1).

Type location : 24° 34' N, 80° 15' E; village Marha, tehsil Lauri, district Chhattarpur, Madhya Pradesh,

Range in characteristics : The A horizon is more than 125 cm thick. Its colour is in hue 2.5Y and 10 YR, value 3 to 5 and chroma 2 to 3. Texture is silty clay loam to silty clay with maximum clay content of 52 per cent. Cracks 2 to 4 cm wide at the surface that taper and extend into the AC horizon.

Competing series and their differentiae : Marha soils compete with Jamra series which is in hue 10YR and calcareous. It belongs to Entic Chromusterts.

Geographic setting : Marha soils are formed in basaltic alluvium on nearly level to gently sloping old flood plain at an elevation of 300 to 330 m above MSL in Bundelkhand region of Madhya Pradesh. The climate is subhumid subtropical with mean annual temperature of 25.2°C and mean annual rainfall of 1330 mm. The estimated MAST is 26.2°C. MSST is 30.2°C and MWST is 20.2°C.

Geographically associated soils : Marha soils are associated with Jamra soils which are calcareous, clayey and belong to Entic Chromusterts.

Drainage and permeability : Moderately well drained with moderate permeability.

Use and vegetation : Cultivated to mixed rainfed crops sorghum, pigeon pea, wheat and gram.

Natural vegetation comprises of *Madhuca spp.*, *Butea spp.*, *Acacia spp.* etc.

Distribution and extent : Extensive in Bundelkhand region of Madhya Pradesh.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Marha soils have good water retention capacity. They are productive, and crops respond to management practices. They are susceptible to erosion.

(a) *Interpretative grouping* :

i) Land capability sub-class	IIs
ii) Irrigability sub-class	2d
iii) Productivity potential	High

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Sorghum	1.5 - 1.8	2.8 - 3.0
Pigeon pea	0.7 - 0.8	1.2 - 1.5
Wheat	1.0 - 1.2	3.0 - 3.5
Gram	0.8 - 1.0	1.5 - 2.0

Soil Series : MARHA

Classification : Entic Chromustert Analysis at : NBSS & LUP,
Regional Centre,
NagpurLocation : District Chattarpur,
Madhya Pradesh

Sampling Date: December 9, 1979

Horizon	Depth (cm)	Size class and particle diameter (mm)										Coarse fragments 72 mm % of whole soil
		Total					Sand			Clay		
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Med-fine (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	(0.002-0.001)	(<0.001)	
← % of < 2 mm →												
Ap	0-12	11.7	44.1	44.2	0.8	1.1	1.0	0.7	8.1	28.0	16.2	4
A12	12-44	9.2	43.6	47.2	1.1	1.0	0.8	0.7	5.6	31.8	15.4	6
A13	44-70	5.5	43.4	51.1	1.0	0.7	0.6	1.0	2.2	34.0	17.1	-
A14	70-105	7.0	45.1	47.9	1.0	1.0	0.9	0.9	3.2	31.2	16.7	-
A15	105-137	5.3	49.4	45.3	1.4	1.0	0.7	1.0	1.2	36.8	8.5	3
AC	137-180	10.6	49.0	40.4	2.3	1.1	0.8	0.5	5.9	23.3	17.1	6

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ <2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³
0-12	0.48		8.0	0.1	1.60
12-44	0.36	Tr	8.0	0.1	1.90
44-70	0.30	Tr	8.0	0.1	1.92
70-105	0.24	Tr	8.0	0.1	1.97
105-137	0.24	Tr	8.0	0.1	1.97
137-180	0.21	2.0	8.1	0.1	2.01

Depth (cm)	Extractable bases			CEC NH ₄ OAc	Exchangeable sodium	Ratio CEC/clay
	Ca+Mg	Na	K			
← c mol(p ⁺) Kg ⁻¹ →						
0-12	45.8	1.6	0.6	48.0	3	1.09
12-44	50.5	1.1	0.6	52.2	2	1.11
44-70	48.7	5.4	0.3	54.4	10	1.06
70-105	41.2	5.4	0.8	47.4	11	0.99
105-137	44.7	1.1	0.6	46.4	2	1.02
137-180	45.4	1.6	0.5	47.5	3	1.18

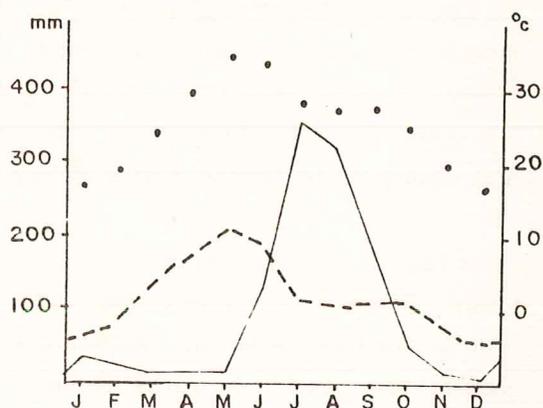
3. JAMRA SERIES (ESTABLISHED)

The Jamra series is a member of the fine, montmorillonitic, hyperthermic family of Entic Chromusterts. Jamra soils have light brownish grey to dark greyish brown, mildly to moderately alkaline, silty clay loam to clay A horizons, and dark greyish brown, moderately alkaline, silty clay loam to clay AC horizons.

Typifying pedon : Jamra clay - cultivated

Satna (M.P.)
24° 34' N, 80° 50'

Precipitation, Temperature and Water Balance



- Ap 0-16 cm --- Light brownish grey (10YR 6/2 D) clay, dark greyish brown (10YR 4/2 M); moderate, medium, subangular blocky; hard, firm, slightly sticky and slightly plastic; common, medium roots; 1.5 to 2 cm wide cracks; slightly effervescent; mildly alkaline (pH 7.8); clear, smooth boundary. --- PE ——— Precip Temp
- A12 16-45 cm --- Greyish brown (10YR 5/2 D) clay, dark greyish brown (10YR 4/2 M); moderate, medium, subangular blocky peds with shiny pressure faces; hard, firm, slightly sticky and slightly plastic; common, medium roots; 0.5 to 1 cm wide cracks; strongly effervescent; moderately alkaline (pH 8.1); clear, smooth boundary.
- A13 45-102 cm --- Greyish brown (10YR 5/2 D) clay, dark greyish brown (10YR 4/2 M); moderate, medium, angular blocky peds with shiny pressure faces and intersecting slickensides; hard, firm, sticky and plastic; few, fine roots; 0.5 to 1 cm wide cracks; powdery lime pockets; strongly effervescent; moderately alkaline (pH 8.1); gradual, smooth boundary.
- AC 102-140 cm --- Dark greyish brown (10YR 4/2 D&M) clay; strong, medium, angular blocky peds with shiny pressure faces; hard, firm, sticky and plastic; 0.5 cm wide cracks; lime accretions; violently effervescent; moderately alkaline (pH 8.4).

Type location : $24^{\circ} 12' N$, $78^{\circ} 12' E$; village Utawa, tehsil Khurai, district Sagar, Madhya Pradesh.

Range in characteristics : The surface soils are 10 to 20 cm thick; its colour is in hue 10YR and 2.5Y, value 4 to 6 and chroma 2 to 4. The texture is clay loam to silty clay and clay. The subsoils are brown to very dark greyish brown in hue 10YR and 2.5Y, value 3 to 5 and chroma 2 to 3. The texture is silty clay loam to clay with clay percentage more than 35 but less than 60. Structure varies from moderate to strong, medium to coarse and subangular to angular blocky. They are slightly to strongly calcareous.

Competing series and their differentiae : Marha series is the competing series. These soils are very deep, moderately well drained and non calcareous. Cracks, pressure faces and slickensides are also present but lime nodules in pockets are absent in Marha series. The Marha soils also belong to Entic Chromusterts.

Geographic setting : Jamra soils are formed in basaltic alluvium and occur on gently sloping old flood plain at an elevation of 400 to 500 m above MSL in Bundelkhand region of Madhya Pradesh and Uttar Pradesh. The climate is subhumid subtropical with mean annual temperature of $25.2^{\circ}C$ and mean annual rainfall of 1394 mm. The estimated MAST is $27.7^{\circ}C$. MSST is $30.3^{\circ}C$ and MWST is $21.8^{\circ}C$.

Geographically associated soils : Jamra soils are associated with Marha soils which are non calcareous, mildly alkaline and dominantly silty clay in texture. Marha soils are belong to Entic Chromusterts.

Drainage and permeability : Moderately well drained with moderately slow permeability.

Use and vegetation : Mostly cultivated to rainfed crops like wheat, gram and mustard.

Natural vegetation comprises of *Acacia spp.*

Distribution and extent : Occurs extensively in Bundelkhand region of Madhya Pradesh and Uttar Pradesh.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Jamra soils have shrink-swell characteristics and it cracks during summer. The moisture retention capacity is high. The early rainfall enters into the soil through cracks and once the cracks are closed the water stagnation occurs due to slow permeability. As the rainfall is high during rainy season, runoff and erosion are the main problems.

These soils need proper surface drainage during rainy season. As the available moisture capacity of the profiles is high, the soils are potential for double cropping. They will respond to management. High lime may pose the problem of phosphate fixation.

Interpretative grouping :

i) Land capability sub-class	IIs
ii) Irrigability sub-class	2d
iii) Productivity potential	High

Soil Series : JAMRA
Location : District Sagar,
 Madhya Pradesh

Classification : Entic Chromustert
Analysis at : NBSS & LUP,
 Regional Centre,
 Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)			Coarse fragments ≥ 2 mm % of whole soil
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	
		← % of < 2 mm →			
Ap	0-16	25.8	29.4	44.8	3
A12	16-45	25.0	23.5	51.5	2
A13	45-102	22.7	19.3	58.0	2
AC	102-140	21.6	25.4	53.0	1

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	EC (1:2.5) H ₂ O dS m ⁻¹	Bulk density Mg m ⁻³
0-16	0.78	0.4	7.8	0.3	1.67
16-45	0.68	8.0	8.1	0.2	1.78
45-102	0.65	9.3	8.1	0.2	1.79
102-140	0.45	10.0	8.4	0.2	1.94

Depth (cm)	Extractable bases					CEC NH ₄ OAc	Base saturation %	
	Ca	Mg	Na	K	Sum			
		← c mol (p ⁺) Kg ⁻¹ →						
0-16	25.4	10.5	1.0	0.5	37.4	40.2	93	
16-45	25.2	15.0	2.1	0.5	42.8	44.2	97	
45-102	24.2	15.4	2.0	0.6	42.2	43.9	96	
102-140	23.4	15.0	3.4	0.7	42.5	43.5	98	

4. SUNDRA SERIES (ESTABLISHED)

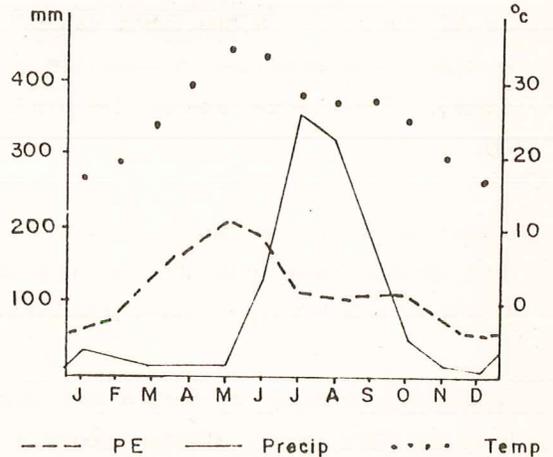
The Sundra series is a member of the very fine, montmorillonitic, hyperthermic family of Entic Chromusterts. Sundra soils have light olive brown to dark greyish brown, moderately to strongly alkaline, clayey A and AC horizons.

Typifying pedon : Sundra clay — cultivated

- Ap 0-12 cm --- Light olive brown (2.5Y 5/3 D) clay, dark greyish brown (2.5Y 4/2 M); moderate, medium, subangular blocky; hard, friable, sticky and plastic; common, fine and medium roots; 1 cm wide cracks; strongly alkaline (pH 8.9); diffuse, smooth boundary.
- A12 12-40 cm --- Light olive brown (2.5Y 5/3 D) clay, dark greyish brown (2.5Y 4/2 M); moderate, medium, subangular blocky peds with pressure faces; hard, firm, sticky and plastic; common, fine and medium roots; 0.5 cm wide cracks; moderately alkaline (pH 7.9); diffuse, smooth boundary.
- A13 40-70 cm --- Dark greyish brown (2.5Y 4/2 M) clay; intersecting slickensides forming parallelepiped structural aggregates breaking to moderate, medium, angular blocky peds; firm, very sticky and very plastic; few, fine and medium roots; 0.5 cm wide cracks; moderately alkaline (pH 8.0); diffuse, smooth boundary.
- AC 70-140 cm --- Dark greyish brown (2.5Y 4/2 M) clay; intersecting slickensides forming parallelepiped structural aggregates breaking to moderate, medium, angular blocky peds; firm, very sticky and very plastic; few, fine roots; strongly alkaline (pH 8.5).

Satna (M.P.)
24° 34' N, 80° 50'

Precipitation, Temperature and Water Balance



Type location : 24° 36' N, 80° 27' E; village Sundra on Panna-Satna road, tehsil and district Panna, Madhya Pradesh.

Range in characteristics : The thickness of the soil ranges from 140 to 165 cm. Colour of the A horizon is in hue 2.5Y, value 4 to 5 and chroma 2 to 3. The texture of the A horizon is uniformly clay. The structure is strong to moderate, medium, subangular to angular blocky. A few basaltic lithorelicts and lime accretions are present throughout the profile. Colour of AC horizon is in hue 2.5Y, value 4 to 5 and chroma 2 to 3. The texture is clay. The structure is moderate to strong, medium to coarse and angular blocky. Clay percentage in the control section below 40 cm is more than 60.

Competing series and their differentiae : Sundra soils compete with Bira series. Bira soils are well drained and their colours are in hue 10YR. The Bira soils belong to Vertic Ustochrepts.

Geographic setting : Sundra soils are formed in basaltic alluvium on nearly level to very gently sloping piedmont plain at an elevation of 300 to 350 m above MSL in Bundelkhand region of Madhya Pradesh. The climate is sub-humid subtropical with mean annual temperature of 25^oC and mean annual rainfall of 1230 mm. The estimated MAST is 27.5^oC, MSST is 30.3^oC and MWST is 21.8^oC.

Geographically associated soils : Sundra soils are associated with Jamra soils which are very deep, moderately well drained, silty clay with accretionary lime pockets in the profiles. The Jamra soils belong to Entic Chromusterts.

Drainage and permeability : Moderately well drained with slow permeability.

Use and vegetation : Cultivated to rainfed mixed crops like pigeon pea, sorghum and minor millets in kharif and wheat and gram in rabi.

Natural vegetation consists of *Acacia spp.*

Distribution and extent : Extensive in Bundelkhand region of Madhya Pradesh.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Sundra soils are moderately well drained and slowly permeable. In periods of excessive rainfall crops may suffer due to water stagnation. Available moisture capacity of the soils is high and is more than 30 cm for 150 cm depth of profile. During the rainy period between 24 and 39 standard weeks the probability of rainfall is good and P/PE is more than 2.5. Stored moisture at the end of the rainy season is expected to be about 25 cm for 100 cm profile depth that can be utilised by rabi crops. Post monsoon rainfall, though little, are useful. Measures to conserve soils and runoff water are necessary. Recycling the runoff water will be advantageous for rabi crops.

During kharif, protection from stagnation effect through proper management of surface drainage is necessary. Under wet conditions, the soils are sticky and plastic and pose problems for tillage operations. Dry sowing of the crops may be necessary to avoid the problems of wetness.

Moisture and nutrient retention capacity of the soils is good. The soils will respond well to fertilizer and other inputs.

Mixed cropping of sorghum, pigeon pea and minor millets is an adapted system. The soils will support other climatically adapted kharif crops. Wheat and gram can be grown successfully on conserved moisture during rabi season.

(a) *Interpretative grouping* :

i) Land capability sub-class	IIs
ii) Irrigability sub-class	2d
iii) Productivity potential	High

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Sorghum	1.2 - 1.5	2.0 - 2.5
Pigeon pea	0.7 - 0.8	1.3 - 1.5
Wheat	1.0 - 1.2	3.0 - 3.5
Gram	0.7 - 0.8	1.2 - 1.5

Soil Series : SUNDRA

Classification : Entic Chromustert

Analysis at : NBSS & LUP
Regional Centre,
NagpurLocation : District Panna,
Madhya Pradesh

Sampling Date: January 8, 1979

Horizon	Depth (cm)	Size class and particle diameter (mm)			Coarse fragments > 2 mm % of whole soil
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	
		← % of < 2 mm →			
Ap	0-12	18.6	22.4	59.0	6
A12	12-40	17.1	28.7	54.2	4
A13	40-70	10.5	26.0	63.5	3
AC	70-140	14.8	20.8	64.4	2

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	Bulk density Mg m ⁻³
0-12	0.7	0.5	8.9	1.61
12-40	0.6	0.6	7.9	1.88
40-70	0.5	0.7	8.0	1.74
70-140	0.2	0.8	8.5	1.79

Depth (cm)	Extractable bases				CEC NH ₄ OAC	Ratio CEC clay	
	Ca	Mg	Na	K			
		← c mol(p+) kg ⁻¹ →					
0-12	24.0	6.5	1.9	0.6	34.4	0.58	
12-40	26.3	5.0	2.0	0.5	37.5	0.69	
40-70	21.7	9.0	2.1	0.5	31.2	0.49	
70-140	24.0	9.0	2.7	0.5	33.2	0.51	

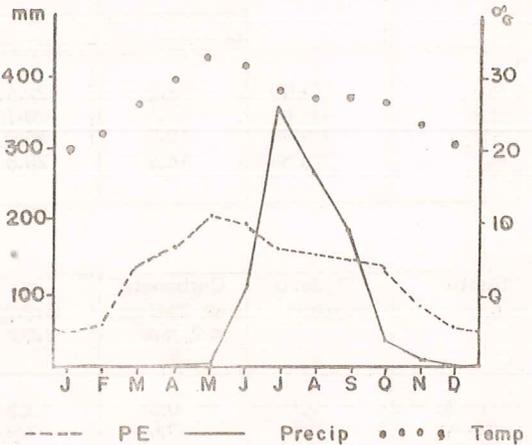
5. GOLANA SERIES (TENTATIVE)

The Golana series is a member of the very fine, mixed, hyperthermic family of Vertic Halaquepts. Golana soils have dark greyish brown to dark brown, moderately alkaline, silty clay to clay A horizons, very dark greyish brown to dark brown, strongly alkaline, silty clay to clay B horizons and dark brown to dark yellowish brown, strongly alkaline, sandy clay loam to clay C horizons.

Typifying pedon : Golana clay — cultivated

Vadodara (Gujarat)
22° 18' N, 73° 15' E

Precipitation, Temperature and Water Balance



- Ap 0-20 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); prismatic polyhedrons breaking into weak, medium, subangular blocky peds; hard, firm, sticky and plastic; many fine roots; strongly effervescent; few rock fragments of 2 to 4 mm; strongly alkaline (pH 8.9); clear, smooth boundary.
- B21 20-55 cm --- Very dark greyish brown (10YR 3/2 M) silty clay; prismatic polyhedrons breaking into moderate, medium, subangular blocky peds with shiny pressure faces; firm, sticky and plastic; common, fine roots; strongly effervescent; few rock fragments of 2 to 4 mm; very strongly alkaline (pH 9.3); diffuse, smooth boundary.
- B22 55-75 cm --- Very dark greyish brown (10YR 3/2 M) silty clay; prismatic polyhedrons breaking into moderate, medium, subangular blocky peds with shiny pressure faces; firm, sticky and plastic; few, fine roots; strongly effervescent; few rock fragments of 2 to 4 mm; strongly alkaline (pH 8.8); diffuse, smooth boundary.
- B23 75-125 cm --- Very dark greyish brown (10YR 3/2 M); silty clay; prismatic polyhedrons breaking into weak, medium, subangular blocky peds with shiny pressure faces; firm, sticky and plastic; strongly

effervescent; few rock fragments of 2 to 4 mm; strongly alkaline (pH 9.0); gradual, smooth boundary.

- C 125-150 cm --- Brown (10YR 5/3 M) clay; massive; firm, sticky and plastic; common lime nodules of 2 to 5 mm; violently effervescent; few rock fragments of 2 to 4 mm; strongly alkaline (pH 8.5).

Type location : 22°24' N, 72°25' E; village Mitali, taluk Khambhat, district Kheda, Gujarat.

Range in characteristics : The depth of solum varies from 90 to 130 cm. The colour of A and B horizons is in hue 10YR, value 3 to 4 and chroma 2 to 3 for both dry and moist soils. The texture of A and B horizons varies from silty clay to clay. The structure is coarse, prismatic which breaks into weak, medium, subangular blocky peds in A horizons while moderate, medium, angular blocky with shiny pressure faces peds in B horizons. The colour of C horizon is in hue 10YR, value 3 to 6 and chroma 3 to 4. Its texture varies from sandy clay loam to clay and structure is massive. During dry periods these soils develop 2 to 4 cm wide cracks which extend downward upto 60 cm.

Competing series and their differentiae : Mahelaj series is competing series which is slight to moderately alkaline.

Geographic setting : Golana soils are formed in alluvium and occur on nearly level to gently sloping flood plain. The climate is subhumid tropical with mean annual temperature of 26.2°C and mean annual rainfall of 909 mm. The estimated MAST is 27.2°C and the difference between MSST and MWST is more than 5°C.

Geographically associated soils : Golana soils are associated with Mahelaj soils which are slight to moderately alkaline in nature.

Drainage and permeability : Poorly drained with slow permeability.

Use and vegetation : These soils are cultivated mainly for cotton, wheat, rice and sorghum.

Natural vegetation comprises of *Acacia spp.*

Distribution and extent : Extensive in coastal plain areas of Gujarat.

Series proposed : Department of Agriculture, Navasari, Gujarat.

Interpretation : Golana soils are poorly drained, moderately to strongly alkaline and clayey. They have high EC ($> 4 \text{ dS m}^{-1}$) and ESP > 15 in the soil control section. Under intensive agriculture, salinity and sodicity problems are likely to further deteriorate the soil health. Therefore, judicious use of fertilizers is required. While irrigating, special care is needed for surface and subsurface drainage.

Interpretative grouping :

i) Land capability sub-class	IIIsw
ii) Irrigability sub-class	3d
iii) Productivity potential	Low

Note : The soil texture is based on International particle size classification.

Soil Series : GOLANA
Location : District Kheda,
 Gujarat

Classification : Vertic Halaquept
Analysis at : Soil Survey Unit,
 Navsari,
 Department of Agri.,
 Gujarat

Horizon	Depth (cm)	Particle size class and particle diameter (mm)				Coarse fragments > 2 mm % of whole soil
		Coarse Sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (< 0.002)	
		————-% of < 2 mm————				
Ap	0-20	15.2	0.7	19.1	65.0	2
B21	20-55	1.6	0.7	32.0	65.7	2
B22	55-75	1.5	0.8	31.4	66.3	2
B23	75-125	3.9	0.7	29.3	66.1	2
C	125-150	11.9	4.2	23.2	60.7	2

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	EC (1:2.5) H ₂ O dS m ⁻¹	Water holding capacity %
0-20	0.58	12.86	8.9	2.24	55.7
20-55	0.63	12.26	9.3	2.30	52.7
55-75	0.62	12.86	8.8	1.65	50.2
75-125	0.67	14.86	9.0	4.30	56.5
125-150	0.70	17.86	8.5	6.10	49.7

Depth (cm)	Extractable bases			CEC NH ₄ OAC	Exchang-eable sodium %
	Ca	Mg	Na		
←————c mol(p+)kg ⁻¹ ————→					
0-20	18.6	11.8	2.6	28.0	9
20-55	14.0	9.2	4.7	28.0	17
55-75	10.0	9.6	5.9	29.0	20
75-125	6.6	6.2	9.1	27.0	34
125-150	10.6	8.0	3.9	24.0	16

6. HALDAR SERIES (ESTABLISHED)

The Haldar series is a member of the fine, montmorillonitic, hyperthermic family of Typic Chromusterts. Haldar soils have dark brown to very dark greyish brown, mildly to moderately alkaline, clayey A and AC horizons, and yellowish brown to very dark greyish brown, moderately alkaline clayey C horizons.

Typifying pedon : Haldar clay —
cultivated.

- Ap 0-17 cm --- Dark greyish brown (10YR 4/2 D) clay, dark brown (10YR 3/3 M); coarse, prismatic breaking into moderate, medium, subangular blocky peds; hard, friable, sticky and plastic; many, fine roots inside peds; 5 to 7 cm wide cracks; few basalt and quartz fragments of 2 to 5 mm; mildly alkaline (pH 7.4); clear, smooth boundary.
- A12 17-39 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); coarse, prismatic breaking into moderate, medium, angular blocky peds with pressure faces; hard, firm, sticky and plastic; common, fine roots; 5 to 6 cm wide cracks; few basalt and quartz fragments; mildly alkaline (pH 7.7); clear, smooth boundary.
- A13 39-56 cm --- Dark brown (10YR 3/3 D&M) clay; coarse, prismatic structure with intersecting slickensides breaking into moderate, medium, angular blocky peds; hard, firm, sticky and plastic; few, fine roots inside peds; 4 to 5 cm wide cracks; moderately alkaline (pH 8.0); diffuse, wavy boundary.
- A14 56-102 cm --- Dark brown (10YR 3/3 D) clay, very dark greyish brown (10YR 3/2 M); coarse, prismatic structure with intersecting slickensides breaking into coarse, medium, angular blocky peds; hard, firm, sticky and plastic; few, fine roots; mildly alkaline (pH 7.6); diffuse, wavy boundary.

- AC 102-130 cm --- Dark yellowish brown (10YR 3/4 D) clay, dark brown and dark yellowish brown (10YR 3/3, 3/4 M); coarse, prismatic with intersecting slickensides breaking into coarse, medium, angular blocky peds; hard, firm sticky and plastic; moderately alkaline (pH 7.9); diffuse, smooth boundary.
- C 130-145 cm --- Yellowish brown (10YR 5/4 D) clay, dark yellowish brown (10YR 3/4 M); weak, medium, subangular blocky; hard, firm, sticky and plastic; common, lime nodules of 2 to 6 mm; violently effervescent; moderately alkaline (pH 8.1).

Type location : 21° 43' N, 70° 55' E; village Haldar, tehsil and district Bharuch, Gujarat.

Range in characteristics : The A horizon is 90 to 140 cm thick and the colour is in hue 10YR, value 3 to 4 and chroma 2 to 3. The texture is clayey and the structure varies from coarse prismatic to angular blocky with prominent slickensides. Quartz and basalt fragments are present throughout the profile.

Competing series and their differentiae : Haldar soils are competing with Sarol and Sisodara soils. Sarol soils are clayey, moderately well drained with moderate permeability and belong to Typic Chromusterts. Sisodara soils are also clayey, moderately well drained with moderately slow permeability and belong to Vertic Ustochrepts.

Geographic setting : Haldar soils are formed in alluvium of mixed origin and occur on nearly level to very gently sloping alluvial plain at an elevation of 20 m above MSL in Bharuch, Surat and Vadodara districts of Gujarat. The climate is subhumid tropical with mean annual temperature of 25.5°C and mean annual rainfall of 1640 mm. The estimated MAST is 26.5°C and difference between MSST and MWST is more than 5°C.

Geographically associated soils : Haldar soils are associated with Sisodara soils which are relatively less clayey and do not have slickensides. Sisodara Soils belong to Vertic Ustochrepts.

Drainage and permeability : Imperfectly drained with slow to very slow permeability.

Use and vegetation : These are intensively cultivated to cotton, rice, sugarcane, wheat, sorghum and banana.

Natural vegetation comprises of *Acacia arabica* and *Tamarindus indica* and grasses *Cynodon dactylon* etc.

Distribution and extent : Extensive in Bharuch, Surat and Vadodra districts of Gujarat.

Series proposed : Soil Survey Organisation, Department of Agriculture, Navasari Unit, Gujarat.

Interpretation : Haldar soils are clayey; they develop cracks due to high swelling and shrinking potential. They are slowly permeable and due to their cracking nature the profile gets saturated during initial rainfall periods and become susceptible to runoff, erosion and ponding. They are imperfectly drained and require measures for disposal of excess water to avoid adverse effects on crops. The available water and nutrient retention capacity is high. Under irrigation, these soils are likely to pose problems of drainage and rising ground water level. Hence, they need adequate surface drainage measures. All climatically adapted crops can be grown.

Interpretative grouping :

i)	Land capability sub-class	III _s
ii)	Land irrigability sub-class	2d
iii)	Productivity potential	Medium to high

Note : The soil texture is based on International particle size classification.

Soil Series : HALDAR

Classification : Typic Chromustert

Location : District Bharuch,
GujaratAnalysis at : Soil Survey Unit
Navasari,
Dept. of Agri.,
Gujarat

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments > 2 mm % of whole soil
		Coarse sand 2.0-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay < 0.002 mm	
		← % of < 2 mm →				
Ap	0-17	0.1	20.1	25.3	54.5	7
A12	17-39	0.1	19.6	20.4	59.9	3
A13	39-56	0.1	23.4	22.0	54.5	2
A14	56-102	0.3	28.1	15.1	56.5	2
AC	102-130	0.2	25.4	18.6	55.8	1
C	130-145	0.8	26.6	22.5	50.1	6

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) dS m ⁻¹	Water holding capacity %
0-17	0.27	0.7	7.4	0.15	63.3
17-39	0.20	1.3	7.7	0.12	63.2
39-56	0.20	1.3	8.0	0.15	65.3
56-102	0.20	1.3	7.6	0.08	62.4
102-130	0.27	1.7	7.9	0.16	64.2
130-145	0.17	10.9	8.1	0.17	60.2

Depth (cm)	Extractable bases			CEC
	Ca	Mg	Na	
← c mol(p+)kg ⁻¹ →				
0-17	32.0	10.0	0.7	44.0
17-39	30.0	10.0	0.4	44.7
39-56	30.4	11.0	Trace	44.8
56-102	32.0	12.4	0.4	46.4
102-130	31.0	11.4	0.3	44.0
130-145	29.4	3.6	Trace	38.6

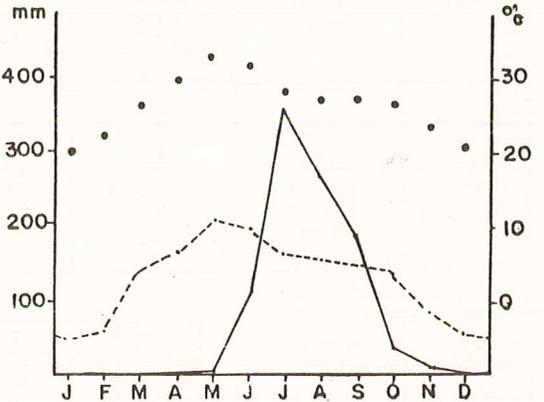
7. JALALPUR SERIES (ESTABLISHED)

The Jalalpur series is a member of the very fine, montmorillonitic, hyperthermic family of Typic Chromusterts. Jalalpur soils have dark brown to very dark greyish brown, moderately to strongly alkaline, clayey A horizons and yellowish brown to dark brown, very strongly alkaline, sandy clay loam to clay AC horizons.

Typifying pedon : Jalalpur clay — cultivated

Vadodara (Gujarat) 22° 18' N, 73° 15' E

Precipitation, Temperature and Water Balance



- Ap 0-22 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); coarse, columnar breaking into moderate, medium, subangular blocky peds; hard, firm, sticky and plastic; few, fine roots; few lime nodules of 2 to 5 mm; slightly effervescent; moderately alkaline (pH 8.3); clear, smooth boundary.
- A12 22-65 cm --- Very dark greyish brown (10YR 3/2 M) clay; coarse, columnar breaking into moderate, medium, subangular blocky peds with shiny pressure faces; firm, sticky and plastic; few, coarse roots; many, lime nodules of 2 to 5 mm; slight effervescent; few basaltic lithorelicts and mica flakes; strongly alkaline (pH 8.5); clear, wavy boundary.
- A13 65-110 cm --- Dark brown (10YR 3/3 M) clay; moderate, medium, angular blocky peds with intersecting slickensides; firm, very sticky and very plastic; few, coarse roots; many, lime nodules of 2 to 5 mm; strongly effervescent; very few basalt fragments; strongly alkaline (pH 8.7); clear, wavy boundary.
- AC 110-150 cm --- Dark brown (10YR 4/3 M) clay; weak, medium, subangular blocky peds; friable, sticky and plastic; many, lime nodules of 2 to 5 mm; violently effervescent; many basalt fragments; very strongly alkaline (pH 9.4).

Type location : 20°04' N, 73°38' E; about 1/4 km east to village Katkui, taluka Tilakvada, district Vadodara, Gujarat.

Range in characteristics : The thickness of Ap horizon is 11 to 25 cm and the colour is in hue 10YR, value 3 and chroma 2 to 3 and its texture is sandy clay to clay. The subsurface A horizon is 80 to 140 cm thick. Its colour is in hue 10YR, value 3 to 4 and chroma 2 to 3 and its structure is coarse columnar breaking into moderate, medium, subangular blocky with wedge shaped aggregates. Slickensides are prominent. Calcium carbonate ranges upto 10 per cent. Colour of AC horizon is in hue 10YR, value 4 to 6 and chroma 3 to 4. The texture varies from sandy clay loam to clay. The structure of AC horizon is weak, medium, subangular blocky with many 2 to 5 mm size lime nodules and basalt fragments. Lime nodules and basalt fragments increase with depth. AC horizon is strongly alkaline.

Competing series and their differentiae : Jalalpur series has two competing series namely Halدار and Mulad. Both these series have less than 60 per cent clay. Halدار series is calcareous while Mulad series is non-calcareous. Both these series have cracks, slickensides and sphenoidal structural aggregates.

Geographic setting : Jalalpur soils are formed in alluvium of mixed origin and occur on nearly level to gently sloping old flood plain at an elevation of 120 to 150 m above MSL in Bharuch, Vadodara and Surat districts of Gujarat. The climate is subhumid tropical with mean annual temperature of 28°C and mean annual rainfall of 967 mm. The estimated MAST is 29°C and difference between MSST and MWST is more than 5°C.

Geographically associated soils : Jalalpur soils are associated with Sisodara and Mulad soils.

Drainage and permeability : Moderately well drained with slow to very slow permeability.

Use and vegetation : Cultivated to cotton, sorghum, pulses and oilseeds during kharif as rainfed crops. Wheat, banana and sugarcane are grown under irrigation.

Natural vegetation comprises of *Acacia arabica* and *Tamarindus indica*; and grasses *Cynodon dactylon*.

Distribution and extent : Extensive in Bharuch, Vadodara and Surat districts, Gujarat.

Series proposed : Soil Survey Organisation, Department of Agriculture, Navasari, Gujarat.

Interpretation : Jalalpur soils are very deep and clayey. They have high water and nutrient retention capacity. Due to their cracking nature, they can conserve most of the initial rainfall. Once saturated, they are susceptible to runoff and erosion even on gently sloping land. Soils occurring on nearly level slopes are susceptible to stagnation of water. Substratum below 100 to 150 cm tends to be high in exchangeable sodium and soluble salts. Without proper drainage measures, they are likely to pose saline/sodic problems under irrigation. Jalalpur soils will respond to the use of fertilizers and other inputs.

Jalalpur soils can support all climatically adapted crops. But during high intensity rainfall periods, crops will suffer due to drainage and water stagnation problems.

Management requirements :

- i) Surface drainage
- ii) Land shaping
- iii) Growing kharif crops on ridges
- iv) Growing double crops to use conserved moisture
- v) Growing mixed crops

- vi) Under irrigation proper drainage is essential to prevent saline/sodic problems.
- vii) Avoid lhigh intensity irrigation crops.

Interpretative grouping :

- | | | |
|------|---------------------------|----------------|
| i) | Land capability sub-class | IIIs |
| ii) | Irrigability sub-class | 3d |
| iii) | Productivity potential | Medium to high |

Note : The soil texture is based on International particle size classification.

Soil Series : JALALPUR
Location : District Vadodara,
 Gujarat

Classification : Typic Chromustert
Analysis at : Soil Survey Unit,
 Navasari,
 Dept. of Agri.,
 Gujarat

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments > 2 mm % of whole soil
		Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (< 0.002)	
		← % of < 2 mm →				
Ap	0-22	6.0	23.4	10.0	60.6	1
A12	22-65	5.1	21.7	12.3	60.9	3
A13	65-110	5.6	20.4	13.6	60.4	1
AC	110-150	2.7	33.9	9.8	53.6	2

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dS m ⁻¹	Bulk density Mg m ⁻³	Water holding capacity %
0-22	0.49	2.9	8.3	8.85	1.20	60.9
22-65	0.42	3.7	8.5	0.25	1.40	54.8
65-110	0.56	7.5	8.7	0.43	1.20	65.1
110-150	0.22	23.2	9.4	0.24	1.20	61.0

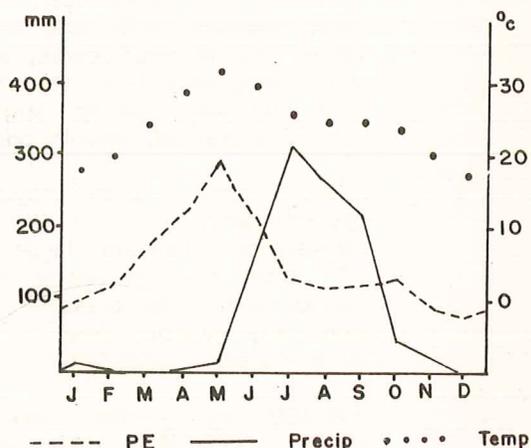
Depth (cm)	C.E.C. c mol(p ⁺)kg ⁻¹
0-22	42.7
22-65	47.1
65-110	36.7
110-150	25.1

8. SAROL SERIES (ESTABLISHED)

The Sarol series is a member of the fine, montmorillonitic, hyperthermic family of Typic Chromusterts. Sarol soils have dark greyish brown to very dark greyish brown, moderately alkaline, clayey A horizons, and very dark greyish brown to greyish brown, moderately alkaline, clayey AC horizons.

Typifying pedon : Sarol clay
cultivated

Indore (M.P.)
22° 43' N, 75° 58' E
Precipitation, Temperature and Water Balance



- Ap 0-11 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown (2.5Y 3/2 M); moderate, medium, subangular blocky; hard, firm, sticky and plastic; many, fine roots inside peds; medium, tubular pores; moderately alkaline (pH 8.0); clear, smooth boundary.
- A12 11-29 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown (2.5Y 3/2 M); moderate, medium, subangular blocky; hard, firm, sticky and plastic; many, fine roots inside peds; fine and medium, tubular pores; moderately alkaline (pH 8.1); clear, smooth boundary.
- A13 29-54 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D) clay, very dark greyish brown (2.5Y 3/2 M); moderate, medium, angular blocky peds with slickensides and shiny pressure faces; hard, firm, sticky and plastic; few, fine roots; fine, irregular pores; slightly effervescent; moderately alkaline (pH 8.1); diffuse, smooth boundary.
- A14 54-95 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D&M) clay; intersecting slickensides forming large

Pedon described by the core group S.P. Gawande, H.S. Shankaranarayana, J.C. Bhattacharjee, S.G. Pandey and H.P. Choudhary; R.J. Landey, G.V. Patel, B.R. Tembhare, S.N. Deshmukh and D.D. Dube associated. December 12, 1979.

parallelepipeds with long axes tilted 40 to 45° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; few, fine roots; fine, irregular pores; slightly effervescent; moderately alkaline (pH 8.1); gradual, smooth boundary.

- A15 95-119 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D&M) clay; intersecting slickensides forming large parallelepipeds with long axes tilted 30° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; few, fine roots; fine, irregular pores; slightly effervescent; moderately alkaline (pH 8.1); gradual, smooth boundary.
- A16 119-147 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown to dark greyish brown (2.5Y 3.5/2 M); intersecting slickensides forming large parallelepipeds with long axes tilted 35° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; few, fine roots; fine, irregular pores; slightly effervescent; moderately alkaline (pH 8.2); clear, smooth boundary.
- AC 147-160 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D&M) clay; intersecting slickensides forming medium parallelepipeds tilted 35° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; fine, irregular pores; strongly effervescent; moderately alkaline (pH 8.2).

Type location : 22° 43' N, 75° 48' E; village Binjalai, tehsil and district Indore, Madhya Pradesh.

Range in characteristics : The A horizon is more than 100 cm thick. Its colour is in hue 2.5Y, value 3 to 4 and chroma 2. The texture is clayey with clay ranging from 50 to 60 per cent. The subsoil layers have intersecting slickensides forming parallelepipeds that break into angular blocks. The soil is slightly calcareous in the A horizon and strongly calcareous in the AC horizon. Cracks 2 to 3 cm wide at the surface that taper and extend to 120 cm depth.

Competing series and their differentiae .: Sarol soils are competing with Baloda soils which have colour in hue 10YR and has more lime. Baloda series belong to Entic Chromusterts.

Geographic setting : Sarol soils are formed in basaltic alluvium on level to gently sloping piedmont plain at an elevation of 540 to 580 m above MSL in the Malwa plateau of Madhya Pradesh. The climate is subhumid tropical with mean annual temperature of 24.4°C and mean annual rainfall of 1050 mm. The estimated MAST is 25.4°C . MSST is 28.0°C and MWST is 21.2°C .

Geographically associated soils : Sarol soils are associated with Kamliakheri and Baloda soils. The Kamliakheri soils are shallow and developed over weathered basalt while the Baloda soils are very deep and grey to very dark grey in colour. Kamliakheri and Baloda soils belong to Lithic Ustochrepts and Entic Chromusterts respectively.

Drainage and permeability : Moderately well drained with moderate permeability.

Use and vegetation : Cultivated to sorghum, pigeon pea, wheat, gram and linseed.

Natural vegetation comprises of *Acacia spp.* and *Zizyphus spp.*

Distribution and extent : Extensive in Indore, Ujjain and Dewas districts in Malwa plateau of Madhya Pradesh.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Delhi.

Interpretation : Sarol soils are fine-textured with high shrink-swell potential. They are susceptible to erosion. They can support a variety of crops. Crops respond to management under both rainfed and irrigated conditions. Under irrigation, provision of appropriate drainage will be necessary to avoid salinity problems.

(a) *Interpretative grouping*

- | | |
|------------------------------|----------------|
| i) Land capability sub-class | IIs |
| ii) Irrigability sub-class | 2d |
| iii) Productivity potential | Medium to high |

(b) *Yield* : Based on data from farmers' fields

Crop	Yield (Mg ha ⁻¹)	
	Farmers' practice	Improved practices
Sorghum	1.0	2.5
Pigeon pea	0.8	1.5
Wheat	0.8 - 1.5	2.5 - 3.0
Gram	0.6	1.3
Linseed	0.4	0.6

Soil Series : SAROL

Classification : Typic Chromustert

Analysis at : NBSS & LUP

Location : District Indore,
Madhya Pradesh

Sampling Date: December 12, 1979

Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)										Coarse fragments >2mm % of whole soil
		Total			Sand					Clay		
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	(0.002-0.001)	<0.001	
← % of < 2 mm →												
Ap	0-11	13.4	30.5	56.1	1.4	1.1	0.5	0.4	10.0	7.3	48.8	5
A12	11-29	10.6	31.5	57.9	1.8	2.9	0.4	0.4	5.1	16.0	41.9	5
A13	29-54	8.3	33.6	58.1	2.1	1.2	0.5	0.6	3.9	19.0	39.1	2
A14	54-95	6.0	35.0	59.0	1.5	0.9	0.5	0.3	2.8	27.0	32.0	7
A15	95-119	7.9	36.6	55.5	2.7	1.2	0.6	0.4	3.0	23.6	31.9	5
A16	119-147	10.0	38.0	52.0	3.2	1.4	0.8	0.5	4.1	22.1	29.9	7
AC	147-160	9.4	38.1	52.5	3.4	2.1	1.1	0.3	2.5	23.4	29.1	2

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³	COLE cm/cm
0-11	0.40	0.9	8.0	0.10	1.92	0.17
11-29	0.34	2.7	8.1	0.10	1.87	0.16
29-54	0.34	3.3	8.1	0.10	1.86	0.16
54-95	0.30	2.3	8.1	0.10	2.05	0.16
95-119	0.30	1.9	8.1	0.10	2.05	0.16
119-147	0.27	3.3	8.2	0.10	1.89	0.16
147-160	0.27	14.9	8.2	0.10	2.00	0.16

Depth (cm)	Extractable bases			CEC NH ₄ OAc	Exchangeable sodium %	Ratio CEC clay
	Ca+Mg	Na	K			
← c mol(p ⁺)kg ⁻¹ →						
0-11	48.7	3.9	0.6	53.2	7	0.95
11-29	40.2	4.2	0.5	44.9	9	0.77
29-54	52.5	4.2	0.5	57.2	7	0.98
54-95	53.2	4.4	0.5	58.1	8	0.98
95-119	40.2	4.5	0.5	45.2	10	0.81
119-147	43.9	4.8	0.5	49.2	10	0.95
147-160	38.4	4.6	0.5	43.5	11	0.83

Analysed by : A.R. Kalbande, Raj Kumar and O. Challa

9. SAUNTHER SERIES (ESTABLISHED)

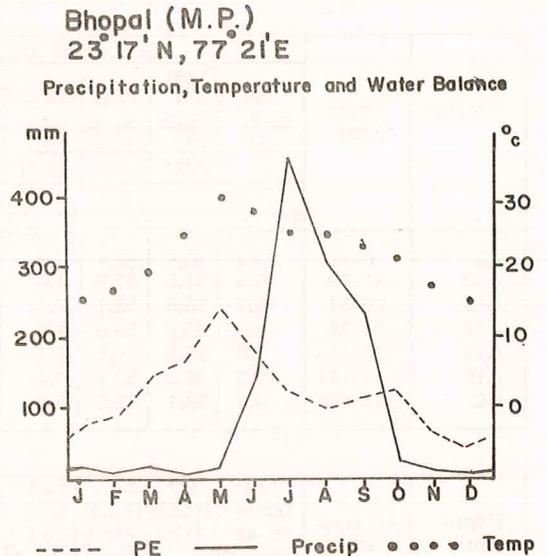
The Saunther series is a member of the very fine, montmorillonitic, hyperthermic family of Vertic Ustochrepts. Saunther soils have very dark grey to very dark greyish brown, clayey A and B horizons with weathered basalt in C horizons.

Typifying pedon : Saunther clay cultivated

Ap	0-27 cm --- Very dark grey (10YR 3/1 D) clay; very dark grey to very dark greyish brown (10YR 3/1.5 M); moderate, medium, subangular blocky; hard, firm, sticky and plastic; common, very fine roots; 2 cm wide cracks; neutral (pH 6.8); clear, smooth boundary.
B1	27-60 cm --- Very dark grey to very dark greyish brown (10YR 3/1.5 M) clay; strong, medium, angular blocky peds with prominent slickensides; firm, sticky and plastic; few, fine roots; 1 cm wide cracks; neutral (pH 7.2); diffuse, smooth boundary.
B2	60-77 cm --- Very dark grey to very dark greyish brown (10YR 3/1.5 M) clay; moderate, medium, subangular blocky peds with slickensides; firm, sticky and plastic; few, fine roots; pockets of weathered basalt; neutral (pH 7.1); clear, smooth boundary.
C	77-105 cm --- Weathered basalt.

Type location : 23° 08' N, 77° 47' E; village Saunther, tehsil Goharganj, district Raisen, Madhya Pradesh.

Range in characteristics : The thickness of the A horizon ranges from 20 to 30 cm. Its colour is in hue 10YR and 2.5Y, value 2 to 3. and chroma 1 to 2.5, respectively for both dry and moist soils. The texture of A horizon



is clayey, and structure is moderate to strong, fine to medium subangular blocky. The thickness of the B horizon ranges from 40 to 60 cm. Colour of the B horizon is in hue 10YR and 2.5Y, value 2.5 to 3 and chroma 1 to 2. The texture of the B horizon is clayey, and structure is moderate to strong, medium to coarse, subangular to angular blocky.

Geographic setting : Saunther soils occur on interplateau valleys and level to gently sloping pediments at an elevation of 300 to 520 m above MSL in Raisen district of Madhya Pradesh. The climate is subhumid tropical with mean annual temperature of 25.2°C and mean annual rainfall of 1394 mm. The estimated MAST is 26.7°C . MSST is 29.3°C and MWST is 21.8°C .

Geographically associated soils : Saunther soils are associated with Begamganj and Chicklod soils which are Entic Chromusterts and Typic Chromusterts respectively.

Drainage and permeability : Moderately well drained with moderately slow to slow permeability.

Use and vegetation : Cultivated to wheat, sorghum, gram and soybean.

Important trees are *Butea frondosa*, *Tectona grandis* and *Zizyphus jujuba*.

Distribution and extent : Extensive in Goharganj, Raisen and Bareilly tehsils of Raisen district, Madhya Pradesh.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Saunther soils are moderately well drained. Available moisture capacity is adequate for most of the locally grown kharif crops. Weathered basalt substratum helps in the internal drainage of these soils which is favourable under irrigation. Clayey texture, shrink-swell

characteristics and plasticity of the soil affect root penetration in the profile as well as workability. As the soils crack, water from initial rainfall is conserved in the profiles. Rabi crops like gram can be grown on conserved moisture.

Nutrient availability and nutrient retention capacity of the soils are good. They will respond to fertilizer, conservation management and other inputs.

Interpretative grouping :

- | | |
|------------------------------|--------|
| i) Land capability sub-class | IIs |
| ii) Irrigability sub-class | 2d |
| iii) Productivity potential | Medium |

Soil Series : SAUNTHER

Classification : Vertic Ustochrept

Location : District Raisen,
Madhya PradeshAnalysis at : NBSS & LUP,
Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2mm % of whole soil
		Total			Sand					
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2mm →										
Ap	0-27	11.4	25.0	63.6	1.4	2.5	1.3	2.1	4.1	1
B1	27-60	15.1	19.5	65.4	0.5	0.6	0.9	1.5	11.6	-
B2	60-77	29.9	15.6	54.5	1.5	8.5	10.1	8.9	0.9	1
C	77-105	Weathered basalt								

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³
0-27	0.84	Tr	6.8	0.13	1.81
27-60	0.64	Tr	7.2	0.13	1.85
60-77	0.50	Tr	7.1	0.16	1.88
77-105	Weathered basalt				

Depth (cm)	Extractable bases					CEC NH ₄ OAc	Base saturation %	Ratio CEC clay
	Ca	Mg	Na	K	Sum			
← c mol(p ⁺)kg ⁻¹ →								
0-27	37.0	11.0	1.8	0.8	50.6	53.8	94	0.85
27-60	38.0	12.0	1.3	0.7	52.0	53.8	97	0.82
66-77	38.0	10.0	1.4	0.5	49.9	51.1	98	0.94
77-105	Weathered basalt							

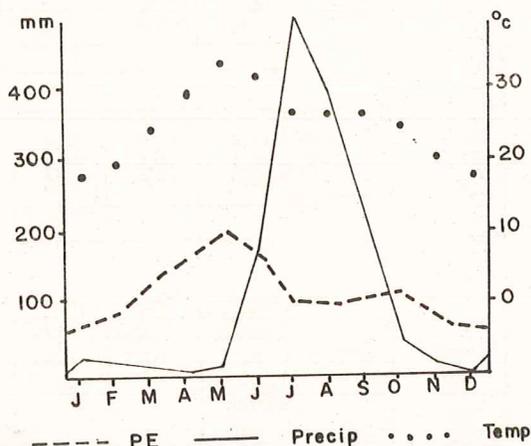
10. KHERI SERIES (ESTABLISHED)

The Kheri series is a member of the very fine, montmorillonitic, hyperthermic family of Typic Chromusterts. Kheri soils have dark greyish brown to very dark greyish brown, neutral to moderately alkaline, clayey A horizons and very dark greyish brown, moderately alkaline, clayey AC horizons.

Typifying pedon : Kheri clay — cultivated

Jabalpur (M.P.)
23° 10' N, 79° 57' E

Precipitation, Temperature and Water Balance



- Ap 0-15 cm --- Very dark greyish brown to dark greyish brown (2.5Y 3.5/2 D) clay, very dark greyish brown (2.5Y 3/2 M); moderate, medium, subangular blocky; hard, firm, sticky and plastic; many, fine and medium roots inside peds; fine, tubular pores; few, fine to medium basalt fragments and fine lime nodules; neutral (pH 7.1); gradual, smooth boundary.
- A12 15-37 cm --- Very dark greyish brown (10YR 3/2 M) clay; moderate, coarse, prismatic breaking to moderate, medium, angular blocky peds; very firm, very sticky and plastic; common, fine roots; very fine, irregular pores; few, fine to medium basalt fragments and lime nodules; neutral (pH 7.3); diffuse, smooth boundary.
- A13 37-60 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming strong, coarse angular blocky structure with shiny pressure faces; very firm, very sticky and plastic; few, fine roots; few, fine to medium basalt fragments and lime nodules; mildly alkaline (pH 7.4); diffuse, smooth boundary.

 Pedon described by the core group S.G. Pandey, H.P. Choudhary and J.C. Bhattacharjee; R.J. Landey, G.V. Patel, S.N. Deshmukh, B.R. Tembhare and G.S. Kaushal associated. December 6, 1979.

- A14 60-84 cm --- Very dark greyish brown and dark greyish brown (10YR 3/2, 4/2 M) clay; intersecting slickensides forming strong, coarse, angular blocky structure with shiny pressure faces; very firm, very sticky and plastic; few, fine roots; slightly effervescent; few, fine to medium basalt fragments and lime nodules; neutral (pH 7.3); diffuse, smooth boundary.
- A15 84-129 cm --- Very dark greyish brown and dark greyish brown (10YR 3/2, 4/2 M) clay; intersecting slickensides forming strong, coarse, parallelepipeds with long axes tilted 40 to 45° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very firm, very sticky and plastic; few, fine roots; strongly effervescent; few, fine to medium basalt fragments and few, fine lime nodules; moderately alkaline (pH 8.0); clear, wavy boundary.
- AC 129-150 cm --- Very dark greyish brown and dark greyish brown (10YR 3/2, 4/2 M) clay; intersecting slickensides forming strong, coarse, parallelepipeds with long axes tilted 30 to 35° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very firm and very sticky; few, fine roots; strongly effervescent; few, fine to medium basalt fragments and lime nodules; moderately alkaline (pH 8.1).

Type location : 23°10' N, 79°57' E; JNKVV Research Farm; village Kheri, tehsil and district Jabalpur, Madhya Pradesh.

Range in characteristics : The A horizon is more than 125 cm thick. Its colour is in hue 2.5Y and 10YR, value 3 to 4 and chroma 2. The texture is clayey with more than 60 per cent clay. In the lower layers of the A horizon, intersecting slickensides forming strong coarse parallelepipeds are observed. The soils crack during dry season.

Geographic setting : Kheri soils are formed in basaltic alluvium on level to very gently sloping piedmont in the upper catchment of Narmada in Jabalpur and Narsinghpur districts of Madhya Pradesh at an elevation of 375 to 400 m above MSL. The climate is subhumid tropical with mean annual temperature of 25.2°C and mean annual rainfall of 1440 mm. The estimated MAST is 26.2°C. MSST is 29.3°C and MWST is 21.2°C.

Geographically associated soils : Kheri soils are associated with Adhartal soils which are cracking and clayey. They do not have gilgai relief, slickensides, and wedge shaped aggregates. The Adhartal soils belong to Vertic Ustochrepts.

Drainage and permeability : Moderately well to imperfectly drained with slow permeability.

Use and vegetation : Cultivated to rice, wheat, gram, linseed, pigeon pea and lentil.

Natural vegetation comprises of *Acacia spp.*, *Butea spp.*, *Annona spp.* and grasses *Cynodon spp.*, *Saccharum spp.* etc.

Distribution and extent : Extensive in the upper catchment of Narmada covering Jabalpur and Narsinghpur districts, Madhya Pradesh.

Series proposed : Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur.

Interpretation : Kheri series are moderately productive and crops respond to management. In some soils poor drainage may give rise to problems.

(a) *Interpretative grouping* :

- | | |
|------------------------------|------------------|
| i) Land capability sub-class | III _s |
| ii) Irrigability sub-class | 3d |
| iii) Productivity potential | Medium |

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Rice	1.6	3.0
Sorghum	0.7	1.5
Pigeon pea	0.7	2.0
Wheat	1.2	2.0
Chickpea	0.5	1.0
Pea	0.6	1.0

Soil Series : KHERI

Classification : Typic Chromustert Analysis at : NBSS & LUP

Location : District Jabalpur,
Madhya Pradesh

Sampling Date: December 6, 1979

Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)										Coarse fragments >2 mm % of whole soil
		Total			Sand					Clay		
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	(0.002-0.001)	<0.001	
← % of < 2 mm →												
Ap	0-15	13.6	22.9	63.5	2.1	1.4	1.6	3.5	5.0	15.2	48.3	-
A12	15-37	15.9	22.3	61.8	-	0.5	1.3	1.8	12.3	18.3	43.5	-
A13	37-60	16.3	19.8	63.9	-	-	1.1	5.7	9.5	12.6	51.3	-
A14	60-84	17.3	19.1	63.6	-	-	1.3	6.0	10.0	7.4	56.2	-
A15	84-129	15.1	20.5	64.4	0.2	1.3	1.0	2.1	10.5	8.4	56.0	-
AC	129-150	13.7	20.6	65.7	-	-	1.0	1.7	11.0	9.6	56.1	-

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ <2 mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³	COLE cm/cm
0-15	0.52	Tr	7.1	0.1	1.67	0.10
15-37	0.30	Tr	7.3	0.1	2.04	0.13
37-60	0.28	Tr	7.4	0.1	1.97	0.14
60-84	0.26	Tr	7.3	0.1	1.96	0.14
84-129	0.25	7.9	8.0	0.1	1.94	0.14
129-150	0.26	4.7	8.1	0.1	2.07	0.11

Depth (cm)	Extractable bases			CEC NH ₄ OAc	Ratio CEC clay
	Ca+Mg	Na	K		
	← c mol(p ⁺)kg ⁻¹ →				
0-15	59.3	0.4	0.7	60.4	0.95
15-37	46.4	0.3	0.7	47.4	0.77
37-60	46.3	0.2	0.7	47.2	0.74
60-84	43.4	0.3	0.8	44.5	0.70
84-129	55.8	0.2	0.8	56.8	0.88
129-150	52.6	0.3	0.8	53.7	0.82

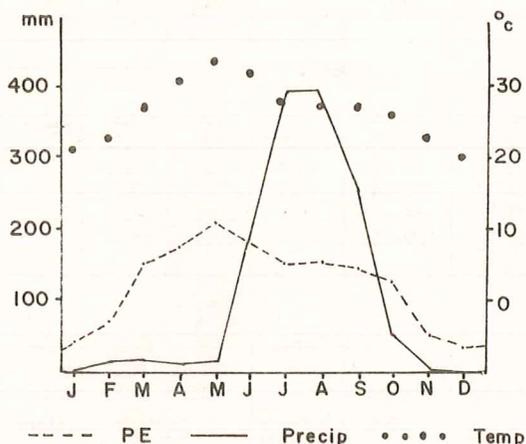
11. ARANG SERIES (TENTATIVE)

The Arang series is a member of the fine, mixed, hyperthermic family of Entic Chromusterts. Arang soils have dark brown to very dark greyish brown, neutral to mildly alkaline silty clay to clay A horizons, dark greyish brown, moderately alkaline, gravelly silty clay to clay AC horizons and olive brown, moderately alkaline, gravelly silty clay to clay C horizons.

Typifying pedon : Gravelly silty clay
— cultivated

Raipur (M.P.)
21° 14' N, 81° 39' E

Precipitation, Temperature and Water Balance



- Ap 0-23 cm --- Dark brown (10YR 4/3 M) gravelly silty clay; moderate, medium, subangular blocky; firm, sticky and plastic; many roots, few ferruginous nodules of 2 mm; few lime nodules; slightly localised effervescent; neutral (pH 6.9); diffuse, smooth boundary.
- A12 23-36 cm --- Dark greyish brown (2.5Y 4/2 M) silty clay; moderate, medium, angular blocky; firm, sticky and plastic; few to many roots; many rounded and dark brown ferruginous nodules of 2 to 5 mm; few lime nodules of 3 to 5 mm; slightly effervescent; neutral (pH 7.1); diffuse, smooth boundary.
- A13 36-53 cm --- Very dark greyish brown (2.5Y 3/2 M) silty clay; strong, angular blocky structure with distinct diagonal cleavages and moderately shining cleavage surfaces; firm, very sticky and plastic; few ferruginous nodules of 2 to 5 mm; many lime nodules of 3 to 5 mm; strongly effervescent; mildly alkaline (pH 7.4); diffuse, smooth boundary.
- A14 53-119 cm --- Very dark greyish brown (2.5Y 3/2 M) clay; strong, angular blocky structure with shining diagonal cleavage surfaces; very firm, very sticky and plastic; many rounded dark brown ferruginous nodules of 3 to 5 mm; many lime nodules of 5 to 10 mm; violently effervescent; mildly alkaline (pH 7.6); clear, smooth boundary.

- AC 119-152 cm --- Dark greyish brown (2.5Y 4/2 M) gravelly clay; massive; firm, very sticky and plastic; many rounded dark brown ferruginous nodules of 3 to 5 mm; many lime nodules of 5 to 15 mm; violently effervescent; moderately alkaline (pH 7.9); clear, smooth boundary.
- IIC 152⁺ cm --- Olive brown (2.5Y 4/4 M) gravelly silty clay; massive, firm, sticky; many rounded ferruginous nodules; many lime nodules of 5 to 25 mm; violent effervescent; moderately alkaline (pH 8.1).

Type location : 21° 58' N; 82° 12' E; village Arang, tehsil and district Raipur, Madhya Pradesh.

Range in characteristics : The A horizon is more than 100 cm thick. Its colour is in hue 10YR and 2.5Y, value 3 to 4 and chroma 2 to 3. The texture is silty clay to clay. The structure of the surface layer is moderate, medium, subangular blocky with medium to coarse, angular blocky in the lower layers. Gilgai micro relief and deep wide cracks are observed. Lime nodules are spread over the surface.

Geographic setting : Arang soils are formed in alluvium of the sedimentary rocks (calcareous shale, limestone and sandstone) on very gently to gently sloping midland and level land in low lying situations at an elevation of 800 to 900 m above MSL in Raipur district of Madhya Pradesh. The climate is subhumid tropical with mean annual temperature of 19.7°C and mean annual rainfall of 1793 mm. The estimated MAST is 20.7°C. The difference between MSST and MWST is more than 5°C.

Geographically associated soils : Arang soils are associated with Porda soils which belong to Udic Ustochrepts.

Drainage and permeability : Moderately drained with moderately slow to slow permeability.

Use and vegetation : Cultivated to rice, wheat, gram, pea, lentil and linseed.

Natural vegetation comprises of *Acacia spp.* and *Butea spp.*

Distribution and extent : Extensive in Raipur district of Madhya Pradesh.

Series proposed : All India Soil and Land Use Survey, Black Soil Region, Nagpur.

Interpretation : Arang soils are moderately productive and respond to management. Under bunded conditions, drainage is restricted and may give rise to stagnation of water. Soils are susceptible to erosion.

(a) *Interpretative grouping* :

i) Land capability sub-class	IIs
ii) Irrigability sub-class	2s
iii) Productivity potential	Medium to high

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Rice	1.6	3.0
Pigeon pea	0.5	0.8
Sesamum	0.2	0.4
Chick pea	0.8	1.7
Linseed	0.4	0.7
Wheat	0.7	1.2

Note : The soil texture is based on International particle size classification.

Soil Series : ARANG

Classification : Entic Chromustert

Analysis at : AIS&LUS,
BSR, NagpurLocation : District Raipur,
Madhya Pradesh

Sampling Date: November, 1960

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments >2 mm % of whole soil
		Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	
		← % of <2 mm →				
Ap	0-23	7.0	14.2	34.8	44.0	20
A12	23-36	6.4	16.0	30.1	47.5	12
A13	36-53	5.9	13.5	28.4	52.2	6
A14	53-119	7.6	16.7	21.8	53.9	16
AC	119-152	5.5	15.4	19.2	59.9	25
IIC	152+	10.9	13.0	30.5	45.6	65

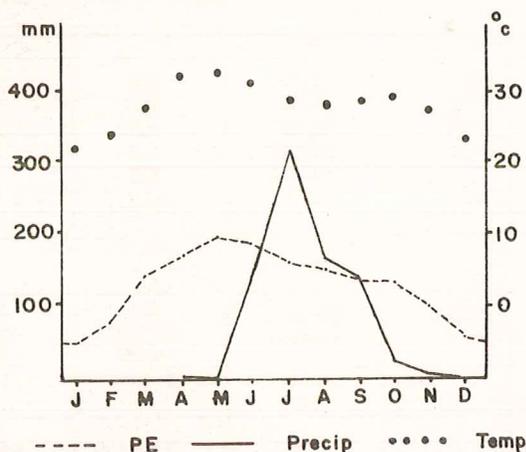
Depth (cm)	Organic carbon %	pH (1:2.5) H ₂ O dS m ⁻¹	E.C. (1:2.5) H ₂ O	Water holding capacity %
0-23	0.57	6.9	< 0.20	46.9
23-36	0.48	7.1	< 0.20	46.5
36-53	0.21	7.4	< 0.20	45.8
53-119	0.19	7.6	0.25	45.7
119-152	0.15	7.9	0.30	47.4
152+	0.15	8.1	0.35	46.3

Depth (cm)	Extractable bases		CEC
	Ca	Mg	
		← c mol(p ⁺)kg ⁻¹ →	
0-23	14.0	3.2	28.4
23-36	15.2	0.7	28.4
36-53	10.2	4.1	21.9
53-119	11.7	0.6	24.5
119-152	16.3	1.6	27.8
152+	13.2	1.3	20.3

12. SISODARA SERIES (ESTABLISHED)

The Sisodara series is a member of the fine, montmorillonitic, hyperthermic family of Vertic Ustochrepts. Sisodara soils have very dark greyish brown to dark brown, moderately alkaline, clayey A and B horizons over yellowish brown to dark yellowish brown, moderately alkaline, clayey C horizons.

Typifying pedon : Sisodara silty clay
— cultivated

Bharuch (Gujarat)**21° 42' N, 72° 58' E****Precipitation, Temperature and Water Balance**

- Ap 0-20 cm --- Dark greyish brown (10YR 4/2 D) silty clay, very dark greyish brown (10YR 3/2 M); coarse, columnar breaking into moderate, medium, subangular blocky peds; hard, firm, sticky and plastic; many, fine roots; moderately alkaline (pH 8.1); abrupt, smooth boundary.
- B1 20-84 cm --- Very dark greyish brown (10YR 3/2 M) clay; medium, prismatic breaking into moderate, medium, angular blocky peds with pressure faces; firm, sticky and plastic; few, fine roots; moderately alkaline (pH 8.0); clear, wavy boundary.
- B2 84-127 cm --- Dark brown (10YR 3/3 M) clay; coarse, prismatic breaking into moderate, medium, angular blocky peds with pressure faces; firm, very sticky and plastic; few, fine roots; moderately alkaline (pH 8.1); gradual, smooth boundary.
- C 127-145 cm --- Dark yellowish brown (10YR 4/4 M) clay; coarse, columnar breaking into weak, fine, subangular blocky peds; friable, slightly sticky and slightly plastic; mildly alkaline (pH 7.8).

Type location : 21° 53' N, 72° 30' E; village Sisodara, tehsil Navasari, district Bharuch, Gujarat.

Range in characteristics : The thickness of A horizon is 10 to 21 cm. Its colour is in hue 10YR, value 3 to 4 and chroma 2 to 3. The texture is silty clay loam to clay and occasionally sandy clay. The structure is moderate, medium, subangular blocky. The B horizon is 70 to 139 cm thick. Its colour is in hue 10YR value 3 to 4 and chroma 2 to 3. The texture is dominantly clay. The structure of B horizon is coarse, prismatic to coarse, columnar breaking into moderate, medium, angular blocky peds. The colour of C horizon is in hue 10YR, value 4 to 5 and chroma 4. The texture is clay or clay loam and occasionally sandy clay loam. The structure is coarse, columnar breaking into weak or moderate, subangular blocky peds.

Geographic setting : Sisodara soils are formed in alluvium and occur on nearly level to very gently sloping river terraces of Narmada and its tributaries at an elevation of 100 to 150 m above MSL in Bharuch district of Gujarat. The climate is warm subhumid tropical with mean annual temperature of 25.5°C and mean annual rainfall of 1640 mm. The estimated MAST is 26.5°C. MSST is 31.7°C and MWST is 23.8°C.

Geographically associated soils : Sisodara soils are associated with Jalalpur soils which are calcareous and belong to Typic Chromusterts.

Drainage and permeability : Moderately well drained with moderately slow permeability.

Use and vegetation : Cultivated to rice, sorghum, cotton and groundnut in kharif and wheat and beans in rabi.

Natural vegetation consists of grasses *Dicanthium annulatum*, *Saccharum spp.* and *Cenchrus ciliaris*.

Distribution and extent : Extensive along the river banks in Vadodara, Surat and Bharuch districts of Gujarat.

Series proposed : Soil Survey Organisation, Navasari, Department of Agriculture, Gujarat.

Interpretation : Sisodara soils are clayey and have high water and nutrient retention capacity. Due to their cracking nature; they can retain much of the initial rainfall. Once saturated, they become susceptible to erosion. If adequate surface drainage is not provided, there will be stagnation of water during high intensity rainfall. The soils will respond to management and can support all climatically adapted crops.

Land shaping, surface drainage growing crops on ridges are the practices required to grow successful kharif crops. With proper management, double cropping may be possible on these soils.

These soils will respond to high level of management with improved crop varieties of millets, cereals and legumes. Continuous cultivation of crops like paddy and sugarcane need frequent irrigation may be avoided.

For irrigating, these lands require proper land shaping and surface drainage.

Interpretative grouping :

i) Land capability sub-class	IIs
ii) Irrigability sub-class	2d
iii) Productivity potential	High

Note : The soil texture is based on International particle size classification.

Soil Series : SISODARA

Classification : Vertic Ustochrept

Location : District Bharuch,
GujaratAnalysis at : Soil Survey Unit,
Navsari,
Dept. of Agriculture,
Gujarat

Horizon	Depth (cm)	Size class and particle diameter (mm)			Coarse fragments > 2mm % of while soil
		Sand (2.0-0.02)	Silt (0.02-0.002)	Clay (< 0.002)	
		← % of < 2mm →			
Ap	0-20	24.0	32.5	43.5	-
B1	20-84	28.5	20.9	50.6	-
B2	84-127	27.8	16.6	55.6	2
C	127-145	40.0	20.2	39.8	-

Depth (cm)	pH (1:2.5) H ₂ O	Extractable bases			C.E.C.	Exchangeable sodium %
		Ca	Mg	Na		
		← c mol(p ⁺)kg ⁻¹ →				
0-20	8.1	25.0	12.4	2.3	38.5	6
20-84	8.0	27.2	13.0	2.2	40.0	6
84-127	8.1	28.0	11.6	3.0	42.0	7
127-145	7.8	30.0	12.2	2.3	40.0	6

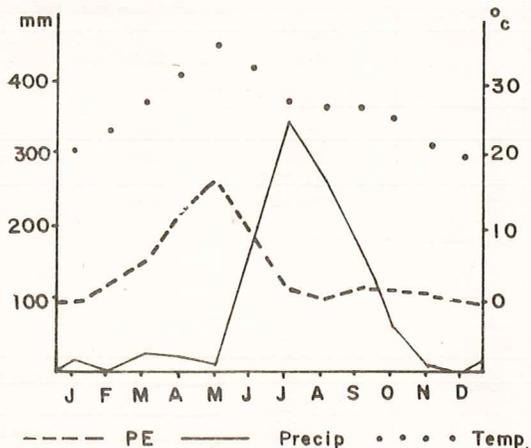
13. LINGA SERIES (ESTABLISHED)

The Linga series is a member of the very fine, montmorillonitic, hyperthermic family of Udic Chromusterts. Linga soils have very dark greyish brown, moderately alkaline, clayey A horizons and very dark greyish brown to greyish brown, moderately alkaline, clayey AC horizons.

Typifying pedon : Linga clay
orange orchard

Nagpur (Maharashtra)
21° 09' N, 79° 07' E

Precipitation, Temperature and Water Balance



- Ap 0-16 cm --- Very dark greyish brown (10YR 3/2 M) clay; strong, coarse, subangular blocky; firm, sticky and plastic; few, fine roots; many, fine, oblique tubular pores; moderately alkaline (pH 8.3); clear smooth boundary.
- A12 16-47 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 30° from the horizontal that break into strong coarse, angular blocky peds with shiny pressure faces; firm, sticky and very plastic; few, fine roots; many, fine oblique tubular pores; few lime nodules; moderately alkaline (pH 8.1); clear, smooth boundary.
- A13 47-84 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 30° from the horizontal that break into strong, coarse, angular blocky peds with shiny pressure faces; firm, sticky and plastic; few, fine roots; many fine, oblique pores; 2 to 10 mm lime-coated basalt fragments 2 to 3 per cent by volume; moderately alkaline (pH 8.1); clear, smooth boundary.

Pedon described by the core group J.C. Bhattacharjee, S.G. Pandey, N.K. Shende, H.S. Shankaranarayana and H.P. Choudhary; G.V. Patel, V.K. Misra, R.J. Landey, A.R. Kalbande and K.P.C. Rana associated. May 18, 1979.

- A14 84-117 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 45° from the horizontal that break into strong, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; few, very fine pores; 2 to 10 mm size of lime-coated basalt fragments 3 per cent by volume; moderately alkaline (pH 8.1); clear, irregular boundary.
- AC 117-140 cm --- Dark greyish brown and greyish brown (2.5Y 4/2, 4.5/2 M) clay; intersecting slickensides forming coarse parallelepipeds that break into strong, coarse, angular blocky peds with shiny pressure faces; firm, sticky and plastic; 2 to 10 mm basalt fragments in pockets; moderately alkaline (pH 8.1).

Remarks : A14 and AC interdigitate with each other in lower and upper parts of respective horizons.

Type location : $21^{\circ}06'$ N, $79^{\circ}03'$ E; Regional Fruit Research Station Farm, village Wandli, tehsil Katol, district Nagpur, Maharashtra.

Range in characteristics : The A horizon is more than 100 cm thick. Its colour is in hue 10YR and 2.5Y, value 3 to 4 and chroma 2. The texture is clayey, with more than 70 per cent clay. The structure of the surface layer is coarse, subangular blocky. The subsoil layers have intersecting slickensides forming parallelepipeds that break into angular blocky peds. The lime content increases with depth. 3 to 5 cm wide cracks are observed. Gilgai microrelief is common.

Competing series and their differentiae : Soils of Panjra and Malegaon series are the competing series. Panjra soils are dark greyish brown to dark brown, and gravelly. These soils belong to Typic Chromusterts. Malegaon soils are dark grey to very dark grey, and compact in the subsoil. Malegaon soils belong to Typic Pellusterts.

Geographic setting : Linga soils are formed in basaltic alluvium of the Jam river on level to gently sloping land at an elevation of 300 to 320 m above MSL in Nagpur and adjoining districts of Maharashtra. The climate is subhumid tropical with mean annual temperature of 27.2°C and mean annual rainfall

of 1125 mm. The estimated MAST is 28.2⁰C. MSST is 30.9⁰C and MWST is 24.1⁰C.

Geographically associated soils : Linga soils are associated with Karla and Wadhora soils which belong to Vertic Ustochrepts and Fluventic Ustochrepts, respectively.

Drainage and permeability : Imperfectly to poorly drained with slow permeability.

Use and vegetation : Cultivated to rainfed cotton, sorghum, wheat, pigeon pea and gram; orange, vegetables and flowers are grown under irrigation.

Natural vegetation comprises of *Acacia spp.* *Madhuca latifolia*.

Distribution and extent : Extensive in Nagpur and adjoining districts of Maharashtra.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Linga soils are fine-textured with high shrink-swell potential. They are prone to develop salinity and alkalinity even when irrigated with water low in soluble salts. During monsoon, crops may be adversely affected due to stagnation of water. These soils are also susceptible to erosion even on gently sloping lands. They are productive with poor management and drainage under both rainfed and irrigated agriculture.

Interpretative grouping :

- | | | |
|------|---------------------------|------------------|
| i) | Land capability sub-class | III _s |
| ii) | Irrigability sub-class | 3d |
| iii) | Productivity potential | Medium |

Soil Series : LINGA

Classification : Udic Chromustert

Analysis at : NBSS & LUP,

Location : District Nagpur,
Maharashtra

Sampling Date: May 18, 1979

Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)										Coarse fragments > 2mm % of whole soil
		Total			Sand					Clay		
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Very coarse (2-1)	Coa- (1-0.5)	Med- (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	(0.002-0.001)	(< 0.001)	
← % of < 2 mm →												
Ap	0-16	4.8	20.6	74.6	-	-	-	-	4.0	12.0	62.6	2
A12	16-47	5.5	20.0	74.5	0.5	-	-	-	5.0	7.0	67.5	3
A13	47-84	9.7	16.5	73.8	-	-	-	0.2	9.5	7.8	66.0	2
A14	84-117	10.3	15.1	74.6	-	0.7	-	-	9.6	8.6	66.0	4
AC	117-140	10.1	19.0	70.9	0.7	-	0.2	0.2	9.0	9.3	61.6	8

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ < 2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	COLE cm/cm
0-16	0.51	1.9	8.3	0.2	0.18
16-47	0.47	4.0	8.1	0.2	0.16
47-84	0.42	5.6	8.1	0.2	0.19
84-117	0.49	6.5	8.1	0.2	0.19
117-140	0.27	8.5	8.1	0.2	0.16

Depth (cm)	Extractable bases			CEC NH ₄ OAc	Exch-ange-able sodium %	Ratio CEC clay
	Ca+Mg	Na	K			
← cmol(p ⁺)kg ⁻¹ →						
0-16	53.7	5.0	0.6	59.3	8	0.79
16-47	50.8	4.6	0.6	56.0	8	0.75
47-84	59.2	4.4	0.6	64.2	7	0.87
84-117	64.0	4.8	0.6	69.4	7	0.93
117-140	60.4	4.1	0.6	65.1	6	0.92

14. KIRNAPUR SERIES (TENTATIVE)

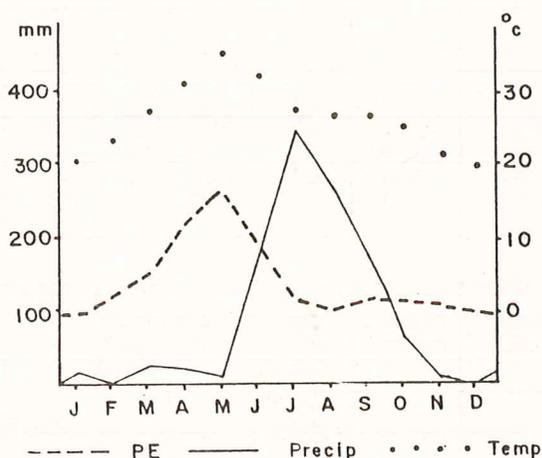
The Kirnapur series is a member of the fine, montmorillonitic, hyperthermic family of Entic Chromusterts. Kirnapur soils have olive brown to very dark greyish brown, mildly alkaline, clayey A horizons and very dark greyish brown, mildly alkaline, clayey C horizons.

Typifying pedon : Kirnapur clay — cultivated

- Ap 0-10 cm --- Olive brown to light olive brown (2.5Y 4.5/4 D) clay, very dark greyish brown to dark greyish brown (2.5Y 3.5/2 M); weak, fine, granular; slightly hard, friable, sticky and plastic; common, medium roots; 2 cm wide cracks; many lime and few iron manganese nodules; mildly alkaline (pH 7.7); clear, smooth boundary.
- A12 10-40 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown to dark greyish brown (2.5Y 3.5/2 M); moderate, medium, subangular blocky peds with shiny pressure faces; very hard, firm, very sticky and very plastic; many, medium roots; 1.5 to 2 cm wide cracks; mildly alkaline (pH 7.7); clear, smooth boundary.
- A13 40-100 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown to dark greyish brown (2.5Y 3.5/2 M); coarse intersecting slickensides breaking into coarse, strong, angular blocky peds with shiny pressure faces; very hard, firm, very sticky and very plastic; 1.5 to 2 cm wide cracks; many, medium irregular and indurated lime nodules and ferruginous gravels as lithorelicts; mildly alkaline (pH 7.7); diffuse, smooth boundary.
- A14 100-128 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown to dark greyish brown (2.5Y 3.5/2 M); coarse, intersecting slickensides forming parallelepipeds breaking into strong, coarse, angular blocky peds with shiny pressure faces; very hard,

Nagpur (Maharashtra)
21° 09' N, 79° 07' E

Precipitation, Temperature and Water Balance



firm, very sticky and very plastic; medium, indurated lime nodules and ferruginous gravels as lithorelicts; mildly alkaline (pH 7.7); gradual, smooth boundary.

AC 128-142 cm --- Dark greyish brown (2.5Y 4/2 D) clay, very dark greyish brown to dark greyish brown (2.5Y 3.5/2 M); moderate, coarse angular blocky; very hard, firm, very sticky and very plastic; mildly alkaline (pH 7.8).

Type location : 21°19' N, 79°24' E; village Kirnapur, tehsil Ramtek, district Nagpur, Maharashtra.

Range in characteristics : The thickness of A horizon ranges from 120 to 160 cm. Its colour is in hue 2.5Y and 10YR, value 3.5 to 4.5 and chroma 2 to 3. The subsoil colour is in hue 2.5Y and 10YR, value 3 to 4 and chroma 2 to 4. The surface texture is clay loam to clay. The sub-soil texture is dominantly clay but silty clay and gravelly clay are also met with. The structure of the surface soil is weak, medium, subangular blocky to moderate, medium, subangular blocky and grades to moderate, medium, subangular blocky and strong, coarse angular blocky through depth. Slickensides are prominent from third layer downwards. The subsoil horizons have coarse intersecting slickensides that break into coarse, strong, angular blocky peds with shiny pressure faces. Ferruginated rock fragments and indurated lime nodules increase in size and volume with depth.

Competing series and their differentiae : Panjra and Aroli are the competing series. Panjra soils are well drained, Typic Chromusterts while Aroli soils are well to moderately well drained Typic Chromusterts.

Geographic setting : Kirnapur soils are formed in basaltic alluvium on nearly level to very gently sloping plain at an elevation of 330 to 350 m above MSL in Nagpur district of Maharashtra. The climate is subhumid tropical with mean annual temperature of 26.9°C and mean annual rainfall 1127 mm. The estimated MAST is 28.9°C. MSST is 30.8°C and MWST is 24.8°C.

Geographically associated soils : Kirnapur soils are associated with Aroli and Bagbori soils which belong to Typic Chromusterts and Vertic Ustochrepts, respectively.

Drainage and permeability : Well drained with moderately slow to slow permeability.

Use and vegetation : These soils are mostly cultivated to sorghum and pigeon pea. Rice, wheat and oilseeds are also grown. Chillies are grown extensively in Umrer tehsil.

Natural vegetation comprises of *Butea monosperma*, *Madhuca latifolia*, *Acacia arabica*, *Zizyphus jujuba* and *Acacia catechu*.

Distribution and extent : These soils are extensive in Ramtek, Umrer, Nagpur tehsils of Nagpur district and the adjoining areas.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Kirnapur soils are very deep, fine textured, with high shrink-swell potential. They are susceptible to erosion. They respond to climatically adapted crops under proper management practices.

Interpretative grouping :

i) Land capability sub-class	Iles-IIIls
ii) Land irrigability sub-class	3s
iii) productivity potential	Medium to high

oil Series : KIRNAPUR
 ication : District Nagpur,
 Maharashtra

Classification : Entic Chromustert
 Sampling date: February 29, 1970

Analysis at : NBSS & LUP,
 Regional Centre,
 Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of whole soil
		Total					Sand			
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-10	24.4	25.0	50.6	2.8	3.4	4.5	4.2	9.5	2
A12	10-40	21.9	22.5	55.6	3.2	3.5	4.0	4.2	7.0	2
A13	40-100	21.5	22.0	56.5	3.9	4.0	3.6	3.5	6.5	4
A14	100-128	18.4	20.5	61.1	1.8	2.6	3.5	3.2	7.3	1
AC	128-142	17.4	18.5	64.1	3.2	2.8	2.9	3.6	4.9	3

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ < 2mm	pH (1:2.5) H ₂ O	EC (1:2.5) H ₂ O dS m ⁻¹	Bulk density Mg m ⁻³	Water retention	
						33 kPa %	1500 kPa %
0-10	0.41	Nil	7.7	0.30	1.81	30.4	17.6
10-40	0.32	Nil	7.7	0.30	1.87	29.9	18.7
40-100	0.22	Nil	7.7	0.30	1.91	33.2	18.3
100-128	0.22	Nil	7.7	0.30	1.94	35.9	20.4
128-142	0.17	Nil	7.8	0.30	1.95	35.8	20.3

Depth (cm)	Extractable bases					CEC NH ₄ OAc	Base saturation %	Ratio CEC clay
	Ca	Mg	Na	K	Sum			
← c mol(p ⁺)kg ⁻¹ →								
0-10	21.0	6.0	0.8	0.5	28.3	30.6	92	0.60
10-40	35.0	8.0	0.9	0.4	44.3	47.0	94	0.84
40-100	36.0	7.0	0.6	0.4	44.0	47.0	94	0.83
100-128	34.0	8.0	0.7	0.7	43.4	46.8	93	0.76
128-142	36.0	8.0	0.9	0.9	45.8	47.6	96	0.74

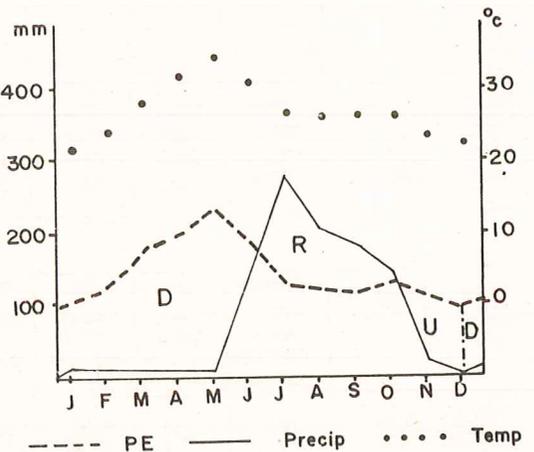
15. JAMBHA SERIES (ESTABLISHED)

The Jambha series is a member of the very fine, montmorillonitic, hyperthermic family of Typic Chromusterts. Jambha soils have dark greyish brown to very dark greyish brown, moderately to strongly alkaline, clayey, A horizons and yellowish brown to dark yellowish brown, strongly alkaline, clayey C horizons.

Typifying pedon : Jambha clay -- cultivated

Amravati (Maharashtra)
20° 56' N, 77° 47' E

Precipitation, Temperature and Water Balance



- Ap 0-20 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); moderate, medium, subangular blocky; very hard, friable, very sticky and very plastic; few, fine roots; fine impeded and exped pores; 2 cm wide cracks; slightly effervescent; strongly alkaline (pH 8.6); diffuse, smooth boundary.
- A12 20-45 cm --- Very dark greyish brown to dark greyish brown (10YR 3.5/2 D) clay, very dark greyish brown (10YR 3/2 M); strong, coarse, prismatic breaking into subangular blocky peds with shiny pressure faces; very hard, firm, sticky and very plastic; few, fine roots; few, irregular pores; 1 to 2 cm wide cracks; slightly effervescent; strongly alkaline (pH 8.5); diffuse, smooth boundary.
- A13 45-65 cm Very dark greyish brown (10YR 3/2 D&M) clay; strong, coarse prismatic breaking into subangular blocky peds with shiny pressure faces; very hard, very firm, very sticky and very plastic; 1 cm wide cracks; slightly effervescent; moderately alkaline (pH 8.4); diffuse, smooth boundary.
- A14 65-105 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; intersecting slickensides forming strong coarse parallelepipeds with long axes tilted 30 to 35° from the horizontal that break into

Pedon described by the core group S.G. Pandey, J.C. Bhattacharjee, R.G. Desai, H.P. Choudhary and N.K. Shende; R.J. Landey, A.R. Kalbande and V.K. Misra associated. May 18, 1979.

strong, coarse, angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; slightly effervescent; moderately alkaline (pH 8.3); diffuse, smooth boundary.

- A15 105-145 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; intersecting slickensides forming strong, coarse parallelepipeds with long axes tilted 30 to 35° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very hard, very firm, very sticky and very plastic; slightly effervescent; strongly alkaline (pH 8.6); diffuse, smooth boundary.
- AC 145-190 cm --- Dark greyish brown to brown (10YR 4/2, 5/3 D) clay, dark brown to brown (10YR 4/3, 5/3 M); intersecting slickensides forming strong, coarse parallelepipeds with long axes tilted 30 to 50° from the horizontal that break into strong, medium, angular blocks with shiny pressure faces; very hard, firm, very sticky and very plastic; strongly effervescent; strongly alkaline (pH 8.7); gradual, smooth boundary.
- C 190-240 cm --- Yellowish brown (10YR 5/4 D) clay, dark yellowish brown (10YR 4/4 M); strong, coarse, angular blocky peds with shiny pressure faces; very hard, firm, very sticky and very plastic; strongly effervescent; strongly alkaline (pH 8.6).

Type location : 20°56' N, 77°47' E; village Palaskheda, tehsil Chandur, district Amravati, Maharashtra.

Range in characteristics : The thickness of the A horizon ranges from 130 to 170 cm. The colour of the A horizon is dark to very dark greyish brown in hue 10YR, value 3 to 4 and chroma 2. It is moderately to strongly alkaline. The structure is medium, subangular blocky in Ap; coarse, prismatic breaking to angular blocky in A12 and A13 and parallelepipeds breaking to coarse angular blocky in A14 and A15. The C horizon is yellowish brown, and clayey. Gilgai micro-relief is common.

Competing series and their differentiae : Kalumna series, also a Typic Chromustert, is mottled in the subsoil.

Geographic setting : Jambha soils are formed in basaltic alluvium on very gently sloping to gently sloping Wardha flood plain at an elevation of 270 to 370 m above MSL. The climate is subhumid tropical with mean annual

temperature of 27.2 C and mean annual rainfall of 975 mm. The estimated MAST is 28.2^oC. MSST is 30.4^oC and MWST is 25.4^oC.

Geographically associated soils : Jambha soils are associated with Kalumna soils which are mottled in the subsurface and belong to Typic Chromusterts.

Drainage and permeability : Somewhat poorly drained with slow to very slow permeability.

Use and vegetation : Mostly cultivated to rainfed cotton, sorghum, pigeon pea, gram, wheat and linsed.

Natural vegetation comprises of *Acacia spp.* and thorny shrubs.

Distribution and extent : Extensive in Amravati, Wardha and Akola districts of Maharashtra.

Series proposed : Soil Survey Division, Directorate of Irrigation Research and Development, Pune.

Interpretation : Jambha soils are deep and clayey. They have high water and nutrient retention capacity. These soils can conserve most of the initial rainfall received due to the cracks. Once saturated they are susceptible to erosion even on gentle slopes, and hence soil conservation measures are required. Under irrigation they may pose waterlogging and salinity problems unless adequate drainage is provided. They can support all climatically adapted crops.

(a) *Interpretative grouping* :

i) Land capability sub-class	III _s
ii) Irrigability sub-class	3d
iii) Productivity potential	Medium

(b) *Yield* : Based on data from farmers' fields

Crop	Yield (Mg ha ⁻¹)	
	Farmers' practice	Improved practices
Cotton	0.8	1.5
Sorghum	1.3	2.8
Groundnut	0.6	1.2
Pigeon pea	0.6	1.1
Safflower	0.7	1.5
Sunflower	0.3	0.7

Soil Series : JAMBHA

Classification : Typic Chromustert Analysis at : NBSS & LUP
Regional Centre,
NagpurLocation : District Amravati,
Maharashtra

Sampling Date: May 18, 1979

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2mm % of whole soil
		Total			Sand					
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.50-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-20	13.6	26.7	59.7	6.2	2.4	0.5	0.4	4.1	5
A12	20-45	15.2	13.3	71.5	6.8	3.4	0.8	0.5	3.7	3
A13	45-65	13.2	21.9	64.9	2.9	5.5	0.9	0.6	3.3	4
A14	65-105	8.5	25.7	65.8	3.6	1.2	0.8	0.4	2.5	3
A15	105-145	8.7	18.3	73.0	1.3	0.5	0.4	1.3	5.2	3
AC	145-190	13.1	29.5	57.4	2.6	0.7	0.5	1.7	7.6	3
C	190-240	7.1	29.2	63.7	2.9	0.8	0.3	0.9	2.2	5

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³	Water Retention	
						33 kPa %	1500 kPa %
0-20	0.46	1.9	8.6	0.17	1.71	38.4	22.5
20-45	0.46	2.3	8.5	0.15	1.88	34.5	21.5
45-65	0.44	2.5	8.4	0.13	2.04	36.6	22.6
65-105	0.37	2.6	8.3	0.17	1.99	36.4	20.9
105-145	0.36	1.4	8.6	0.20	1.97		
145-190	0.31	3.0	8.7	0.23	1.90		
190-240	0.17	5.3	8.6	0.23	1.93		

Depth (cm)	Extractable bases			CEC NH ₄ OAc	Exchangeable sodium	Ratio CEC clay
	Ca+Mg	Na	K			
← c mol(p ⁺)kg ⁻¹ →						
0-20	54.0	0.2	1.0	55.2	1	0.92
20-45	48.3	0.4	0.9	49.6	1	0.69
45-65	45.8	0.4	0.8	47.0	1	0.72
65-105	41.5	1.3	0.9	43.7	3	0.66
105-145	46.0	2.8	0.9	49.7	6	0.68
145-190	39.0	5.0	1.0	45.0	11	0.78
190-240	38.3	6.0	1.0	45.3	13	0.71

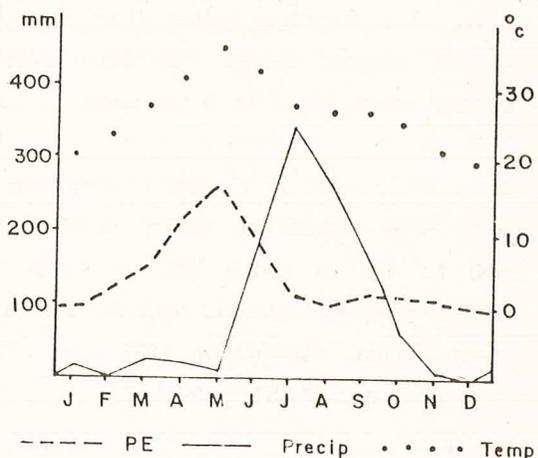
16. KARLA SERIES (TENTATIVE)

The Karla series is a member of the very fine, montmorillonitic, hyperthermic family of Vertic Ustochrepts. Karla soils have very dark greyish brown, mildly alkaline, clayey A horizons and dark greyish brown to dark brown, moderately alkaline, clayey B horizons underlain by weathered basalt.

Typifying pedon : Karla clay — cultivated

Nagpur (Maharashtra)
21° 09' N, 79° 07' E

Precipitation, Temperature and Water Balance



- Ap 0-17 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); strong, medium, subangular blocky; hard, firm, sticky and plastic; few, fine roots; 1 to 2 wide cracks; mildly alkaline (pH 7.7); gradual, smooth boundary.
- B2 17-40 cm --- Dark brown (10YR 3/3 M) clay; strong, coarse, angular blocky with shiny pressure faces; vary firm, very sticky and very plastic; 1.0 to 1.5 cm wide cracks; pockets of lime concretions; strongly effervescent; moderately alkaline (pH 7.9); clear, smooth boundary.
- B3 40-66 cm --- Dark brown (10YR 3/3 M) clay; strong, medium, angular blocky; firm, sticky and plastic; 1 cm wide cracks; many nodules; strongly effervescent; mildly alkaline (pH 7.8); clear, smooth boundary.
- C 66-95 cm --- Massive unconsolidated weathered basaltic material with lime nodules.

Type location : 20° 19' N, 78° 35' E; village Karla, tehsil Katol, district Nagpur, Maharashtra.

Range in characteristics : The thickness of the solum varies from 50 to 70 cm. The surface colour is in hue 10YR with moist value 3 and dry value 4 while chroma is 2 for both dry and moist soils. The surface texture is mostly clay. The subsoil colour is in hue 10YR, value 2 to 4 and chroma 2 to 3 for both moist and dry soils. The texture is generally clay to silty clay. The structure varies from strong, medium, subangular blocky to strong, coarse, angular blocky with shiny pressure faces. During dry periods cracks appear which are 1 to 3 cm wide.

Geographic setting : Karia soils are formed over basaltic material mixed with lime nodules on nearly level to gently sloping plain at an elevation of 350 to 400 m above MSL in Katol tehsil of Nagpur district, Maharashtra. The climate is subhumid tropical with mean annual temperature of 26.9°C and mean annual rainfall of 1127 mm. The estimated MAST is 27.9°C. MSST is 30.8°C and MWST is 24.1°C.

Geographically associated soils : Karla soils are associated with Linga and Muserkhapa soils which are Udic Chromusterts and Typic Ustochrepts, respectively.

Drainage and permeability : Moderately well drained with moderately slow permeability.

Use and vegetation : Cultivated to sorghum, cotton, groundnut, pigeon pea and oranges.

Natural vegetation comprises of *Acacia spp.* and *Azadirachta indica*.

Distribution and extent : Extensive in Nagpur district, Maharashtra.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Karla soils are clayey and moderately deep. Due to high shrink-swell nature of clay, they develop wide cracks on drying. They are moderately well drained and have high nutrient and water retention capacity. These soils are suitable for crops having shallow to moderate rooting depth. They respond to management both under rainfed and irrigated agriculture.

Interpretative grouping :

i)	Land capability sub-class	Iles, IIIs
ii)	Irrigability sub-class	3s
iii)	Productivity potential	Medium

Soil Series : KARLA

Classification : Vertic Ustochrept

Analysis at : NBSS & LUP
Regional Centre,
NagpurLocation : District Nagpur,
Maharashtra

Sampling date: March 8, 1970

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of whole soil
		Total			Sand					
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-17	13.4	26.0	60.6	1.6	1.7	2.3	2.2	5.6	3
B2	17-40	11.4	25.5	63.1	0.7	1.3	1.4	2.3	5.7	7
B3	40-66	10.4	23.5	66.1	1.1	1.2	1.9	2.6	3.6	11
C	66-95	-----Weathered basalt-----								

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dS m ⁻¹	Bulk density Mgm ⁻³	Water retention		
						33kPa %	1500 kPa %	
0-17	0.59	3.6	7.7	0.3	1.80	47.3	24.3	
17-40	0.68	3.6	7.9	0.3	1.83	49.7	25.4	
40-66	0.33	5.6	7.8	0.3	1.80	53.0	26.6	
66-95	-----Weathered basalt-----							

Depth (cm)	Extractable bases					CEC NH ₄ OAc	Base saturation %	Ratio CEC clay %
	Ca	Mg	Na	K	Sum			
← c mol (p ⁺)kg ⁻¹ →								
0-17	39.6	14.8	1.6	0.7	56.7	57.2	99	0.94
17-40	38.4	16.2	1.3	0.6	56.5	58.8	96	0.93
40-66	38.8	16.2	1.3	1.0	57.3	58.4	98	0.88
66-95	-----Weathered basalt-----							

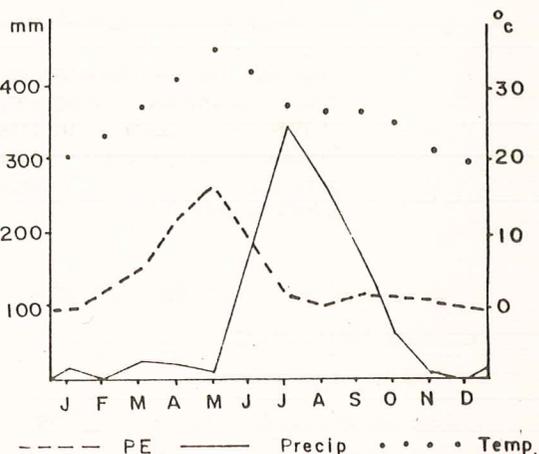
17. AROLI SERIES (TENTATIVE)

The Aroli series is a member of the fine, montmorillonitic, hyperthermic family of Typic Chromusterts. Aroli soils have dark brown to very dark greyish brown, moderately alkaline, clay A horizons, and brown to dark brown and occasionally very pale brown, moderately to strongly alkaline, clayey AC and C horizons.

Typifying pedon : Aroli clay — cultivated

Nagpur (Maharashtra)
21° 09' N, 79° 07' E

Precipitation, Temperature and Water Balance



- Ap 0-17 cm --- Very dark greyish brown (10YR 3/2M) clay; moderate, coarse, prismatic structure breaking to moderate, medium, subangular blocky peds; firm, sticky and plastic; few, fine roots; few, fine, impeded pores; common, fine lime nodules; slightly effervescent; moderately alkaline (pH 8.4); clear, smooth boundary.
- A12 17-42 cm --- Very dark greyish brown (10YR 3/2 M) clay; moderate, coarse, prismatic structure breaking to moderate, medium, angular blocky peds with shiny pressure faces; firm, sticky and plastic; few, very fine roots; few, fine, impeded pores; common, medium, lime nodules; slightly effervescent; moderately alkaline (pH 8.4); diffuse, smooth boundary.
- A13 42-67 cm --- Very dark greyish brown (10YR 3/2 M) clay; strong, coarse, angular blocky peds with shiny pressure faces; intersecting slickensides; firm, sticky and plastic; few, medium roots; few, fine pores; common, medium lime nodules; slightly effervescent; moderately alkaline (pH 8.4); clear, wavy boundary.
- AC1 67-120 cm --- Dark brown and very pale brown (10YR 3/3, 7/3 M) clay; intersecting slickensides forming parallelepiped peds breaking to strong, coarse, angular blocky peds with shiny pressure faces;

Pedon described by J.C. Bhattacharjee, R.J. Landey, A.R. Kalbande and S. Vadivelu. December 6, 1981.

firm, sticky and plastic; few, fine roots; patches of soft powdery lime; strongly effervescent; moderately alkaline (pH 8.4); clear, wavy boundary.

AC2 120-163 cm --- Dark brown and very pale brown (10YR 4/3, 7/3 M) clay; intersecting slickensides forming parallelepipeds breaking to strong, coarse, angular blocky peds with shiny pressure faces; firm, sticky and plastic; patches of powdery lime; strongly effervescent; strongly alkaline (pH 8.5); clear, wavy boundary.

C 163-190 cm --- Dark brown and very pale brown (10YR 4/3, 7/3 M) clay; common, medium, faint mottles of yellowish brown (10YR 5/6) colour, intersecting slickensides forming parallelepipeds breaking to strong, coarse, angular blocky peds; firm, sticky and plastic; patches of powdery lime; violently effervescent; strongly alkaline (pH 8.5).

Type location : 21°08' N, 79°04' E; field No.11, main block, Agricultural College farm, Nagpur.

Range in characteristics : The A horizon is more than 100 cm thick. The moist colour of A horizon is in hue 10YR, value 3 to 4 and chroma 2 to 3. The texture is clay. The structure in the surface layer is moderate, medium, subangular blocky while subsoil layers have intersecting slickensides forming parallelepipeds that break into angular blocks. Cracks 2 to 3 cm wide taper and extend to 80 cm depth.

Competing series and their differentiae : Panjra and Kirnapur soils are the competing soils. Panjra soils are relatively less clayey and Kirnapur soils are noncalcareous or slightly calcareous. They belong to Typic Chromusterts and Entic Chromusterts, respectively.

Geographic setting : Aroli soils are formed in basaltic alluvium on nearly level to very gently sloping plain at an elevation of 300 to 350 m above MSL in Nagpur district of Maharashtra. The climate is dry subhumid tropical with mean annual temperature of 27.2°C and mean annual rainfall of 1125 mm. The estimated MAST is 28.2°C. MSST is 30.9°C and MWST is 24.1°C.

Geographically associated soils : Aroli soils are associated with Linga and Kirnapur soils. The Linga soils are more clayey and Kirnapur soils are noncalcareous or slightly calcareous. The Linga and Kirnapur soils belong to Udic Chromusterts and Entic Chromusterts respectively.

Drainage and permeability : Well to moderately well drained with moderately slow to very slow permeability.

Use and vegetation : Cultivated to rice, sorghum, pigeonpea.

Natural vegetation consists of *Acacia arabica* and *Azadirachta indica*.

Distribution and extent : Extensive in Nagpur district of Maharashtra.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Aroli soils are fine textured soils with high shrink-swell potential. During monsoon, crops may be affected due to stagnation of water. They are susceptible to erosion. They are productive with proper management and drainage under both rainfed and irrigated agriculture.

(a) *Interpretative grouping* :

- | | |
|---------------------------------|----------------|
| i) Land capability sub-class | IIs - IIIs |
| ii) Land irrigability sub-class | 3s |
| iii) Productivity potential | Medium to high |

(b) *Yield* : Based on data from farmers' fields

Crop	Yield (Mg ha ⁻¹)	
	Farmers' practice	Improved practices
Cotton	1.0	1.6
Sorghum	1.5	2.2
Pigeon pea	0.6	0.9
Groundnut	0.7	1.1
Sunflower	0.5	0.9
Soybean	0.6	1.1

Soil Series : AROLI

Classification : Typic Chromustert

Analysis at : NBSS & LUP
Regional Centre
NagpurLocation : District Nagpur,
Maharashtra

Sampling Date: December 6, 1981

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2mm % of whole soil
		Total			Sand					
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-17	6.9	29.2	63.9	1.1	1.1	1.4	0.8	2.5	2
A12	17-42	8.8	30.3	60.9	2.3	2.0	1.1	0.9	2.5	-
A13	42-67	8.3	32.8	58.9	2.5	1.3	1.1	0.8	2.6	2
AC1	67-120	8.3	32.9	58.8	2.2	1.9	1.6	1.2	1.4	1
AC2	120-163	10.3	32.1	57.6	5.1	1.1	1.8	1.2	1.1	1
C	163-190	13.2	31.8	55.0	5.8	3.0	2.1	1.0	1.3	4

Depth (cm)	Organic carbon	Carbonate as CaCO ₃ < 2mm(%)	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dS m ⁻¹	Bulk density Mgm ⁻³	COLE cm/cm
0-17	0.43	4.5	8.4	0.20	1.65	0.09
17-42	0.34	4.9	8.4	0.22	1.85	0.09
42-67	0.31	4.6	8.4	0.23	1.90	0.09
67-120	0.20	13.6	8.4	0.37	2.00	0.08
120-163	0.11	14.3	8.5	0.35	2.00	0.08
163-190	0.05	18.2	8.5	0.40	2.00	0.07

Depth (cm)	Extractable bases			CEC NH ₄ OAc
	Ca+Mg	Na	K	
← c mol (p ⁺) kg ⁻¹ →				
0-17	56.4	0.3	0.9	57.6
17-42	57.4	0.4	0.4	58.2
42-67	53.8	0.4	0.3	54.5
67-120	54.0	0.6	0.4	55.0
120-163	51.6	0.8	0.4	52.8
163-190	49.1	1.2	0.4	50.7

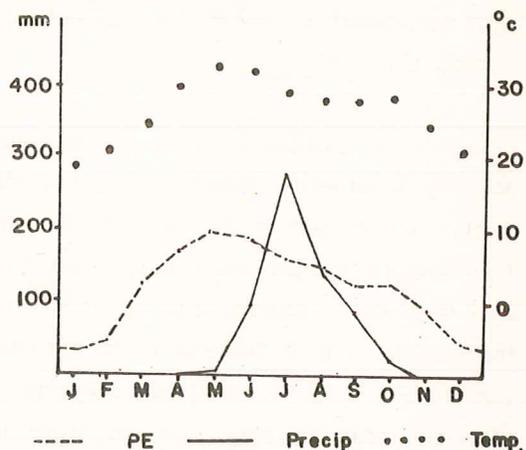
18. BHOLA SERIES (ESTABLISHED)

The Bhola series is a member of the fine, montmorillonitic, hyperthermic family of Vertic Ustochrepts. Bhola soils have very dark greyish brown to dark brown, moderately to strongly alkaline, clay loam to clay A horizons, very dark brown to dark yellowish brown, strongly alkaline, clayey B horizons, and yellowish brown, gravelly sandy loam C horizons.

Typifying pedon : Bhola sandy clay
— cultivated

Rajkot (Gujarat)
24° 18' N, 70° 47' E

Precipitation, Temperature and Water Balance



- Ap 0-16 cm --- Brown (10YR 5/3 D) sandy clay, dark brown (10YR 3/3 M); moderate, medium, subangular blocky; hard, friable, slightly sticky and slighty plastic; many, fine roots; 1 to 2 cm wide cracks; few, fine lime nodules; violently effervescent; moderately alkaline (pH 8.1); clear, smooth boundary.
- A12 16-33 cm --- Brown (10YR 5/3 D) sandy clay, dark brown (10YR 3/3 M); moderate, medium, subangular blocky; hard, friable, sticky and plastic; many, fine roots; 1 to 2 cm wide cracks; few, fine lime nodules; violently effervescent; strongly alkaline (pH 8.7); clear, smooth boundary.
- B21 33-56 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; strong, coarse, subangular blocky; hard, firm, sticky and plastic; many, very fine roots; 1 to 2 cm wide cracks; many, fine lime nodules; violently effervescent; strongly alkaline (pH 8.6); gradual, smooth boundary.
- B22 56-73 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; strong, coarse, subangular blocky; hard, firm, sticky and plastic; common, very fine roots; many, fine lime nodules; violently effervescent; strongly alkaline (pH 8.7); clear, smooth boundary.

- B3 73-96 cm --- Dark yellowish brown (10YR 4/4 M) gravelly clay; massive, friable, sticky and plastic; few, very fine roots; many, medium lime nodules; violently effervescent; strongly alkaline (pH 8.7); abrupt, smooth boundary.
- Ck 96-113 cm --- Yellowish brown (10YR 5/6 M) gravelly sandy loam with pebbles, cobbles and many lime nodules; violently effervescent.

Type location : 21° 45' N, 75° 05' E; village Bhola, tehsil Dhoraji, district Rajkot, Gujarat.

Range in characteristics : The solum is 87 to 122 cm thick below which gravelly weathered basalt with lime occurs. The A horizon is 20 to 35 cm thick. Its colour is in hue 7.5YR and 10YR, value 3, and chroma 2 to 3. The texture ranges from clay loam to clay and structure is weak to strong and medium to coarse, subangular blocky. There are 2 to 12 per cent coarse fragments. The B horizon is 50 to 100 cm thick. Its colour is in hue 7.5YR and 10YR, value 2 to 3 and chroma 2 to 4. The texture is clay loam to clay and gravelly clay. Its structure is moderate, medium to strong, coarse, subangular blocky. 3 to 10 per cent concretionary lime litho-relicts of 5 to 20 cm size are present. 1 to 2 cm wide cracks extend upto 50 cm from the surface.

Geographic setting : Bhola soils are formed in alluvium and colluvium and occur on nearly level to very gently sloping old flood plain and upland at an elevation of 50 to 150 m above MSL in Rajkot district of Gujarat. The climate is semiarid tropical with mean annual temperature of 26.7°C and mean annual rainfall of 673 mm. The estimated MAST is 28.7°C. MSST is 29.0°C and MWST is 23.2°C.

Geographically associated soils : Bhola soils are associated with Shivrajgad and Semla soils. Shivrajgad soils are calcareous and Semla soils have intersecting slickensides. Shivrajgad and Semla soils belong to Vertic Ustochrepts and Udic Chromusterts, respectively.

Drainage and permeability : Moderately well drained with slow permeability.

Use and vegetation : Mostly under wasteland; occasionally cultivated to cotton, wheat and sugarcane (fodder).

Natural vegetation comprises of *Acacia spp.*, *Calotropis spp.*, *Cassia spp.* and *Azadirachta indica*.

Distribution and extent : Extensive in Rajkot district, Gujarat.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Bholia soils are moderately deep to deep and strongly calcareous. They are subjected to severe erosion and water stagnation during rainy season. Exchangeable sodium is high in the lower layer. Due to shrink-swell nature, these soils are less permeable to water. They may pose saline/sodic problems under irrigation. These soils can be reclaimed. Reclaimed soils are productive. They can be cultivated with proper management practices for both rainfed and irrigated crops. Under rainfed agriculture, proper water and soil conservation measures are necessary. They can support a variety of climatically adapted crops.

Interpretative grouping :

- | | | |
|------|---------------------------|--------|
| i) | Land capability sub-class | IIs |
| ii) | Irrigability sub-class | 3s |
| iii) | Productivity potential | Medium |

Soil Series : BHOLA

Classification : Vertic Ustochrept Analysis at : NBSS & LUP

Location : District Rajkot,
Gujarat

Sampling date: February, 1979

Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2mm % of whole soil
		Total			Sand					
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of <2mm →										
Ap	0-16	45.4	12.6	42.0	2.5	4.3	8.4	15.2	15.0	1
A12	16-33	45.5	13.5	41.0	3.0	3.5	13.0	11.0	15.0	-
B21	33-56	27.5	21.9	50.6	3.0	2.0	2.5	4.5	15.5	2
B22	56-73	25.5	26.0	48.5	3.0	2.0	3.0	7.0	10.5	6
B3	73-96	31.5	28.0	40.5	2.0	3.0	2.0	13.5	11.0	39

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2mm %	pH (1:2.0) H ₂ O	E.C. dSm ⁻¹	Bulk density Mgm ⁻³	Water retention	
						33 kPa %	1500 kPa %
0-16	0.70	21.8	8.1	1.05	1.68	24.4	13.4
16-33	0.62	14.3	8.7	1.80	1.86	24.0	14.7
33-56	0.45	18.2	8.6	3.80	1.87	40.0	23.0
56-73	0.29	23.2	8.7	4.10	1.81	42.9	24.0
73-96	0.27	26.6	8.7	0.50	1.72	44.1	23.5

Depth (cm)	Extractable bases					CEC (NH ₄ OAc)	Base saturation NH ₄ OAc %	Ratio CEC/clay
	Ca	Mg	Na	K	Sum			
← c mol (p ⁺)kg ⁻¹ →								
0-16	24.0	12.4	0.8	0.3	37.5	37.9	99	0.90
16-33	22.4	11.6	2.1	0.4	36.5	37.1	98	0.90
33-56	26.8	11.2	3.9	0.5	42.4	44.3	96	0.87
56-73	22.8	13.2	4.3	0.4	40.7	41.9	97	0.86
73-96	22.8	10.0	4.6	0.4	37.8	38.9	97	0.96

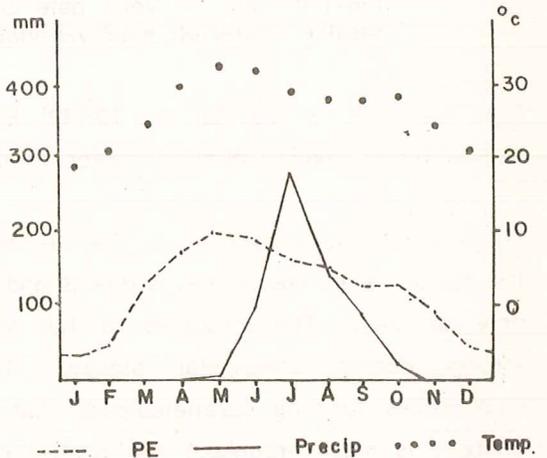
19. SEMLA SERIES (ESTABLISHED)

The Semla series is a member of the very fine, montmorillonitic, hyperthermic family of Udic Chromusterts. Semla soils have dark greyish brown to very dark grey, strongly alkaline, silty clay to clay A horizons, and light grey to very dark greyish brown, strongly alkaline, sandy clay to clay AC horizons over Ck horizons.

Typifying pedon : Semla clay — cultivated

Rajkot (Gujarat)
24° 18' N, 70° 47' E

Precipitation, Temperature and Water Balance



- Ap 0-10 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; moderate, medium, subangular blocky; hard, firm, sticky and plastic; many, fine roots; many, fine, oblique pores; few, fine lime nodules; strongly effervescent; strongly alkaline (pH 8.5); clear, smooth boundary.
- A12 10-23 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; strong, coarse, subangular blocky with shiny pressure faces; hard, firm, sticky and plastic; few, fine roots; many, fine, oblique, tubular pores; few lime nodules; strongly effervescent; strongly alkaline (pH 8.8); clear, smooth boundary.
- A13 23-45 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 30° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; firm, sticky and plastic; few, fine roots; common, fine, oblique, tubular pores; strongly effervescent; strongly alkaline (pH 8.8); gradual, smooth boundary.
- A14 45-115 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 45° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very firm, very sticky and very plastic; few, very fine roots; few, fine pores; strongly effervescent; 3 to 4 per cent lime coated basalt fragments 2 to 10 mm; strongly alkaline (pH 9.0); gradual, smooth boundary.

- AC 115-156 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 30 to 45° from the horizontal that break into strong, coarse, angular blocks with shiny pressure faces; very firm, very sticky and very plastic; many, fine lime nodules; violently effervescent; strongly alkaline (pH 8.9).
- Ck 156-170 cm --- Very pale brown (10YR 7/3 M); calcareous, fine basaltic material; massive; violently effervescent.

Type location : 23° 03' N, 70° 48' E; about 500 m south-west of village Semla, tehsil Gondal, district Rajkot, Gujarat.

Range in characteristics : The A horizon is more than 100 cm thick. Its colour is in hue 10YR, value 3 and chroma 1 to 2. The texture is silty clay to clay. The structure of the surface layer is moderate, medium to strong, coarse, subangular blocky. The subsoil layers have intersecting slickensides forming parallelepipeds that break into angular blocks. The lime content is high throughout the profile depth. Cracks 2 to 4 cm wide taper and extend to 100 cm depth. Gilgai microrelief is common. Lower horizons remain moist for most part of the year.

Competing series and their differentiae : Sokhada series is brown to dark brown and compact in the subsoil. Sokhada soils belong to Typic Chromusterts.

Geographic setting : Semla soils are formed in basaltic alluvium and occur on nearly level to very gently sloping lower piedmont at an elevation of 100 to 120 m above MSL in Rajkot district of Gujarat. The climate is semiarid tropical with mean annual temperature of 26.7°C and mean annual rainfall of 673 mm. The estimated MAST is 28.7°C. MSST is 29.0°C and MWST is 23.2°C.

Geographically associated soils : Semla soils are associated with Shivraj-gadh and Bholia soils which are Vertic Ustochrepts.

Drainage and permeability : Imperfectly drained with slow permeability.

Use and vegetation : Cultivated to rainfed cotton, sorghum, wheat, sugarcane and gram.

Natural vegetation comprises of *Acacia spp.*, *Cassia spp.*, *Calotropis spp.* and *Azadirachta indica*.

Distribution and extent : Extensive in Rajkot district of Gujarat.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Semla soils are fine textured with high shrink-swell potential. They are prone to develop salinity and sodicity even when irrigated with water low in soluble salts. During monsoon, crops may be adversely affected due to stagnation of water. These soils are susceptible to erosion even on very gently sloping lands. They are highly productive with proper management and drainage under both rainfed and irrigated agriculture.

(a) *Interpretative grouping* :

i) Land capability sub-class	III _s
ii) Irrigability sub-class	3d
iii) Productivity potential	High

(b) *Yield* : Based on data from farmers' fields

Crop	Yield ($\text{Mg}^{-1}\text{ha}^{-1}$)	
	Farmers' practice	Improved practices
Groundnut	0.5	1.3
Cotton	0.6	1.0
Pearl millet	0.5	1.8
Sorghum	0.3	1.6
Pigeon pea	0.6	1.0
Wheat	1.0	2.2

Soil Series : SEMLA

Classification : Udic Chromustert

Analysis at : NBSS & LUP
Regional Centre,
NagpurLocation : District Rajkot,
Gujarat

Sampling Date: November, 1978

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of whole soil
		Total			Sand					
		Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-10	22.6	20.5	56.9	6.4	4.4	2.3	2.3	7.0	-
A12	10-23	20.5	19.5	60.0	5.0	3.5	2.3	3.3	6.0	-
A13	23-45	23.6	15.5	60.9	5.0	3.0	2.4	2.2	11.0	-
A14	45-115	19.4	18.7	61.9	5.6	2.5	2.0	2.0	7.3	3
AC	115-156	16.6	25.6	57.8	2.0	2.0	5.0	1.5	6.1	2

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.0) H ₂ O	E.C. (1:2.5) H ₂ O dS m ⁻¹	Bulk density Mgm ⁻³	Water retention 33kPa	1500 kPa
0-10	0.72	21.8	8.5	0.50	1.80	31.6	16.1
10-23	0.67	21.1	8.8	0.70	1.80	32.9	15.7
23-45	0.62	24.7	8.8	0.80	1.82	35.9	16.5
45-115	0.59	21.7	9.0	1.10	1.89	42.2	20.4
115-156	0.43	22.1	8.9	0.90	1.82	40.6	20.8

Depth (cm)	Extractable bases					CEC NH ₄ OAc	Base saturation NH ₄ OAc %	Ratio CEC clay
	Ca	Mg	Na	K	Sum			
← c mol (p ⁺) kg ⁻¹ →								
0-10	32.3	12.0	1.4	1.0	46.7	47.8	98	0.84
10-23	37.6	16.8	2.7	0.9	58.0	58.9	98	0.96
23-45	34.8	16.4	2.9	0.6	54.7	55.7	98	0.51
45-115	30.8	20.0	3.8	0.8	55.4	56.1	99	0.91
115-156	27.6	19.6	3.1	0.4	50.7	51.7	98	0.88

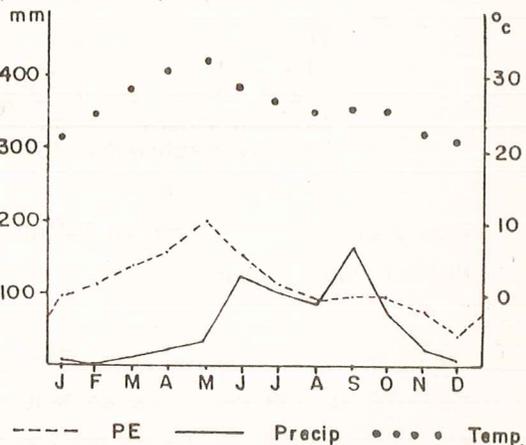
20. OTUR SERIES (ESTABLISHED)

The Otur series is a member of the fine, montmorillonitic, isohyperthermic family of Typic Chromusterts. Otur soils have dark brown to very dark greyish brown, moderately alkaline, silty clay to clay A horizons, dark brown to dark yellowish brown, moderately alkaline, silty clay to clay AC horizons and dark yellowish brown, strongly alkaline, gravelly silty clay loam C horizons.

Typifying pedon : Otur silty clay -- cultivated

Ahmadnagar (Maharashtra)
19° 05' N, 74° 55' E

Precipitation, Temperature and Water Balance



- Ap 0-18 cm --- Dark brown (10YR 3/3 D&M) silty clay; coarse, prismatic breaks into moderate, medium, subangular blocky peds; hard, firm, sticky and plastic; many, fine and medium roots; 2 to 3 cm wide cracks; very few, fine, indurated lime nodules; slightly effervescent; moderately alkaline (pH 8.4); clear, smooth boundary.
- A12 18-35 cm --- Dark brown (10YR 3/3 D&M) silty clay; coarse slickensides close enough to intersect breaks into moderate, coarse, angular blocky peds; hard, firm, sticky and plastic; many, fine roots between peds; 2 to 2.5 cm wide cracks; few, fine, indurated lime nodules; slightly effervescent; moderately alkaline (pH 8.4); clear, smooth boundary.
- A13 35-70 cm --- Dark brown (10YR 3/3 D&M) clay; coarse intersecting slickensides forming parallelepipeds with 30 to 35 cm long axes tilting at an angle of 45° from horizontal that breaks into strong, coarse, angular blocky peds; very hard, very firm, very sticky and plastic; few, fine and medium roots; 1.5 to 2 cm wide cracks; many, soft and indurated lime; strongly effervescent; strongly alkaline (pH 8.5); clear, wavy boundary.
- AC 70-110 cm --- Dark brown (10YR 3/3 D&M) silty clay; many, dark yellowish brown (10YR 3/4) interdigitating upward cores from

underlying C horizon in the matrix; scattered dark yellowish brown (10YR 3/4) mottles; coarse intersecting slickensides forming parallelepipeds with 30 to 35 cm long axes tilting at 30 to 45° from horizontal and break into strong, coarse, angular blocky peds; hard, firm, sticky and plastic; few, fine roots; 1 to 1.5 cm wide cracks; many, medium, indurated lime nodules and soft, powdery lime; strongly effervescent; moderately alkaline (pH 8.4); gradual, wavy boundary.

- C 110-120 cm --- Dark yellowish brown (10YR 4/4 D&M) gravelly silty clay loam; weak, medium, subangular blocky; slightly hard, friable, sticky and plastic; many lime coated basaltic gravels with medium, indurated lime nodules and soft lime; violently effervescent; strongly alkaline (pH 8.6).

Type location : 19°59' N, 74°16' E; village Pimpalwadi, tehsil Junnar of district Pune, Maharashtra.

Range in characteristics : The thickness of the A and AC horizons ranges from 90 to 130 cm. The content of clay within the depth of 18 cm to 100 cm ranges from 40 to 60 per cent and coarse fragments larger than 2 mm size ranges from 2 to 8 per cent. The CaCO₃ content ranges from 3 to 7 per cent through depth. The colour of A horizon is predominantly in the hue of 10YR, value 2 to 3 and chroma 2 to 3 for dry and moist soil. The colour of C horizon is in hue 10YR, value 4 to 5, and chroma 3 to 5. The contents of coarse fragments increase abruptly in C horizon and range from 25 to 30 per cent.

In most of the years the surface cracks of 3 to 7 cm wide are observed. The cracks extend vertically down to 60 to 70 cm in the pedons and remain open for more than 150 days in most of the years till the onset of monsoon rain.

Competing series and their differentiae : The competing soils are those of Umbraj and Nimone series. The solum depth of Umbraj series ranges from 100 to 150 cm and in Nimone series it ranges from 90 to 100 cm. The clay content in Umbraj and Nimone series ranges from 52 to 65 per cent and 50 to 60 per cent, respectively. The silt content is relatively higher in Otur than Umbraj and Nimone soils. The colours of Umbraj and Nimone

soils are in hue of 10YR with values 2 to 3 and chroma 2 for moist soils. Nimone soils express relatively much darker colour. The colour of Otur soils is relatively more towards brownish tinge ranging from 10YR 4/3 to 10YR 3/3 as compared to Umbraj soils. Otur soils, as compared to Umbraj and Nimone soils develop wider cracks which extend much deeper and remain open for more number of days in most of the years.

Geographic setting : Otur soils are formed in basaltic alluvium on very gently sloping outer terraces in the old flood plain of Godavari river system at an elevation of 550 m above MSL in the Pune and Ahmadnagar districts of Maharashtra. The climate is semiarid tropical with mean annual temperature of 25.5°C and mean annual rainfall of 650 mm. The estimated MAST is 26.5°C. The difference between MSST and MWST is less than 5°C.

Geographically associated soils : The associated soils are of Nimone and Dholwad series. Nimone soils are very deep and Typic Chromusterts while soils of Dholwad series are deep and Vertic Ustropepts.

Drainage and permeability : Moderately well drained with moderate to moderately slow permeability.

Use and vegetation : Cultivated for pearl millet, groundnut, wheat and gram.

Natural vegetation comprises mainly of *Acacia spp.* and needle grasses.

Distribution and extent : Extensive in upper flood plain of Godavari river system along the leeward side of Sahyadri range in Pune and Ahmadnagar districts of Maharashtra.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Otur soils are clayey, very deep and develop cracks on drying due to shrink-swell nature of the clay. They are moderately well drained and have high nutrient and water retention capacity. All climatically adapted crops can be grown.

(a) *Interpretative grouping* :

- | | |
|------------------------------|----------------|
| i) Land capability sub-class | IIs - IIIs |
| ii) Irrigability sub-class | 3sd |
| iii) Productivity potential | Medium to high |

(b) *Yield* :

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Cotton	1.2	1.9
Groundnut	0.6	1.2
Sorghum	0.7	1.8
Pearl millet	0.8	2.0
Pigeon pea	0.6	0.9
Chick pea	0.6	1.2

Note : The soil texture is based on International particle size classification.

Soil Series : OTUR

Classification : Typic Chromustert

Location : District Pune,
MaharashtraAnalysis at : NBSS & LUP,
Regional Centre,
Nagpur.

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments > 2 mm of whole soil
		Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	
		% of < 2 mm				
Ap	0-18	6.6	14.7	25.5	53.2	2
A12	18-35	6.5	13.7	27.3	52.5	3
A13	35-70	5.8	14.0	24.3	55.9	4
AC	70-110	8.9	20.5	28.3	42.3	8
C	110-120	14.8	25.3	27.5	32.4	30

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	EC (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³	COLE cm/cm	Water holding capacity %
0-18	0.62	2.3	8.4	0.20	1.54	0.10	40.1
18-35	0.68	2.9	8.4	0.35	1.71	0.11	37.4
35-70	0.45	3.9	8.5	0.30	1.75	0.12	37.3
70-110	0.41	4.8	8.4	0.26	1.80	0.11	34.0
110-120+	0.25	6.6	8.6	0.25	1.65	-	-

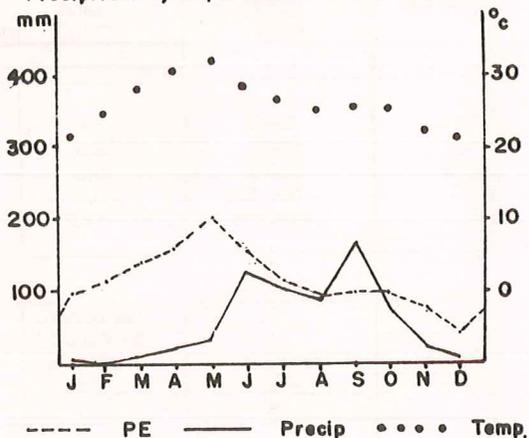
Depth (cm)	Extractable bases		CEC NH ₄ OAc	Ratio CEC clay
	Ca	Mg		
c mol(p ⁺)Kg ⁻¹				
0-18	37.4	4.2	55.6	1.05
18-35	38.3	5.1	56.2	1.07
35-70	35.2	7.1	59.3	1.06
70-110	35.2	8.2	46.0	1.08
110-120+	23.0	-	35.3	1.09

21. NIMONE SERIES (ESTABLISHED)

The Nimone series is a member of the fine, montmorillonitic, isohyperthermic family of Typic Chromusterts. Nimone soils have dark greyish brown to dark brown, moderately to strongly alkaline, silty clay to clay A horizons, grading to yellowish brown to dark yellowish brown, strongly alkaline, gravelly clay C horizons.

Typifying pedon : Nimone clay -- cultivated

Ahmadnagar (Maharashtra)
19° 05' N, 74° 55' E
 Precipitation, Temperature and Water Balance



- Ap 0-18 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); moderate, medium, subangular blocky; hard, friable, sticky and plastic; many, fine roots; few, fine to medium, irregularly rounded lime nodules; strongly effervescent; moderately alkaline (pH 8.1); diffuse, smooth boundary.
- A12 18-46 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark brown (10YR 2/2 M); coarse intersecting slickensides breaking into strong, medium, subangular blocky peds with shiny pressure faces; hard, firm, sticky and plastic; many, fine and medium roots; few, medium, irregularly rounded lime nodules; strongly effervescent; moderately alkaline (pH 8.2); diffuse, smooth boundary.
- A13 46-76 cm --- Dark greyish brown (10YR 4/2 D) clay, very dark brown (10YR 2/2 M); few, medium, dark grey (10YR 4/1) and black (10YR 2/1) mottles; coarse, intersecting slickensides forming parallelepipeds with 20 to 25 cm long axes tilted at about 45° from horizontal breaking into strong, coarse, angular blocky peds with shiny pressure faces; very hard, firm, sticky and plastic; few, medium roots; strongly effervescent; moderately alkaline (pH 8.4); diffuse, smooth boundary.
- A14 76-125 cm --- Dark greyish brown (10YR 4/2 D) gravelly clay, very dark brown (10YR 2/2 M); few, coarse, grey (10YR 5/1) and very dark grey (10YR 3/1) disseminated mottles; coarse, intersecting

Note : 2 to 3 cm thick loose dark grey (10YR 4/1) surface mulch is common.

slickensides forming parallelepipeds with 40 to 45 cm long axes tilted at about 45° from horizontal breaking into strong, coarse, angular blocky peds with shiny pressure faces; very hard, firm, sticky and plastic; many, medium to coarse, irregularly rounded lime nodules; violently effervescent; strongly alkaline (pH 8.5), clear, wavy boundary.

Ck 125-139 cm --- Dark yellowish brown (10YR 3/4 M) gravelly clay; massive, firm, sticky and plastic; many, medium and coarse lime nodules; violently effervescent; many gravels and pebbles; strongly alkaline (pH 8.6).

Type location : 18° 24' N, 74° 42' E; village Nimone, tehsil Sirur, district Pune, Maharashtra.

Range in characteristics : The thickness of the solum ranges from 100 to 140 cm. The contents of particles coarser than 2 mm range from 5 to 25 per cent and content of CaCO₃ range from 3 to 10 per cent. The contents of clay in the series control section range from 50 to 60 per cent. Due to differential impedance to internal drainage there are coarse to medium, disseminated mottles of dark grey (10YR 4/1), very dark grey (10YR 3/1) and black (N 2/0) colours in A13 and A14 horizons.

The colour of soils in A horizon ranges from dark greyish brown (10YR 4/2) to very dark brown (10YR 2/2) for dry and moist soils, while the colour in C horizon ranges from brownish yellow (10YR 6/6) to yellowish brown (10YR 5/4) for dry and dark yellowish brown (10YR 3/4, 4/4) for moist soils. The moisture regime between 18 to 30 cm of the surface remains at or below wilting point for 150 cumulative days while the lower part remains moist. The surface cracks appear in the later part of winter and remain open till the onset of monsoon. Sixty cm deep and 2 to 3 cm wide cracks remain open for approximately 150 days in most of the years. Gilgai relief appears during dry period usually with the frequencies of linear distances measuring 1/2 to 3/4 of a metre between micro high and micro low.

Competing series and their differentiae : The competing soils are those of Umbraj series which are very deep and imperfectly drained soils. The content of clay within the series control section of Umbraj soils is relatively less than Nimone soils.

Geographic setting : Nimone soils are formed in alluvium and colluvium from piedmont slope and occur on level to gently sloping piedmont plain at an elevation of 550 m above MSL in Pune district of Maharashtra. The climate is semiarid tropical with mean annual temperature of 25.5°C and mean annual rainfall of 650 mm. The estimated MAST is 26.5°C . The difference between MSST and MWST is less than 5°C .

Geographically associated soils : Nimone soils are associated with Umbraj, Dholwad, Sangamner and Annapur soils. The Umbraj soils belong to Typic Chromusterts, Dholwad and Sangamner belong to Vertic Ustropepts and Annapur belong to Fluventic Ustropepts.

Drainage and permeability : Imperfectly drained with slow to very slow permeability.

Use and vegetation : These are mostly cultivated soils. At places there may be patches of cultural waste lands with isolated stands of *Acacia arabica* and needle grasses.

Distribution and extent : These soils are extensive and occur on lower piedmont slope merging with flood plain along the leeward side of Sahyadri in Maharashtra.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : The Nimone soils are fine textured with high shrink-swell potential. They are prone to develop salinity and sodicity even when irrigated with water low in soluble salts. During monsoon, crops may be adversely affected due to stagnation of water. These soils are also susceptible to erosion even on gently sloping land. They are productive with proper management and drainage under both rainfed and irrigated agriculture.

(a) *Interpretative grouping* :

- | | |
|------------------------------|----------------|
| i) Land capability sub-class | IIsw - IIIsw |
| ii) Irrigability sub-class | 3sd |
| iii) Productivity potential | Medium to high |

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Cotton	0.6	1.2
Chick pea	0.7	1.3
Safflower	0.6	1.1
Sorghum	0.5	1.5
Groundnut	0.5	1.0
Pigeon pea	0.5	0.8

Note : Soil texture is based on International particle size classification.

Soil Series : NIMONE

Classification : Typic Chromustert

Location : District Pune,
MaharashtraAnalysis at : NBSS & LUP,
Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments >2 mm % of whole soil
		Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	
		← % of <2mm →				
Ap	0-18	10.3	21.2	14.3	54.2	9
A12	18-46	10.0	22.0	13.0	55.0	6
A13	46-76	10.4	21.5	12.3	55.8	9
A14	76-125	10.1	18.1	12.7	59.1	20
Ck	125-139	22.4	21.7	10.6	45.3	30

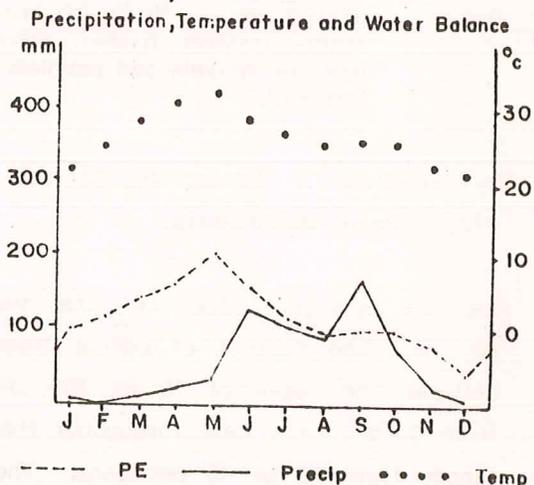
Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³ cm/cm	COLE cm/cm
0-18	0.6	3.0	8.1	0.3	1.6	0.10
18-46	0.3	8.1	8.2	0.3	1.6	0.11
46-76	0.5	9.5	8.4	0.4	1.6	0.11
76-125	0.4	10.2	8.5	0.5	1.6	0.11
125-139	0.4	13.1	8.6	0.6	1.6	0.12

Depth (cm)	Extractable bases		CEC NH ₄ OAc
	Ca	Mg	
		← c mol (p ⁺)kg ⁻¹ →	
0-18	42.5	7.4	56.9
18-46	38.0	8.2	56.4
46-76	38.0	7.5	59.8
76-125	33.0	8.1	56.1
125-139	21.3	8.9	35.0

22. DHOLWAD SERIES (ESTABLISHED)

The Dholwad series is a member of the fine-loamy, montmorillonitic, isohyperthermic family of Vertic Ustropepts. Dholwad soils have dark greyish brown to brown, mildly alkaline, clay loam to clay A horizons and brown to dark greyish brown, mildly to moderately alkaline, gravelly silty clay to gravelly clay B horizons over yellowish brown to dark yellowish brown, strongly alkaline, gravelly sandy loam to gravelly loamy sand C horizons.

Ahmadnagar (Maharashtra)
19° 05' N, 74° 55' E



Typifying pedon : Dholwad clay — cultivated

- Ap 0-19 cm --- Greyish brown (10YR 5/2 D) clay; dark brown (10YR 4/3 M), weak, medium, subangular blocky; slightly hard, friable, sticky and plastic; many, fine roots; many, fine pores; 1 to 2 cm wide cracks; few, fine lime nodules; strongly effervescent; mildly alkaline (pH 7.4); gradual, smooth boundary.
- B2 19-40 cm --- Brown (10YR 5/3 D) gravelly clay, dark brown (10YR 3/3 M); strong, medium, subangular blocky peds with shiny pressure faces; hard, firm, sticky and plastic; many, fine to medium roots; 1 to 2 cm wide cracks; lime nodules; violently effervescent; mildly alkaline (pH 7.8); gradual, smooth boundary.
- Bk3 40-64 cm --- Dark brown (10YR 4/3 D, 3/3 M) gravelly clay loam; moderate, medium, subangular blocky peds with shiny pressure faces; hard, friable, sticky and plastic; 1 to 1.5 cm wide cracks; irregularly, yellowish brown lime nodules and fine to medium veins of powdery lime along the lower part; violently effervescent; many, lime coated basalt fragments; few, coarse, yellowish brown (10YR 5/4) worm tracks; moderately alkaline (pH 8.1); gradual, smooth boundary.

- IIcK1 64-97 cm --- Yellowish brown (10YR 5/4 D) gravelly loam, dark yellowish brown (10YR 4/4 M); weak, medium, subangular blocky; slightly hard, friable, slightly sticky; few, coarse roots; many, irregular, yellowish lime nodules and lime coated gravels; sporadic pockets and medium veins of powdery lime; violently effervescent; strongly alkaline (pH 8.5); clear, smooth boundary.
- IIIcK2 97-150 cm --- Yellowish brown (10YR 5/8 D, 5/4 M) gravelly loamy sand; massive; friable, non-sticky; many, medium to coarse, lime nodules; gravels and pebbles; violently effervescent; strongly alkaline (pH 8.6).

Type location : 19° 38' N, 74° 14' E; village Pimpalwandi, tehsil Junnar, district Pune, Maharashtra.

Range in characteristics : The thickness of solum ranges from 50 to 80 cm. The content of coarse fragments ranges from 20 to 50 per cent between the depth of 15 to 100 cm, while the content of CaCO₃ ranges from 6 to 21 per cent throughout the depth. The clay content in the solum ranges from 30 to 45 per cent. The colour of A horizon is in hue 10YR, value 4 to 5 in dry soils and 3 to 4 in moist soils while chroma varies from 2 to 3 for both dry and moist soils. The texture ranges from clay loam to clay and at places silty clay loam is also met with. The structure ranges from weak, fine, subangular blocky to moderate, medium, subangular blocky. The soil colour in B2 horizon usually ranges from brown (10YR 5/3) to dark greyish brown (10YR. 4/2) for dry soil while it ranges from dark brown (10YR 4/3, 3/3) to dark yellowish brown (10YR 4/4) for moist soils. The texture of the B horizon is usually gravelly silty clay to gravelly clay. The structure is generally strong, medium, subangular blocky with shiny pressure faces. The colour is dark brown (10YR 4/3, 3/3) and at places dark yellowish brown (10YR 4/4, 3/4) for dry and moist soils, respectively. The texture ranges from gravelly clay loam to gravelly sandy clay loam. The structure ranges from moderate to strong, medium, subangular blocky. The colour of C horizon is yellowish brown (10YR 5/8, 5/4) to dark yellowish brown (10YR 4/4, 3/4) for dry and moist soils, respectively. The texture of the Ck horizon is gravelly sandy loam to gravelly loam sand. There are many medium to big pockets and veins of soft powdery lime which increase with depth.

Competing series and their differentiae : The competing series are the soils of Annapur and Sawargaon series which are deep with the solum thickness ranging from 55 to 85 cm and 50 to 80 cm, respectively. The clay content in Annapur soils ranges from 25 to 35 per cent while in Sawargaon soils ranges from 35 to 55 per cent. The CaCO_3 content in Annapur series ranges from 5 to 14 per cent and in Sawargaon series it ranges from 4 to 12 per cent. The Annapur and Sawargaon soils belong to Fluventic Ustropepts and Vertic Ustropepts respectively.

Geographic setting : Dholwad soils are formed in basaltic alluvium and occur on gently sloping old levees or minor terraces in Godavari flood plain at an elevation of 550 m above MSL in the Pune and Ahmadnagar districts of Maharashtra. The climate is semiarid tropical with mean annual temperature of 25.5°C and mean annual rainfall of 650 mm. The estimated MAST is 26.5°C . The difference between MSST and MWST is less than 5°C .

Geographically associated soils : These are Otur and Umbraj soils which are very deep and both qualify for Typic Chromusterts.

Drainage and permeability : Well drained with moderate permeability.

Use and vegetation : These are cultivated to rainfed crops where conditions are favourable otherwise left as fallow. The major rainfed crops are pearl millet and sorghum.

The natural vegetation comprises of sporadic growth of coarse grasses and thorny bushes with lonely stands of *Acacia arabica*.

Distribution and extent : These soils are extensive and occur on the levees and inner terraces of rivers Mula and Mutha tributaries of Godavari river and along the course of several streamlets in upper catchment of Godavari river in the Pune and Ahmadnagar districts of Maharashtra.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Nagpur.

Interpretation : Dhalwad soils are clayey and moderately deep. These soils develop cracks on drying due to the presence of high shrink-swell nature of clay. They are well drained and have medium nutrient and water retention capacity. These are severely gullied at places along the streams and require measures for checking soil erosion. These soils are suitable for rainfed crops like pearl millet and sorghum.

Interpretative grouping :

i) Land capability sub-class	IIe - IIIe
ii) Irrigability sub-class	3st
iii) Productivity potential	Medium

Note : The soil texture is based on International particle size classification.

Soil Series : DHOLWAD

Classification : Vertic Ustropept

Location : District Pune,
MaharashtraAnalysis at : NBSS & LUP,
Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments > 2 mm % of whole soil
		Coarse sand (2-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (< 0.002)	
		← % of < 2 mm →				
Ap	0-19	2.6	42.6	17.7	37.1	14
B2	19-40	0.6	36.5	17.1	45.8	21
B3k	40-64	0.7	46.7	19.1	33.5	36
IIcK1	64-97	2.8	59.9	17.6	19.7	46
IIIcK1	97-150	5.3	75.4	9.2	10.1	50

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	EC (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³	COLE cm/cm	Water holding capacity %
0-19	0.70	6.4	7.4	0.35	1.69	0.06	30.5
19-40	0.33	10.1	7.8	0.50	1.40	0.09	33.1
40-64	0.18	18.2	8.1	0.50	1.40	0.08	26.2
64-97	0.15	20.4	8.5	0.60	1.30	0.05	-
97-150	0.10	-	8.6	0.60	-	-	-

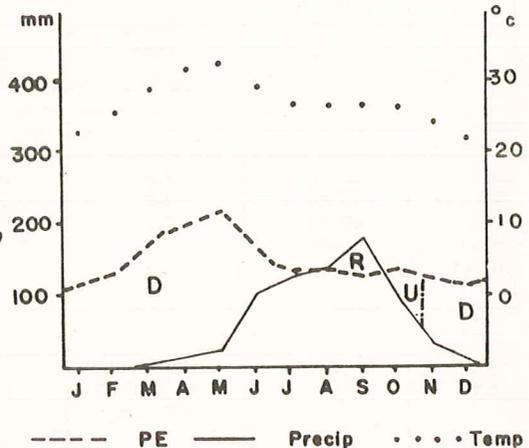
Depth (cm)	Extractable bases		CEC NH ₄ OAc	Ratio CEC/clay
	Ca	Mg		
		← c mol(p ⁺)kg ⁻¹ →		
0-19	30.7	5.7	39.9	1.07
19-40	32.3	7.4	42.8	0.93
40-64	23.5	6.1	32.1	0.96
64-97	-	-	-	-
97-150	-	-	-	-

23. BARSII SERIES (TENTATIVE)

The Barsii series is a member of the very fine, montmorillonitic, isohyperthermic family of Typic Chromusterts. Barsii soils have very dark grey to very dark greyish brown, moderately to strongly alkaline, clayey A horizons, and dark yellowish brown and dark brown moderately alkaline, clayey AC and C horizons.

Typifying pedon : Barsii clay — cultivated

Sholapur (Maharashtra)
17°40' N, 75°54' E
 Precipitation, Temperature and Water Balance



- Ap 0-12 cm --- Very dark grey to very dark greyish brown (10YR 3/1.5 D) clay, very dark greyish brown (10YR 3/2 M); moderate, medium, subangular blocky breaking in to moderate, medium, granular peds; slightly hard, friable, sticky and plastic; many, fine roots; common, fine interstitial pores; cracks 2 to 3 cm wide; many, medium and large lime-coated basalt fragments; strongly alkaline (pH 8.5); diffuse, smooth boundary.
- A12 12-36 cm --- Very dark greyish brown (10YR 3/2 M) clay; strong, coarse, angular blocky peds with shiny pressure faces; firm, sticky and plastic; common, fine roots; fine, interstitial pores; cracks 1 to 2 cm wide; common, large lime coated basalt fragments; moderately alkaline (pH 8.4); diffuse, smooth boundary.
- A13 36-69 cm --- Very dark greyish brown (10YR 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 30 to 35° from the horizontal that break into strong, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; few, fine and coarse roots; cracks 0.5 to 1 cm wide; few, lime nodules; few, large basalt fragments; moderately alkaline (pH 8.3); clear, wavy boundary.

Pedon described by the core group H.P. Choudhary, J.C. Bhattacharjee and S.G. Pandey; R.J. Landey, V.K. Mishra, G.V. Patel and B.R. Tembhare associated. November 16, 1979.

- A14 69-114 cm --- Dark greyish brown to very dark greyish brown (10YR 3.5/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 45 to 50° from the horizontal that break into strong, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; few, fine and coarse roots; few, fine pores; few, lime nodules; few, large lime coated basalt fragments; moderately alkaline (pH 8.4); clear, wavy boundary.
- AC 114-147 cm --- Dark yellowish brown and very dark greyish brown (10YR 4/4, 3/2 M) clay; intersecting slickensides forming coarse parallelepipeds with long axes tilted 30 to 35° from the horizontal that break into strong, coarse, angular blocky peds with shiny pressure faces; very hard, sticky and plastic; few, lime nodules; few, large basalt fragments; moderately alkaline (pH 8.4); diffuse, smooth boundary.
- C 147-167 cm --- Dark yellowish brown and dark brown (10YR 4/4, 3/3 M) clay; moderate, medium, angular blocky with shiny pressure faces; very firm, very sticky and very plastic; many, lime coated basalt fragments; moderately alkaline (pH 8.2).

Type location : 18° 13' N, 75° 40' E; village Kalegaon, tehsil Barsi, district Solapur, Maharashtra.

Range in characteristics : The A horizon is more than 100 cm thick. Its colour is in hue 10YR, value 3 to 4 and chroma 2 to 4. The texture is clayey with more than 65 per cent clay. The structure of the surface layer is subangular blocky breaking to granular. The subsoil layers have intersecting slickensides forming parallelepipeds that break into angular blocks. Lime content increases from 0.5 to 5 per cent with depth.

Geographic setting : Barsi soils are formed in basaltic alluvium on level to gently sloping land at an elevation of 450 to 500 m above MSL in Solapur and Osmanabad districts of Maharashtra. The climate is semiarid tropical with mean annual temperature of 27.1°C and mean annual rainfall of 740 mm. The estimated MAST is 28.1°C. MSST is 28.9°C and MWST is 26.3°C.

Drainage and permeability : Moderately well drained with slow permeability.

Use and vegetation : Cultivated to sorghum, pigeon pea, groundnut and safflower.

Natural vegetation comprises of *Acacia spp.*, *Zizyphus spp.*

Distribution and extent : Extensive in Solapur and Osmanabad districts of Maharashtra.

Series proposed : Department of Agriculture, Maharashtra.

Interpretation : Barsi soils are fine textured with high shrink-swell potential. They are prone to salinity and alkalinity if irrigated without provision of suitable drainage. They are also susceptible to erosion. The soils are productive and crops respond to management under both rainfed and irrigated agriculture.

(a) *Interpretative grouping* :

i) Land capability sub-class	III _s
ii) Irrigability sub-class	3d
iii) Productivity potential	Medium

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Groundnut	0.5	1.2
Pigeon pea	0.7	1.3
Sorghum	0.6	1.1
Safflower	0.6	1.3
Sunflower	0.5	1.3
Chick pea	0.4	1.2

Soil Series : BARSII

Classification : Typic Chromustert

Analysis at : NBSS & LUP

Location : District Solapur,
Maharashtra

Sampling Date: November 16, 1979

Regional Centre,
Nagpur

Horizon	Depth (cm)	Size class and particle diameter (mm)										Coarse fragments >2mm % of whole soil
		Total										
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	Clay (0.002-0.001)	Clay (<0.001)	
← % of < 2 mm →												
Ap	0-12	8.6	25.5	65.9	2.6	2.5	0.3	0.7	2.5	26.6	39.3	5
A12	12-36	7.2	28.5	64.3	1.1	1.1	2.2	0.3	2.5	21.5	42.8	5
A13	36-69	7.0	24.0	69.0	0.1	0.1	0.2	0.3	6.3	28.9	40.1	-
A14	69-114	2.8	21.0	76.2	0.1	-	0.1	0.2	2.4	26.1	50.1	-
AC	114-147	10.3	18.6	71.1	0.5	1.0	1.8	2.2	4.8	15.9	55.2	6
C	147-167	18.1	23.5	58.4	2.3	1.3	3.2	4.2	7.1	47.2	11.2	10

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ <2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Bulk density Mgm ⁻³	Water Retention		COLE cm/cm
						33 kPa %	1500 kPa %	
0-12	0.53	0.4	8.5	0.20	1.58	45.1	30.6	0.13
12-36	0.52	0.4	8.4	0.30	1.52	47.0	28.8	0.18
36-69	0.50	0.3	8.3	0.35	1.70			0.19
69-114	0.53	1.1	8.4	0.50	1.87			0.18
114-147	0.39	4.7	8.4	0.70	1.83			0.16
147-167	0.26	5.2	8.2	0.75	1.69			0.14

Depth (cm)	Extractable bases			CEC NH ₄ OAc	Exch-ange-able sodium %	Ratio CEC clay
	Ca+Mg	Na	K			
	← c mol(p ⁺)kg ⁻¹ →					
0-12	67.6	1.7	0.8	70.1	2	1.06
12-36	52.9	3.5	0.8	57.2	6	0.89
36-69	60.1	4.5	0.8	65.4	7	0.95
69-114	50.2	6.7	0.6	57.5	12	0.76
114-147	58.7	7.3	0.8	66.8	11	0.94
147-167	56.3	7.5	0.8	64.6	12	1.10

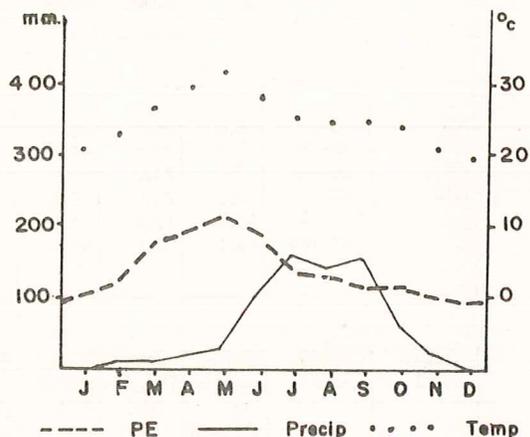
24. KASIREDDIPALLI SERIES (ESTABLISHED)

The Kasireddipalli series is a member of the fine/very fine, montmorillonitic, isohyperthermic family of Typic Pellusterts. Kasireddipalli soils have very dark grey to very dark greyish brown, strongly to very strongly alkaline, clayey A horizons, very dark grey, very strongly alkaline, clayey AC horizons, and light yellowish brown to light olive brown, very strongly alkaline, clayey C horizons.

Typifying pedon : Kasireddipalli clay
— cultivated

Hyderabad (A.P.)
17° 27' N, 78° 28' E

Precipitation, Temperature and Water Balance



- Ap 0-20 cm --- Very dark grey (10YR 3/1 M) clay; moderate, medium, subangular blocky and weak, medium, granular; friable, sticky and plastic; common, medium and fine roots; many, fine to medium, tubular impeded pores; common, fine, subrounded, segregated lime nodules and powdery lime; strongly effervescent; strongly alkaline (pH 8.8); clear, smooth boundary.
- A12 20-40 cm --- Very dark grey (10YR 3/1 M) clay; strong, coarse, prismatic breaking to moderate, medium, subangular blocky peds with shiny pressure faces; firm, sticky and plastic; common, medium and fine roots; few, fine, impeded and exped pores; common, subrounded, fine to medium, lime nodules; strongly effervescent; few quartz fragments; very strongly alkaline (pH 9.2); gradual, smooth boundary.
- A13 40-60 cm --- Very dark grey to black (10YR 2.5/1 M) clay; intersecting slickensides forming coarse parallelepipeds breaking into strong, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and plastic; few, medium roots; few, fine to

Pedon described by the core group J.C. Bhattacharjee and N.K. Barde; K.V. Seshagiri Rao associated. July 23, 1980.

very fine, oblique, impeded and expanded pores; few, coarse to medium, lime nodules; strongly effervescent; very strongly alkaline (pH 9.4); gradual, smooth boundary.

- A14 60-90 cm --- Very dark grey to black (10YR 2.5/1 M) clay; intersecting slickensides forming coarse parallelepipedes breaking into strong, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; few, fine roots; very fine, irregular, expanded pores; common, fine to medium lime nodules strongly effervescent; very strongly alkaline (pH 9.4); clear, wavy boundary.
- AC 90-130 cm --- Very dark grey (10YR 3/1 M) clay; common, coarse, distinct, very dark greyish brown to black (2.5Y 2.5/2) and light olive brown (2.5Y 5/4) mottles; intersecting slickensides forming coarse parallelepipedes breaking into strong, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; few, medium roots; very fine, irregular pores; few, fine, lime nodules; strongly effervescent; few quartz fragments; very strongly alkaline (pH 9.4); gradual, smooth boundary.
- C 130-180 cm --- Light yellowish brown to light olive brown (2.5Y 5.5/5 M) clay; few, coarse, faint, dark greyish brown (2.5Y 4/2) mottles; intersecting slickensides forming parallelepipedes breaking into moderate, coarse, angular blocky peds with shiny pressure faces; very firm, very sticky and very plastic; strongly effervescent; very strongly alkaline (pH 9.4).

Type location : 17°35' N, 78°17' E; Block No. BW 7, ICRISAT Farm, village Patancheru, tehsil and district Medak, Andhra Pradesh.

Range in characteristics : The A horizon is more than 100 cm thick. Its colour is in hue 10YR, value 2.5 to 3 and chroma 1 to 1.5. The texture is clayey. Intersecting slickensides breaking to angular blocky peds with shiny pressure faces are common. The AC horizon is about 30 to 40 cm thick. It is similar to A horizon but contains light olive brown mottles. The C horizon is in hue 2.5Y, value 5 to 6 and chroma 4 to 5. It also has mottles. The soils develop cracks during dry season.

Geographic setting : Kasireddipalli soils are formed in basaltic alluvium on nearly level lower pediment and depression in Medak district of Andhra Pradesh at an elevation of 530 to 550 m above MSL. The climate is semiarid

tropical with mean annual temperature of 25.8°C and mean annual rainfall of 760 mm. The estimated MAST is 26.8°C . The difference between MSST and MWST is 3.3°C .

Drainage and permeability : Imperfectly drained with slow to very slow permeability.

Use and vegetation : Cultivated to chick pea, pigeon pea, sorghum and safflower.

Natural vegetation comprises of *Acacia spp.* and local grasses.

Distribution and extent : Extensive in Medak district, Andhra Pradesh.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore

Interpretation : The soils occupy lower position and hence pose problems of drainage. The subsoils have a tendency to become sodic. Crops like sorghum, chick pea, pigeon pea and safflower can be raised under rainfed conditions.

(a) *Interpretative grouping* :

i) Land capability sub-class	III _s
ii) Irrigability sub-class	3 _s
iii) Productivity potential	Medium

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha^{-1}	
	Farmers' practice	Improved practices
Pearl millet	0.8	2.4
Sorghum	0.9	1.5
Finger millet	1.3	3.6
Pigeon pea	0.7	1.5
Groundnut	0.5	1.1
Cotton	0.6	1.2

Soil Series : KASIREDDIPALLI Classification : Typic Pellustert Analysis at : NBSS & LUP
 Location : District Medak, Andhra Pradesh Sampling Date: July 23, 1980 Regional Centre, Bangalore

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments >2mm % of whole of soil
		Total			Sand					
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-20	23.5	22.8	53.7	4.0	2.2	4.3	8.6	4.4	6
A12	20-40	21.7	21.6	56.7	3.6	2.2	3.9	7.6	4.4	6
A13	40-60	19.5	22.1	58.4	4.4	2.0	3.1	6.2	3.8	6
A14	60-90	16.2	23.7	60.1	1.5	1.9	3.0	5.9	3.9	6
AC	90-130	11.6	21.0	67.4	1.0	1.1	2.1	4.3	3.1	7
C	130-180	12.9	20.4	66.7	2.2	1.5	2.1	3.9	3.2	9

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ <2mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Water Retention	
					33 kPa %	1500 kPa %
0-20	0.73	5.3	8.8	0.09	31.2	13.4
20-40	0.54	7.4	9.2	0.09	32.6	14.2
40-60	0.47	7.0	9.4	0.09	-	-
60-90	0.39	6.3	9.4	0.18	-	-
90-130	0.28	6.2	9.4	0.45	34.6	17.2
130-180	0.25	7.5	9.4	0.54	34.2	16.7

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Excha- ngea- ble so- dium %	Ratio CEC clay
	Ca	Mg	Na	K	Sum			
← c mol (p ⁺) kg ⁻¹ →								
0-20	41.7	10.9	0.9	0.7	54.2	57.2	2	1.06
20-40	37.5	14.7	5.3	0.6	58.1	58.5	9	1.03
40-60	38.4	13.0	2.9	0.6	54.9	56.1	5	0.96
60-90	34.1	16.4	7.8	0.6	58.9	60.0	13	1.00
90-130	30.2	18.4	12.8	0.6	62.0	62.9	20	0.93
130-180	26.2	19.1	14.2	0.6	60.1	61.5	23	0.92

Analysed by : V.A.K. Sarma, P. Krishnan and S.L. Budihal

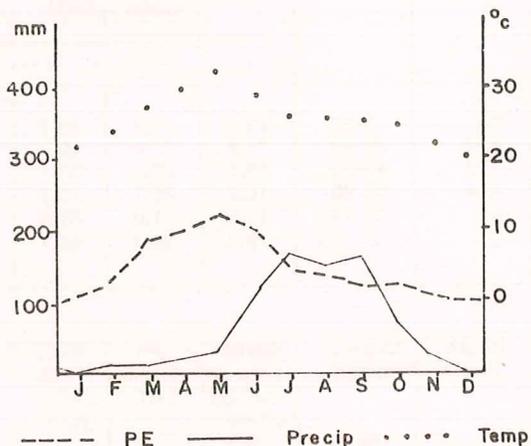
25. KADIRABAD SERIES (TENTATIVE)

The Kadirabad series is a member of the fine, montmorillonitic, isohyperthermic family of Entic Chromusterts. Kadirabad soils have dark greyish brown to very dark greyish brown, moderately alkaline clay loam to clay A horizons, and very dark greyish brown, moderately alkaline gravelly clay AC horizons over weathered granodiorite C horizons.

Typifying pedon : Kadirabad clay loam
— cultivated

Hyderabad (A.P)
17°27' N, 80°50' E

Precipitation, Temperature and Water Balance



- Ap1 0-2 cm --- Dark greyish brown (10YR 4/2 D&M) clay loam; weak, fine, subangular blocky and weak, fine, granular; loose, friable, sticky and plastic; many, fine roots; 2 to 5 mm irregular lime nodules 3 per cent; slightly effervescent; 2 to 5 mm irregular quartz fragments 3 per cent; moderately alkaline (pH 8.0); abrupt, smooth boundary.
- Ap2 2-19 cm --- Dark greyish brown (10YR 4/2 M) clay; moderate, medium, subangular blocky; firm, sticky and plastic; few, fine roots inside peds; common, fine to very fine pores; cracks more than 1 cm wide; 2 to 3 mm irregular lime nodules 3 per cent; slightly effervescent; 2 to 5 mm irregular quartz fragments 2 per cent; moderately alkaline (pH 8.1); clear, smooth boundary.
- A12 19-38 cm --- Very dark greyish brown (2.5Y 3/2 M) clay; moderate, medium, subangular blocky; firm, sticky, and plastic; few, fine, roots inside peds; common, fine to very fine pores; cracks more than 1 cm wide; 2-5 mm irregular lime nodules 3 per cent; slightly effervescent; irregular quartz fragments about 5 per cent by volume; moderately alkaline (pH 8.1); clear, smooth boundary.
- A13 38-66 cm --- Very dark greyish brown (2.5Y 3/2 M) clay; moderate, medium, angular blocky with sphenoids and slickensides intersecting

Pedon described by the core group N.G. Godse, N.K. Barde, M.A. Mirajkar and H.S. Shankaranarayana; C.S. Harindranath associated. February 3, 1980.

- at 45° ; firm, sticky and plastic; few, fine roots inside peds; common, fine to very fine pores; few cracks less than 1 cm wide; 2 to 5 mm irregular lime nodules 5 per cent; slightly effervescent; moderately alkaline (pH 8.1); gradual, smooth boundary.
- A14 66-86 cm --- Very dark greyish brown (2.5Y 3/2 M) clay; moderate, medium, angular blocky with spheroids and prominent slickensides close enough to intersect at 45° ; firm, sticky and plastic; few, very fine roots between peds; common, fine to very fine pores; few cracks; 2 to 5 mm irregular lime nodules 5 per cent; slightly effervescent; moderately alkaline (pH 8.2); clear, smooth boundary.
- ACk 86-103 cm --- Very dark greyish brown (10YR 3/2 M) gravelly clay; moderate, medium, subangular blocky; friable, slightly sticky and slightly plastic; common, very fine, discontinuous pores; 10 to 20 per cent lime nodules and soft powdery lime; strongly effervescent; moderately alkaline (pH 8.3); clear, smooth boundary.
- Ck 103-115 cm --- Weathered granodiorite, highly calcareous.

Type location : $17^{\circ}40'$ N, $78^{\circ}05'$ E; village Kadirabad, tehsil Andol, district Medak, Andhra Pradesh.

Range in characteristics : The A horizon is 80 to 120 cm thick with a thin mulch layer at the surface. Its colour is in hue 2.5Y and 10YR, value 3 to 4 and chroma 2. The texture is clay loam to clay. Spheroids and intersecting slickensides are commonly observed. Quartz fragments and lime nodules are present. The ACk horizon is 20 to 25 cm thick with 10 to 20 per cent, lime nodules and powdery lime. It is also clayey.

Geographic setting : Kadirabad soils occur on gently sloping plain in Medak district, Andhra Pradesh at an elevation of about 500 m above MSL. The climate is semiarid tropical with mean annual temperature of 25.8°C and mean annual rainfall of 730 mm. The estimated MAST is 26.8°C . The difference between MSST and MWST is 4.3°C .

Drainage and permeability : Moderately well drained with moderately slow permeability.

Use and vegetation : Cultivated to sorghum, safflower, maize, cotton, coriander, gram and wheat.

Natural vegetation comprises of *Acacia spp.* and *Azadirachta indica*.

Distribution and extent : Extensive in Medak district, Andhra Pradesh.

Series proposed : All India Soil and Land Use Survey, Regional Centre, Bangalore.

Interpretation : Kadirabad soils have favourable air-water relationship and have high available water holding capacity. They are suited to a variety of crops. Provision of drainage is necessary for irrigated farming on sustained basis.

(a) *Interpretative grouping* :

- | | |
|------------------------------|----------------|
| i) Land capability sub-class | IIs |
| ii) Irrigability sub-class | 2s |
| iii) Productivity potential | Medium to high |

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practices	
	Unirrigated	Irrigated
Sorghum	1.0 - 2.0	2.0 - 2.5
Maize	0.6 - 0.8	3.0
Wheat	0.6 - 0.8	1.2 - 1.5
Safflower	0.4 - 0.5	---

Soil Series : KADIRABAD

Classification : Entic Chromustert

Analysis at : NBSS & LUP,
Regional Centre,
BangaloreLocation : District Medak,
Andhra Pradesh

Sampling Date : February 3, 1988

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments >2 mm % of whole soil
		Total				Sand				
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap1	0-2	40.6	22.7	36.7	9.6	7.4	9.6	9.2	4.8	9
Ap2	2-19	39.1	20.6	40.3	8.5	7.4	9.3	9.6	4.3	7
A12	19-38	35.0	20.5	44.5	8.1	7.2	7.7	7.8	4.2	7
A13	38-66	30.3	22.3	47.4	7.9	5.7	6.7	6.4	3.6	13
A14	66-86	29.1	22.1	48.8	8.6	5.4	5.8	5.7	3.6	10
ACk	86-103	37.2	19.9	42.9	15.7	6.5	5.9	5.4	3.7	17

Depth (cm)	Organic carbon %	Carbo-nate CaCO ₃ <2mm %	pH (1:2.5) H ₂ O
0-2	0.71	2.2	8.0
2-19	0.59	3.0	8.1
19-38	0.48	3.3	8.1
38-66	0.47	3.8	8.1
66-86	0.47	4.4	8.2
86-103	0.40	7.9	8.3

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Ratio CEC/Clay
	Ca	Mg	Na	K	Sum		
	← c mol(p ⁺)kg ⁻¹ →						
0-2	34.4	2.2	0.4	0.7	37.7	40.5	1.10
2-19	37.0	2.1	0.4	0.5	40.0	42.4	1.05
19-38	39.9	3.1	0.3	0.5	43.8	44.9	1.01
38-66	41.6	3.4	0.4	0.4	45.8	46.7	0.99
66-86	41.9	4.7	0.5	0.5	47.6	47.9	0.98
86-103	33.5	4.5	0.5	0.4	38.9	40.8	0.95

Analysis by : V.A.K. Sarma, P. Krishnan and S.L. Budihal

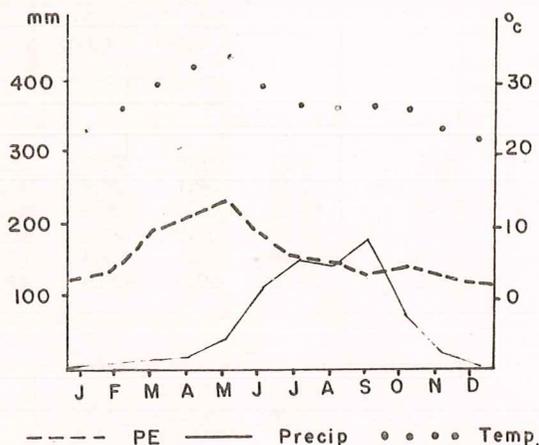
26. KAGALGOMB SERIES (TENTATIVE)

The Kagalgomb series is a member of the very fine, montmorillonitic, isohyperthermic family of Typic Chromusterts. Kagalgomb soils have dark greyish brown to very dark greyish brown, strongly to very strongly alkaline, clay A horizons, over dark yellowish brown to olive brown, strongly to very strongly alkaline, clay AC horizons.

Typifying pedon : Kagalgomb clay — cultivated

Gulbarga (Karnataka)
17° 21' N, 76° 51' E

Precipitation, Temperature and Water Balance



- Ap 0-10 cm - Dark greyish brown (10YR 4/2 D) clay, very dark greyish brown (10YR 3/2 M); weak, fine, subangular blocky; slightly hard, friable, sticky and plastic; many, coarse and fine roots; cracks 3 to 7 cm wide; 5 per cent lime nodules 3 to 5 mm; slightly effervescent; strongly alkaline (pH 8.5); clear, smooth boundary.
- A12 10-50 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; moderate, medium, subangular blocky; hard, firm, sticky and plastic; many, coarse to fine roots inside peds; many, very fine, vertical, tubular, impeded pores; cracks 3 to 5 cm wide; 5 per cent lime nodules 3 to 5 mm; slightly effervescent; strongly alkaline (pH 8.6); gradual, smooth boundary.
- A13 50-75 cm --- Very dark greyish brown (10YR 3/2 M) clay; strong, coarse, angular blocky peds with slickensides; very firm, very sticky and very plastic; common, fine roots inside peds; many, very fine, discontinuous, vertical, tubular pores; cracks 3 to 5 cm wide; 5 per cent lime nodules 2 to 10 mm; slightly effervescent; strongly alkaline (pH 8.8); gradual, wavy boundary.
- A14 75-131 cm --- Very dark greyish brown to dark greyish brown (10YR 3.5/2 M) clay; strong, coarse, angular blocky peds with prominent slickensides and sphenoids; very firm, very sticky and very plastic; few, very fine roots between peds; many, very fine,

Pedon described by the core group N.K. Barde and H.S. Shankaranarayana; B. Ramesh and C.S. Harindranath associated. June 18, 1979.

discontinuous, tubular, impeded pores; 5 per cent lime nodules 4 to 10 mm; slightly effervescent; very strongly alkaline (pH 9.3); gradual, wavy boundary.

- AC1 131-172 cm --- Dark yellowish brown (10YR 4/4 M), about 75% and dark brown (10YR 3/3 M), about 25%, clay; strong, coarse, angular blocky peds with slickensides firm, sticky and plastic; few, very fine roots between peds; many, very fine, discontinuous tubular, impeded pores; 20 to 25 per cent lime nodules 2 to 10 mm; 2 to 3 per cent violet to black manganese nodules 2 to 5 mm; strongly effervescent; strongly alkaline (pH 9.0); clear, smooth boundary.
- AC2 172-200 cm --- Olive brown (2.5Y 4/4 M) gravelly clay; strong, coarse, angular blocky peds with slickensides; firm, sticky and plastic; few, very fine roots between peds; many, very fine, discontinuous, tubular, impeded pores; 20 to 25 per cent lime nodules 3 to 5 mm; strongly effervescent; very strongly alkaline (pH 9.3).

Type location : 16°35' N, 76°50' E; village Sirwal, tehsil Shahapur, district Gulbarga, Karnataka.

Range in characteristics : The A horizon is 100 to 150 cm thick. Its colour is in hue 10YR, value 3 to 4 and chroma 2 to 4. The texture is clayey. Slickensides and spheroids are prominent. Lime and manganese nodules are present. The AC horizon is 70 to 100 cm thick. Its colour is in hue 2.5Y and 10YR, value 3 to 4 and chroma 3 to 4. It is also clayey.

Geographic setting : Kagalgomb soils are formed in old alluvium of limestone origin on nearly level to very gently sloping interfluvium in Gulbarga district of Karnataka at an elevation of 450 to 500 m above MSL. The climate is semi-arid tropical with mean annual temperature of 27.9°C and mean annual rainfall of 760 mm. The estimated MAST is 28.9°C. The difference between MSST and MWST is 3.6°C.

Drainage and permeability : Moderately well drained with slow permeability.

Use and vegetation : Cultivated to sorghum, cotton, safflower and pigeon pea.

Natural vegetation comprises of *Acacia spp.*, *Azadirachta indica*, *Prosopis spp.*

Distribution and extent : Extensive in Gulbarga district, Karnataka.

Series proposed : State Soil Survey Organization, Department of Agriculture, Karnataka.

Interpretation : Kagalgomb soils are highly clayey and pose problems due to slow permeability and sodic subsoils. The available moisture capacity is high. Initial moisture intake rate during early monsoon is favourable for moisture storage. Even on gently sloping lands the soils are susceptible to erosion. Sorghum, cotton, safflower and pigeon pea are the common rainfed crops raised on these soils. Provision of drainage is essential for irrigated farming.

(a) *Interpretative grouping* :

i) Land capability sub-class	III _s
ii) Irrigability sub-class	3 _s
iii) Productivity potential	Medium

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹	
	Farmers' practice	Improved practices
Sorghum	0.6 - 0.8	1.4 - 1.6
Cotton	0.2 - 0.3	1.0 - 1.1
Safflower	0.3 - 0.4	0.7 - 0.8
Pigeon pea	0.5 - 0.7	1.2 - 1.4

Soil Series : KAGALGOMB

Classification : Typic Chromustert

Analysis at : NBSS & LUP,
Regional Centre,
BangaloreLocation : District Gulbarga,
Karnataka

Sampling Date : June 18, 1979

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of whole soil
		Total			Sand					
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-10	9.4	38.6	52.0	0.9	1.2	1.3	3.4	2.6	2
A12	10-50	8.2	34.5	57.3	1.3	1.1	1.2	1.7	2.9	3
A13	50-75	9.2	23.1	67.7	1.8	1.1	1.2	2.8	2.3	5
A14	75-131	8.9	23.7	67.4	2.5	1.3	1.1	2.1	1.9	2
AC1	131-172	8.6	22.6	68.8	2.1	1.2	1.1	2.2	2.0	2
AC2	172-200	9.2	19.0	71.8	3.1	1.4	1.1	1.8	1.8	15

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	Water Retention	
				33 kPa %	1500 kPa %
0-10	0.63	5.7	8.5	32.7	13.2
10-50	0.66	5.0	8.6	31.9	12.0
50-75	0.65	6.3	8.8	33.2	17.0
75-131	0.48	8.0	9.3	33.1	16.9
131-172	0.46	8.0	9.0	34.0	17.2
172-200	0.24	9.0	9.3	35.2	18.0

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Exchan-geable sodium %	Ratios to clay	
	Ca	Mg	Na	K	Sum			CEC NaOAc	1500 kPa water
← c mol (p ⁺)kg ⁻¹ →									
0-10	53.8	13.4	2.6	0.8	70.6	67.6	4	1.30	0.25
10-50	52.3	14.1	4.3	0.6	71.3	67.0	6	1.17	0.21
50-75	43.8	16.9	8.5	0.6	69.8	66.4	13	0.98	0.25
75-131	36.6	19.4	12.8	0.7	69.5	66.4	19	0.99	0.25
131-172	39.5	17.5	10.8	0.7	68.5	67.0	16	0.97	0.25
172-200	28.7	20.6	14.7	0.7	64.7	60.1	24	0.84	0.25

Analysed by : V.A.K. Sarma, P. Krishnana and S.L. Budihal

Water Retention by : T. Satyanarayana

27. RAICHUR SERIES (ESTABLISHED)

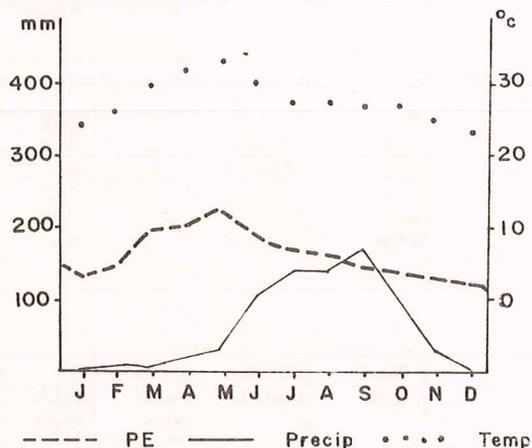
The Raichur series is a member of the very fine, montmorillonitic, isohyperthermic family of Entic Pellusterts. Raichur soils have dark grey to very dark grey, moderately alkaline, clay A horizons, overlying lithologically discontinuous sandy C horizons.

Typifying pedon : Raichur clay — cultivated

- Ap 0-12 cm --- Dark grey (10YR 4/1 D) clay, very dark grey (10YR 3/1 M); moderate medium, sub-angular blocky; hard, firm, sticky and plastic; many, coarse and fine roots inside peds; cracks more than 2 cm wide; few, quartz fragments and lime nodules to 2 mm; slightly effervescent; moderately alkaline (pH 8.0); clear, smooth boundary.
- A12 12-60 cm --- Very dark grey to dark grey (10YR 3.5/1 M) clay; moderate, medium, subangular blocky structure with partially developed sphenoids; firm, sticky and plastic; common, fine roots; many, fine, discontinuous, oblique, open, tubular impeded pores; cracks 1 cm wide; few, quartz fragments 1 to 2 mm; slightly effervescent; moderately alkaline (pH 8.0); clear, smooth boundary.
- A13 60-112 cm --- Very dark grey to dark grey (10YR 3.5/1 M) clay; prominent intersecting slickensides 10 cm across forming sphenoids that break into strong medium to coarse, angular blocky peds; very firm, very sticky and very plastic; few, very fine roots; many, fine, discontinuous, oblique, open, tubular, impeded pores; few, irregular lime nodules and quartz fragments 3 to 5 mm; slightly effervescent; moderately alkaline (pH 8.0); clear, smooth boundary.
- A14 112-150 cm --- Very dark grey to dark grey (10YR 3.5/1 M) clay; prominent intersecting slickensides 20 cm across forming sphenoids

Raichur (Karnataka)
16° 12' N, 77° 21' E

Precipitation, Temperature and Water Balance



Pedon described by the core group M.A. Mirajkar, N.K. Barde and H.S. Shankaranarayana; C.S. Harindranath associated. June 17, 1979.

that break to strong, coarse, angular blocky peds; very firm, very sticky and very plastic; few, very fine roots; many, fine, discontinuous, oblique, tubular, impeded pores; moderately alkaline (pH 8.0); clear, smooth boundary.

IIC 150 cm --- Layer of sand with few fine pieces of snail shells.

Type location : 16° 12' N, 77° 23' E; Regional Research Station (UAS), Plot No. 17, Raichur, Karnataka.

Range in characteristics : The A horizon is 110 to 150 cm thick. Its colour is in hue 10YR, value 3 to 4 and chroma 1. The texture is clayey. Nearly intersecting slickensides forming sphenoids that break into angular blocky peds. The A horizon is underlain by sandy IIC horizon.

Geographic setting : Raichur soils are formed in alluvium on gently sloping land at an elevation of 350 to 400 m above MSL in Raichur district of Karnataka. The climate is semi-arid tropical with mean annual temperature of 27.8°C and mean annual rainfall of 750 mm. The estimated MAST is 28.8°C. The difference between MSST and MWST is 1.7°C.

Geographically associated soils : Raichur soils are associated with Rampur and Agsihole soils which belong to Lithic Ustropepts and Typic Haplustalfs, respectively.

Drainage and permeability : Moderately well drained with slow permeability.

Use and vegetation : Cultivated to cotton, sorghum, bengal gram, safflower and wheat.

Natural vegetation comprises of *Acacia spp.* and *Azadirachta indica*.

Distribution and extent : Extensive in Raichur district, Karnataka.

Series proposed : University of Agricultural Sciences, Bangalore.

Interpretation : Raichur soils are suitable for a variety of climatically adapted crops like cotton, sorghum, safflower, bengal gram and wheat.

(a) *Interpretative grouping* :

- | | |
|------------------------------|------------------|
| i) Land capability sub-class | III _s |
| ii) Irrigability sub-class | 3 _s |
| iii) Productivity potential | Medium to high |

(b) *Yield* : Based on data from farmers' fields and the research station.

Crop	Yield Mg ha ⁻¹ (under protective irrigation)	
	Farmers' practice	Improved practices
Pearl millet	1.4 - 1.6	3.0 - 3.2
Sorghum	1.8 - 2.0	4.0 - 5.0
Bengal gram	0.7 - 0.8	1.8 - 2.0
Cotton	1.0 - 1.2	2.0 - 2.5
Wheat	1.2 - 1.5	2.5 - 3.0

Soil Series : RAICHUR

Classification : Entic Pellustert

Analysis at : NBSS & LUP,
Regional Centre,
BangaloreLocation : District Raichur,
Karnataka

Sampling Date : June 17, 1979

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of white soil
		Total				Sand				
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-12	5.5	29.9	64.6	0.6	0.9	1.1	1.4	1.5	1
A12	12-60	4.5	30.8	64.7	0.4	0.7	0.8	1.1	1.5	1
A13	60-112	4.3	27.5	68.2	0.7	0.8	0.9	0.6	1.3	1
A14	112-150	4.0	26.7	69.3	0.4	0.6	0.7	1.0	1.3	2

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ <2mm %	pH (1:2.5) H ₂ O	Water Retention	
				33 kPa %	1500kPa %
0-12	0.97	3.4	8.0	33.2	16.3
12-60	0.70	3.3	8.0	32.3	16.2
60-112	0.65	3.4	8.0	34.1	17.0
112-150	0.53	3.4	8.0	35.7	17.2

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Exchan-geable sodium %	Ratios to clay	
	Ca	Mg	Na	K	Sum			CEC NaOAc	1500kPa water
← c mol(p ⁺)kg ⁻¹ →									
0-12	44.5	18.0	1.9	1.4	65.8	71.8	3	1.11	0.25
12-60	46.7	16.2	2.7	0.9	66.5	71.5	4	1.10	0.25
60-112	46.2	15.5	4.2	1.3	67.2	71.8	6	1.05	0.25
112-150	47.4	14.1	3.6	1.7	66.8	70.7	5	1.02	0.25

Analysis by : V.A.K. Sarma, P. Krishnan and S.L. Budihal

Moisture Retention by : T. Satyanarayana

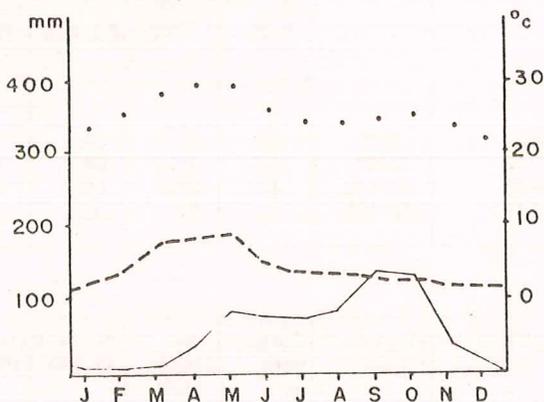
28. ACHMATTI SERIES (ESTABLISHED)

The Achmatti series is a member of the very fine, montmorillonitic, isohyperthermic family of Typic Pellusterts. Achmatti soils have very dark grey to dark grey, moderately to strongly alkaline, clayey, A horizons, and dark greyish brown, moderately to strongly alkaline, clayey AC horizons.

Typifying pedon : Achmatti clay -- cultivated

Gadag, Dharwar (Karnataka)
15° 25' N, 75° 38' E

Precipitation, Temperature and Water Balance



----- PE ———— Precip Temp.

- Ap1 0-4 cm --- Dark grey to very dark grey (10YR 3.5/1 D) clay, very dark grey (10YR 3/1 M); weak, fine, granular; slightly hard, friable, sticky and plastic; common, very fine and medium roots; 2 per cent irregularly rounded lime nodules 2 to 10 mm; strongly effervescent; moderately alkaline (pH 8.3); clear, smooth boundary.
- Ap2 4-22 cm --- Very dark grey (10YR 3/1 M) clay; moderate, medium, subangular blocky and granular; firm, sticky and plastic; few, medium roots inside peds; few, very fine, discontinuous, vertical, simple, tubular, impeded pores; cracks 3 cm wide; 5 per cent irregularly rounded lime nodules 2 to 10 mm; strongly effervescent; strongly alkaline (pH 8.6); clear, smooth boundary.
- A12 22-54 cm --- Very dark grey (10YR 3/1 M) clay; intersecting slickensides breaking into strong, coarse, angular blocky peds; firm, sticky and plastic; few, very fine roots inside peds; common, very fine, discontinuous, vertical, simple, tubular, impeded pores; cracks 1 to 1.5 cm wide; few, 1 to 3 mm rounded manganese nodules; and very few 2 to 5 mm lime nodules; strongly effervescent; strongly alkaline (pH 8.7); gradual, smooth boundary.
- A13 54-87 cm --- Very dark grey (10YR 3/1 M) about 60 per cent and dark greyish brown (10YR 4/2 M) about 40 per cent, clay;

Pedon described by the core group N.K. Barde, H.S. Shankaranarayana and N.G. Godse; B.V. Venkata Rao, C.S. Harindranath and V. Rajeshwarakar associated. April 27, 1979.

coarse intersecting slickensides breaking into strong, coarse, angular blocky peds; very firm, very sticky and very plastic; few, very fine roots inside peds; few, very fine, discontinuous, vertical, simple, tubular, impeded pores; cracks 1 cm wide; few, 2 mm lime concretions; strongly effervescent; Strongly alkaline (pH 8.8); gradual, irregular boundary.

ACK1 87-152 cm --- Dark greyish brown (10YR 4/2 M about 70 per cent) and dark grey (10YR 4/1 M about 30 per cent) clay; coarse intersecting slickensides breaking to strong, coarse, angular blocky peds; firm, sticky and plastic; few, very fine roots; few, very fine, discontinuous, vertical, simple, open, tubular pores; cracks less than 1 cm wide; 7 per cent lime nodules 10 to 20 mm violently effervescent; strongly alkaline (pH 8.9); gradual, irregular boundary.

ACK2 152-170 cm --- Very dark grey (10YR 3/1 M) clay; weak, coarse, angular blocky with slickensides forming sphenoids; firm, sticky and plastic; cracks less than 1 cm wide; 10 per cent lime and manganese nodules 1 to 5 mm; violently effervescent; moderately alkaline (pH 8.4).

Type location : 15°39' N, 75°20' E; village Gobbargumpi, taluk Navalgund, district Dharwad, Karnataka.

Range in characteristics : The A horizon is 100 to 125 cm thick. Its colour is in hue 10YR, value 3 to 4 and chroma 1 to 1.5. Its texture is clay. The subsoil has prominent intersecting slickensides and well developed sphenoids. 2 to 5 cm wide cracks extend deep into the profile. The ACK horizon is also clayey and has 7 to 10 per cent lime nodules.

Competing series and their differentiae : Hirekumbi series has distinct pale yellowish brown mottles below 60 cm. It is also a Typic Pellusterts.

Geographic setting : Achmatti soils are formed in mixed alluvium on very gently sloping basin at an elevation of about 600 m above MSL in Dharwad district of Karnataka. The climate is semiarid tropical with mean annual temperature of 25.7°C and mean annual rainfall of 660 mm. The estimated MAST is 26.7°C. The difference between MSST and MWST is 0.8°C.

Geographically associated soils : Achmatti soils are associated with Hirekumbi and Hanchinal series which belong to Typic Pellusterts and Typic Chromusterts, respectively.

Drainage and permeability : Imperfectly drained with slow permeability.

Use and vegetation : Cultivated to cotton, sorghum, safflower and wheat under rainfed conditions.

Natural vegetation comprises of *Acacia spp.*, *Prosopis spp.* and *Azadirachta spp.*

Distribution and extent : Extensive in Dharwad district of Karnataka.

Series proposed : State Soil Survey Organization, Department of Agriculture, Karnataka.

Interpretation : Soils of Achmatti series are highly clayey and pose problems due to cracking, slow permeability and sodic subsoil. The soils are susceptible to erosion. They are suitable for crops like sorghum, cotton, safflower and wheat. They are not suited for paddy. The soils are not recommended for perennial irrigation due to sodic condition in the subsoil.

(a) *Interpretative grouping* :

- | | |
|------------------------------|------------------|
| i) Land capability sub-class | III _s |
| ii) Irrigability sub-class | 4d |
| iii) Productivity potential | Medium to high |

(b) *Yield* : Based on data from farmers' fields

Crop	Yield Mg ha ⁻¹		
	Farmers' practice		Improved practices
	Rainfed	Irrigated	Irrigated
Hybrid sorghum	2.0	3.0	5.0
Bengal gram	0.7	1.0	2.5
Safflower	0.7	1.2	2.3
Maize	1.2	2.6	4.0
Cotton	---	1.5	2.7
Wheat	0.7	1.5	2.2

Soil Series : ACHMATTI

Classification : Typic Pellustert

Analysis at : NBSS & LUP,

Location : District Dharwar,
Karnataka

Sampling Date : April 27, 1979

Regional Centre,
Bangalore

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of whole soil
		Total			Sand					
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap1	0-4	23.5	21.9	54.6	3.5	3.8	4.8	7.0	4.4	12
Ap2	4-22	22.3	19.1	58.6	2.8	3.4	5.0	7.6	3.5	12
A12	22-54	13.2	18.8	68.0	2.5	2.3	2.4	3.5	2.5	5
A13	54-87	9.8	20.7	69.5	1.4	1.7	1.8	2.6	2.3	8
ACk1	87-152	9.8	20.1	70.1	1.7	1.6	1.7	2.6	2.2	13
ACk2	152-170	10.0	19.7	70.3	1.5	2.0	1.7	2.6	2.2	9

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹	Water Retention	
					33kPa %	1500kPa %
0-4	1.25	16.2	8.3	0.2	33.8	13.6
4-22	1.21	13.6	8.6	0.2	35.1	14.6
22-54	1.27	12.8	8.7	1.1	35.7	17.2
54-87	0.78	15.2	8.8	0.4	35.9	17.3
87-152	0.71	15.0	8.9	0.5	36.0	17.5
152-170	0.48	13.7	8.4	3.3	36.1	17.4

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Exchan-geable sodium %	Base saturation Na OAc %	Ratios to clay	
	Ca	Mg	Na	K	Sum				CEC Na OAc	1500 kPa water
	← c mol(p ⁺)kg ⁻¹ →									
0-4	48.5	12.6	2.4	1.1	64.6	59.4	4	100	1.09	0.25
4-22	47.7	14.3	4.2	0.7	66.9	60.5	7	100	1.03	0.25
22-54	46.3	22.1	10.0	0.7	79.1	71.5	14	100	1.05	0.25
54-87	37.7	24.5	11.3	0.7	74.2	67.4	17	100	0.97	0.25
87-152	36.3	25.2	13.1	0.7	75.3	66.1	20	100	0.94	0.25
152-170	37.6	27.9	18.3	0.9	84.7	66.7	27	100	0.95	0.25

Analysed by V.A.K. Sarma, P. Krishnan and S.L. Budihal

29. HUGALURU SERIES (ESTABLISHED)

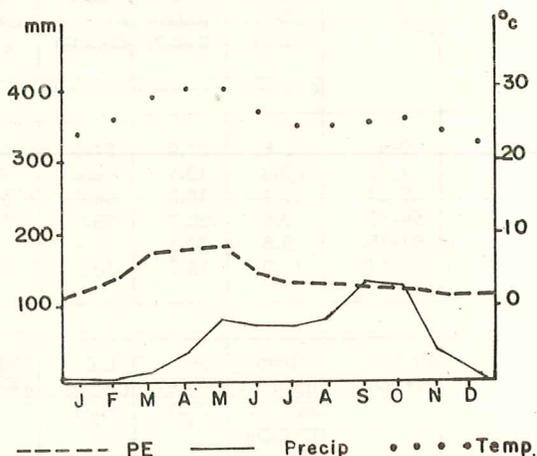
The Hugaluru series is a member of the fine, montmorillonitic, isohyperthermic family of Typic Chromusterts. Hugaluru soils have very dark greyish brown to very dark grey, moderately to strongly alkaline, clay loam to clay A horizons over Ck horizons.

Typifying pedon : Hugaluru silty clay loam — cultivated

- Ap 0-18 cm --- Very dark greyish brown (10YR 3/2 D &M) silty clay loam; moderate, medium subangular blocky; slightly hard, friable, sticky and plastic; many, fine and very fine roots; few, lime nodules; slightly effervescent; moderately alkaline (pH 8.2); clear, smooth boundary.
- A12 18-53 cm --- Very dark greyish brown (10YR 3/2 D&M) silty clay loam; moderate, coarse, angular blocky; hard, firm, sticky and plastic; few roots; 1 to 2 per cent irregular shaped lime nodules 2 to 3 mm; strongly effervescent; strongly alkaline (pH 8.9); clear, smooth boundary.
- A13 53-91 cm --- Very dark grey (10YR 3/1 D&M) silty clay; strong, coarse, angular blocky with prominent intersecting slickensides; hard, firm, sticky and plastic; few roots; 2 to 3 per cent irregular shaped lime nodules 2 to 3 mm; strongly effervescent; strongly alkaline (pH 9.0); diffuse, smooth boundary.
- A14 91-183 cm --- Very dark grey (10YR 3/1 D&M) silty clay; strong, coarse, angular blocky with slickensides; extremely hard, very firm, very sticky and plastic; 3 to 5 per cent lime nodules 2 to 3 mm; strongly effervescent; strongly alkaline (pH 9.0); clear, smooth boundary.
- Ck 183+ cm --- Weathered chlorite schist with abundant lime concretions.

Gadag, Dharwar (Karnataka)
15° 25' N, 75° 38' E

Precipitation, Temperature and Water Balance



----- PE ——— Precip Temp.

Type location : $14^{\circ}15'$ N, $75^{\circ}38'$ E; about 1.5 km north of Guttal village of Guttal-Belvigi road in Haveri taluk, Dharwad district, Karnataka.

Range in characteristics : The thickness of the regolith is more than 150 cm. The Ap horizon is 13 to 20 cm thick and its colour is in hue 10YR, value 3 and chroma 2. The texture of the Ap horizon ranges from clay loam to silty clay loam. The thickness of A12 horizon varies from 17 to 71 cm. The A12 horizon has the same colour and clay loam to clay texture. The content of lime concretions vary from 2 to 10 per cent. The A13 and A14 horizons are 48 to 130 cm thick and have very dark grey colour in hue 10YR, value 3 and chroma 1. The texture of A13 and A14 horizons ranges from silty clay to clay. Weathered chlorite schist with abundant lime nodules are found in Ck horizon.

Competing series and their differentiae : Teligi soils are comparable to Hugaluru soils, except for the colour and parent material. They have black to very dark grey colour and are formed on calcic gneiss. Teligi soils belong to Typic Pellusterts.

Geographic setting : Hugaluru soils are formed on weathered chlorite schist on very gently to gently sloping plain at an elevation of 500 to 550 m above MSL in Bellary and Dharwad districts, Karnataka. The climate is semiarid tropical with mean annual temperature of 25°C and mean annual rainfall of 800 to 850 mm. The estimated MAST is 26.5°C . MSST is 25.4°C and MWST is 25.1°C .

Geographically associated soils : Hugaluru soils are associated with Virapuram and Angur soils. Virapuram series is a clayey - skeletal Typic Ustropepts whereas Angur series is fine-loamy Typic Ustropepts.

Drainage and permeability : Moderately well drained with moderate permeability.

Use and vegetation : These soils are mainly used for cultivation of sorghum, pearl millet, cotton and safflower.

Natural vegetation comprises of *Acacia spp.*, *Calotropis gigantea* and *Azadirachta indica*.

Distribution and extent : Extensive (about 75,000 ha) in Bellary and Dharwad districts, Karnataka.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore.

Interpretation : Hugaluru soils are moderately well drained and moderately permeable. In periods of moderate to excessive rainfall, the sticky and plastic nature of the soils may pose problems for tillage operations. Available moisture capacity of the soils is high. Runoff, erosion, wetness or water logging are common due to heavy texture. Measures to conserve soils and check runoff are necessary. Hugaluru soils are occasionally affected by sodicity.

Protection from stagnation effect through surface and internal drainage is necessary. Dry sowing of crops may be necessary to avoid problems of wetness.

These soils are used for cotton, sorghum and safflower and the yields are fairly high. The management problems associated with these soils include drainage, susceptibility to erosion and wetness or waterlogging. Suitable crop rotation and addition of organic manures as basal dose will improve structure, tilth and permeability of the soils. Use of improved culturable practices, improved seeds and surface drainage have to be adopted.

Interpretative grouping :

- | | |
|------------------------------|------|
| i) Land capability sub-class | IIs |
| ii) Irrigability sub-class | 2d |
| iii) Productivity potential | High |

Note : The soil texture is based on International particle size classification.

Soil Series : HUGALURU

Classification : Typic Chromustert

Location : District Dharwad,
Karnataka

Analysis at : NBSS & LUP,
Regional Centre,
Bangalore

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments >2 mm % of wholesoil
		Coarse sand (2.0-0.2)	Fine sand (0.2-0.02)	Silt (0.02-0.002)	Clay (<0.002)	
		← % of < 2mm →				
Ap	0-18	6.7	21.1	40.3	31.9	8
A12	18-53	8.4	12.3	47.4	31.9	9
A13	53-91	8.7	19.1	28.9	43.3	4
A14	91-183	2.6	19.0	31.5	46.9	8

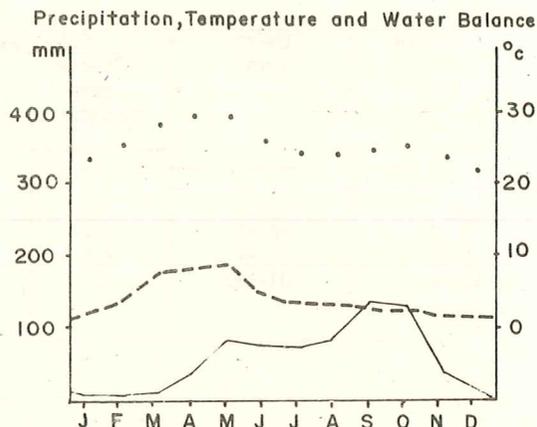
Depth (cm)	Organic carbon %	pH (1:2.5) H ₂ O
0-18	0.6	8.2
18-53	0.7	8.9
53-91	0.6	9.0
91-183	0.6	9.0

30. HUNGUND SERIES (ESTABLISHED)

The Hungund series is a member of the very fine, montmorillonitic, isohyperthermic family of Typic Chromusterts. Hungund soils have very dark greyish brown, strongly alkaline, clayey A horizons over light grey and light yellowish brown, very strongly alkaline Ck horizons.

Typifying pedon : Hungund clay loam
— cultivated

Gadag, Dharwar (Karnataka)
15° 25' N, 75° 38' E



- Ap 0-9 cm --- Very dark greyish brown (10YR 3/2 M) clay loam, fine to very fine, granular; friable sticky and plastic; many, fine and coarse roots; 2 to 6 cm wide cracks; 10 per cent irregular lime nodules of 2 to 10 mm; strongly effervescent; 15 per cent chlorite-schist and banded ferruginous quartzite fragments of 10 to 75 mm; strongly alkaline (pH 8.7); clear, smooth boundary.
- A12 9-28 cm --- Very dark greyish brown (10YR 3/2 M) clay; strong, medium to coarse, subangular blocky with few, angular blocky peds; firm, sticky and plastic; few, fine to coarse roots; many, very fine, discontinuous impeded pores; 2 to 4 cm wide cracks; 5 to 10 per cent rounded to irregular lime nodules of 2 to 10 mm; strongly effervescent; 5 per cent quartz gravel of 10 to 20 mm; strongly alkaline (pH 8.7); clear, smooth boundary.
- A13 28-44 cm --- Very dark greyish brown (10YR 3/2 M) clay; strong, coarse, angular blocky with small sphenoids; extremely firm, very sticky and plastic; many, fine and very fine roots between peds; many, fine discontinuous impeded pores; 2 to 4 cm wide cracks; 5 to 10 per cent iron-manganese nodules and rounded to irregular lime nodules of 2 to 5 mm; strongly effervescent; 5 per cent quartz fragments of 10 to 30 mm; strongly alkaline (pH 8.8); gradual, wavy boundary.

Pedon described by the core group M.A. Mirajkar, N.K. Barde and H.S. Shankaranarayana; C.S. Harindranath associated. June 22, 1979.

- A14 44-70 cm --- Very dark greyish brown (10YR 3/2 M) gravelly clay; strong, coarse, angular blocky with prominent sphenoids and intersecting slickensides about 8 cm across; extremely firm, very sticky and plastic; few, very fine roots inside peds; many, very fine, discontinuous, vertical, tubular pores; 2 to 4 cm wide cracks; 5 to 10 per cent iron-manganese nodules and rounded to irregular lime nodules of 2 to 5 mm; strongly effervescent; strongly alkaline (pH 8.9); gradual, smooth boundary.
- ACk 70-81 cm --- Very dark greyish brown (10YR 3/2 M) about 75 per cent and dark yellowish brown (10YR 4/4 M) about 25 per cent, gravelly clay; strong, medium to coarse, angular blocky with pressure faces; firm, sticky and plastic; very fine roots inside peds; many, very fine, discontinuous, vertical, tubular, impeded pores; 50 to 60 per cent iron-manganese nodules and subrounded to rounded irregular lime nodules of 10 to 20 mm; violently effervescent; strongly alkaline (pH 8.9); gradual, smooth boundary.
- Ck 81-133 cm --- Light grey and dark greyish brown (10YR 7/2, 4/4), weathered chlorite-schist with lime nodules.

Type location : 14°38' N, 75°40' E; village and tehsil Ranibennur, district Dharwad, Karnataka.

Range in characteristics : The A horizon is 65 to 90 cm thick. Its colour is in hue 10YR, value 2 to 3 and chroma 2 to 3. Texture is clayey. Intersecting slickensides and sphenoids are present. Iron-manganese and lime nodules are also present. The underlying Ck horizon is light grey to yellowish brown, weathered chlorite-schist with high amount of lime nodules.

Competing series and their differentiae : Hugaluru series is a very deep Typic Chromusterts.

Geographic setting : Hungund soils are formed on weathered calcareous chlorite schist and occur on gently to very gently sloping middle pediment in Bijapur and Dharwad districts of Karnataka at an elevation of 550 to 600 m above MSL. The climate is semiarid tropical with mean annual temperature of 25.7°C and mean annual rainfall of 660 mm. The estimated MAST is 27.7°C. The difference between MSST and MWST is 0.8°C.

Geographically associated soils : Hungund soils are associated with Hugaluru soils which belong to Typic Chromusterts.

Drainage and permeability : Moderately well drained with moderately slow permeability.

Use and vegetation : Cultivated to rainfed sorghum, cotton and chillies.

Natural vegetation consists of *Acacia spp.*, *Azadirachta indica* and local grasses.

Distribution and extent : Extensive in parts of Bijapur and Dharwad districts of Karnataka.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore.

Interpretation : Hungund soils are agriculturally important. Available water holding capacity is high. Initial water intake during early monsoon is favourable for moisture storage. Soils are susceptible to erosion. The subsoils have tendency to become sodic.

Interpretative grouping :

i) Land capability sub-class	IIIe
ii) Irrigability sub-class	3s
iii) Productivity potential	Medium to high

Soil Series : HUNGUND

Classification : Typic Chromustert

Analysis at : NBSS & LUP,

Location : District Dharwad,
Karnataka

Sampling Date : June 22, 1979

Regional Centre,
Bangalore

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments > 2 mm % of whole soil
		Total				Sand				
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of < 2 mm →										
Ap	0-9	26.7	38.1	35.2	7.0	2.0	2.2	8.1	7.4	12
A12	9-28	23.2	17.8	59.0	5.6	2.3	2.1	7.2	6.0	9
A13	28-44	19.1	17.5	63.4	4.8	2.2	1.7	5.1	5.3	14
A14	44-70	18.1	16.8	65.1	5.5	1.9	1.5	4.3	4.9	30
ACk	70-81	18.3	17.9	63.8	8.0	1.8	1.3	3.2	4.0	41
Ck	81-133	39.2	30.4	30.4	22.8	6.1	4.0	3.4	2.9	51

Depth (cm)	Organic carbon %	Carbo-nate as CaCO ₃ < 2 mm %	pH (1:2.5) H ₂ O
0-9	0.62	10.0	8.7
9-28	0.66	10.0	8.7
28-44	0.63	11.0	8.8
44-70	0.64	10.0	8.9
70-81	0.57	12.0	8.9
81-133	0.20	25.0	

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Exchan-geable sodium %	Ratio CEC Clay
	Ca	Mg	Na	K	Sum			
← c mol(p ⁺)kg ⁻¹ →								
0-9	42.5	11.3	1.6	0.8	56.2	--	--	--
9-28	41.0	12.8	3.2	0.6	57.6	57.2	6	0.97
28-44	38.7	16.2	6.6	0.6	62.1	60.4	11	0.95
44-70	34.3	19.0	8.0	0.6	61.9	60.0	13	0.92
70-81	31.8	19.2	8.9	0.6	60.5	58.1	15	0.91
81-133	12.6	9.4	5.5	0.3	27.8	26.3	21	0.87

Analysed by : V.A.K. Sarma, P. Krishnan and S.L. Budihal

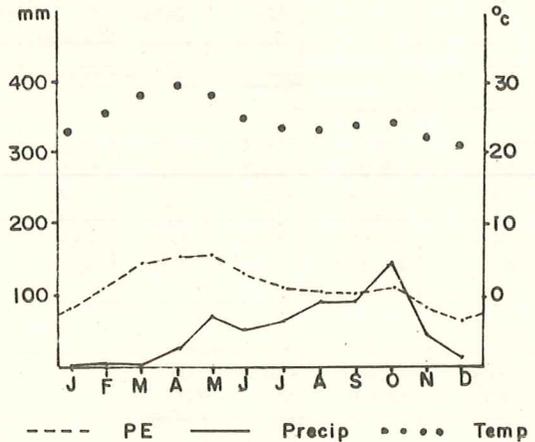
31. TELIGI SERIES (ESTABLISHED)

The Teligi series is a member of the fine, montmorillonitic, isohyperthermic family of Typic Pellusterts. Teligi soils have very dark greyish brown to black, strongly to very strongly alkaline, clayey A horizons over Ck horizons.

Typifying pedon : Teligi silty clay loam — cultivated

Chitradurga (Karnataka) 14° 14' N, 76° 26' E

Precipitation, Temperature and Water Balance



- Ap 0-10 cm --- Very dark grey (10YR 3/1 D&M) silty clay loam; weak, medium, subangular blocky structure; slightly hard, friable, slightly sticky and plastic; many, fine roots; few, fine, lime nodules; strongly effervescent; strongly alkaline (pH 8.7); clear, smooth boundary.
- A12 10-30 cm --- Black (10YR 2/1 D&M) clay; moderately, medium, subangular blocky with slickensides; slightly hard, firm, sticky and plastic; many, fine roots; 8 to 10 per cent lime nodules 2 to 5 mm; strongly effervescent; strongly alkaline (pH 8.7); clear, smooth boundary
- A13 30-97 cm --- Very dark greyish brown (10YR 3/2 D) clay, very dark grey (10YR 3/1 M); strong, coarse, angular blocky with intersecting slickensides; hard, firm, sticky and plastic; few roots; 10 to 12 per cent lime nodules 5 to 8 mm; strongly effervescent; very strongly alkaline (pH 9.4); gradual, smooth boundary.
- A14 97-122 cm --- Very dark greyish brown (10YR 3/2 D) silty clay loam, very dark grey (10YR 3/1 M); coarse, strong angular blocky with intersecting slickensides; hard, firm, sticky and plastic; few roots; 15 to 18 per cent lime nodules 5 to 8 mm; strongly effervescent; strongly alkaline (pH 9.0); gradual, smooth boundary.
- Ck 122-152 cm --- Weathered calcic gneiss with abundant lime nodules.

Type location : $14^{\circ} 31'$ N, $75^{\circ} 51'$ E; village Kodihalli on Harihar-Hospet road, Harihar taluk of Chitradurga district, Karnataka.

Range in characteristics : The Ap horizon is 10 to 15 cm thick and its moist colour is in hue 10YR value 3 and chroma 1. The texture is silty clay loam to clay loam. The thickness of A12 horizon ranges from 20 to 54 cm. The A12 horizon has clay loam to clay texture, and moist colour in hue 10YR, value 2 to 3 and chroma 1. The A13 horizon is 27 to 56 cm thick and has moist colour of very dark grey in hue 10YR, value 3 to 4 and chroma 1. Its texture is clay. The A14 horizon ranges from 10 to 20 cm in thickness and has the same colour and texture as A13 with 15 to 20 per cent lime nodules. Ck horizon has weathered calcic gneiss with abundant lime nodules. These soils develop deep, wide cracks.

Competing series and their differentiae : Hugaluru soils are comparable to Teligi series but are relatively lighter in colour and formed on chlorite schist. Hugaluru soils belong to Typic Chromusterts.

Geographic setting : Teligi soils are formed on weathered, calcic gneiss on very gently sloping plain at an elevation of 500 to 550 m above MSL in Chitradurga and Dharwad districts of Karnataka. The climate is semiarid tropical with mean annual temperature of 24.5°C and mean annual rainfall of 500 to 550 mm. The estimated MAST is 27°C . The difference MSST and MWST is less than 5°C .

Geographically associated soils : Teligi soils are associated with Itigi and Koppal soils. Itigi soils are shallow to moderately deep and Koppal soils have moist colour value of 3.5 or more in upper 30 cm depth. Itigi and Koppal soils belong to Vertic Ustropepts and Entic Pellusterts, respectively.

Drainage and permeability : Moderately well drained with slow permeability.

Use and vegetation : These soils are mainly used for cultivation of cotton, sorghum, pigeon pea and tobacco.

Natural vegetation comprises of *Acacia spp.*, *Azadirachta indica* and some xerophytes.

Distribution and extent : Extensive (about 1,35,000 ha) in Chitradurga and Dharwad districts, Karnataka.

Series proposed : National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore.

Interpretation : Teligi soils are moderately well drained and slowly permeable. In periods of moderate to excessive rainfall the sticky and plastic nature of the soils pose problems for tillage operations. Available moisture capacity of the soils is fairly high. The soils are susceptible to runoff, erosion and waterlogging due to fine textures and slow permeability. Measures to conserve soils and water are necessary. Soil salinity and sodicity are occasional problems.

These soils are presently cultivated to cotton and sorghum but the yields are not very satisfactory. For stepping up production, the use of improved seeds, manures and fertilizers, improved cultural practices and drainage have to be adopted.

Interpretative grouping :

i) Land capability sub-class	4is
ii) Irrigability sub-class	2d
iii) Productivity potential	Medium

Note : Soil texture is based on International particle size classification.

Soil Series : TELIGI

Classification : Typic Pellustert

Location : District Chitradurga,
KarnatakaAnalysis at : NBSS & LUP,
Regional Centre,
Bangalore

Horizon	Depth (cm)	Size class and particle diameter (mm)				Coarse fragments >2 mm % of whole soil
		Coarse sand (2.0-0.2)	Fine sand (0.2-0.02)	Silt (0.02- 0.002)	Clay (<0.002)	
		← % of <2mm →				
Ap	0-10	13.6	23.5	30.2	32.7	6
A12	10-30	14.4	23.3	22.4	39.9	11
A13	30-97	14.4	19.0	23.1	43.5	11
A14	97-122	11.5	15.7	35.0	37.8	14

Depth (cm)	Organic carbon %	pH (1:2.5) H ₂ O
0-10	0.4	8.7
10-30	0.3	8.7
30-97	0.3	9.4
97-122	0.2	9.0

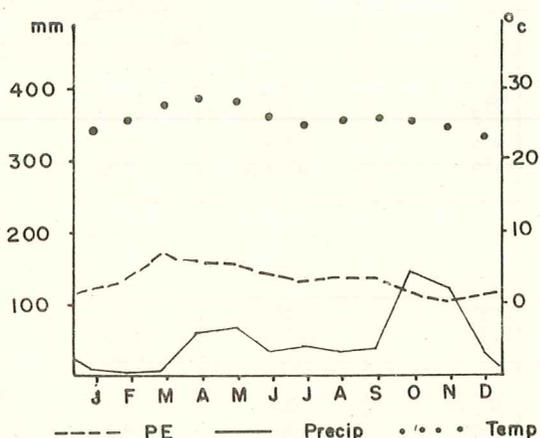
32. COIMBATORE SERIES (ESTABLISHED)

The Coimbatore series is a member of the fine, montmorillonitic, isohyperthermic family of Vertic Ustropepts. Coimbatore soils have greyish brown to dark greyish brown, strongly alkaline, clayey A horizons, and very dark greyish brown to dark yellowish brown, strongly alkaline, clayey B horizons, over variegated calcareous, strongly alkaline, clayey C horizons.

Typifying pedon : Coimbatore clay
— cultivated

Coimbatore (Tamil Nadu)
11°00' N, 76°58' E

Precipitation, Temperature and Water Balance



- Ap 0-15 cm --- Dark greyish brown (10YR 4/2 D) clay, greyish brown (10YR 5/2 M); moderate, fine to coarse, granular; loose, friable, sticky and plastic; few, fine roots inside peds; very few, irregular lime nodules 2 to 5 mm; slightly effervescent; strongly alkaline (pH 8.7); clear, smooth boundary.
- B2 15-42 cm --- Very dark greyish brown (10YR 3/2 D&M) clay; strong, coarse, prismatic structure breaking to angular blocky with prominent pressure faces; very hard, firm, very sticky and plastic; few, fine roots inside peds; many, very fine, discontinuous, expd pores; few, subrounded lime nodules 2 to 10 mm; strongly effervescent; few, coarse rock fragments; strongly alkaline (pH 8.8); clear, smooth boundary.
- B3 42-75 cm --- Dark yellowish brown and very dark greyish brown (10YR 4/4, 3/2 M) clay; moderate, coarse, prismatic and subangular blocky, friable, sticky and plastic; common, medium and coarse roots; many, very fine, discontinuous pores; subrounded lime nodules 2 to 10 mm; violently effervescent; few, rock fragments 1 to 2 mm; strongly alkaline (pH 8.5); clear, wavy boundary.

Pedon described by the core group N.K. Barde, M. Jayaraman and H.S. Shankaranarayana; P.S.A. Reddy associated. July 14, 1979.

Ck 75-124 cm --- Variegated light yellowish brown, dark yellowish brown, brown, very dark greyish brown and white (10YR 6/4, 4/4, 5/3, 3/2, 8/1 M) clay; moderate, coarse, prismatic and subangular blocky; friable, sticky and plastic; many, fine roots inside peds; 10 per cent subrounded lime nodules 2 to 10 mm; violently effervescent; strongly alkaline (pH 8.5).

Type location : 10°00' N, 78°56' E; plot No. 7, Tamil Nadu Agricultural University farm, Coimbatore, Tamil Nadu.

Range in characteristics : The thickness of the solum is 70 to 90 cm. The thickness of the A horizon is 10 to 20 cm. Its colour is in hue 10YR, value 3 to 5 and chroma 2 to 3. Its texture is clay loam to clay. Lime nodules are present. The cambic B horizon is 20 to 30 cm thick. It is darker in colour than the A horizon and has hue 10YR, value 3 to 4 and chroma 2. Its texture is clay. Peds show prominent pressure faces. Lime concretions are present. The B3 horizon is about 25 to 35 cm thick. Its colour is in hue 10YR, value 4 to 5 and chroma 2 to 4. It is also clayey and has lime concretions. The underlying Ck horizon is variegated in colour and is clayey. The soils crack during dry season.

Geographic setting : Coimbatore soils are formed in alluvium of calcic gneiss on level to very gently sloping interfluvial plain at an elevation of 375 to 400 m above MSL in Coimbatore district of Tamil Nadu. The climate is semiarid tropical with mean annual temperature of 26.5°C and mean annual rainfall of 570 mm. The estimated MAST is 27.5°C. The difference between MSST and MWST is 0.5°C.

Geographically associated soils : Coimbatore soils are associated with Palathurai and Salem soils which belong to Typic Haplustalfs.

Drainage and permeability : Imperfectly drained with moderately slow permeability.

Use and vegetation : Cultivated to sorghum, cotton pigeon pea under rainfed conditions, and rice and sugarcane under irrigation.

Natural vegetation and comprises of *Acacia spp.* and *Prosopis spp.*

Distribution and extent : Extensive in Coimbatore, Salem and Dharampuri districts, Tamil Nadu.

Series proposed : All India Soil and Land Use Survey, Regional Centre, Bangalore.

Interpretation : Fine texture and imperfect drainage pose problems. The soils can be used for all adapted crops. Provision of drainage is necessary to raise irrigated crops.

Interpretative grouping :

i) Land capability sub-class	III _s
ii) Irrigability sub-class	2 _d
iii) productivity potential	Medium

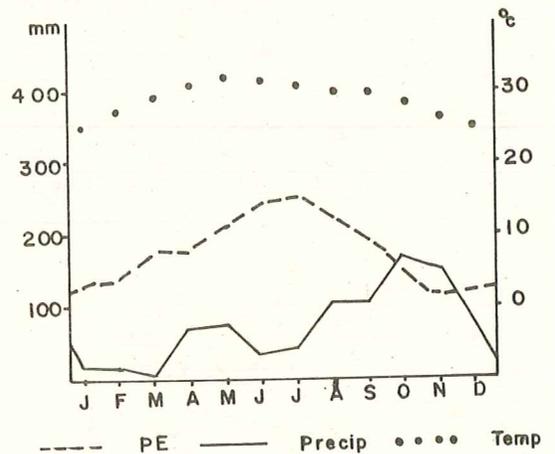
33. KALATHUR SERIES (ESTABLISHED)

The Kalathur series is a member of the fine, montmorillonitic, isohyperthermic family of Udorthentic Pellusterts. Kalathur soils have dark grey, very strongly alkaline, clay loam to clayey A horizons and dark grey, very strongly alkaline, clayey AC horizons over dark greyish brown, very strongly alkaline, clayey C horizons.

Typifying pedon : Kalathur clay loam
— cultivated

Tiruchirapalli (Tamil Nadu)
10° 46' N, 78° 43' E

Precipitation, Temperature and Water Balance



- Ap 0-14 cm --- Dark grey (10YR 4/1 D) clay loam, dark grey to very dark grey (10YR 3.5/1 M); strong, coarse, subangular blocky; very hard, friable, very sticky and very plastic; common, fine roots; common, medium, discontinuous, vertical, tubular pores; few, 2 to 3 per cent rounded lime nodules; slightly effervescent; very strongly alkaline (pH 9.1); clear, smooth boundary.
- A12 14-49 cm --- Dark grey (10YR 4/1 D) clay, dark grey to very dark grey (10YR 3.5/1 M); strong, coarse, subangular blocky with slickensides; hard, firm, very sticky and very plastic; common, fine roots inside peds; few, discontinuous, vertical, tubular pores; 2 per cent lime nodules; slightly effervescent; few quartz fragments; very strongly alkaline (pH 9.7); diffuse, smooth boundary.
- A13 49-87 cm --- Dark grey (10YR 4/1 M) clay; strong, coarse, angular blocky with prominent intersecting slickensides; firm, very sticky and very plastic; 3 to 5 per cent lime nodules; slightly effervescent; few quartz fragments; very strongly alkaline (pH 9.4); clear, smooth boundary.
- AC 87-104 cm --- Dark grey (10YR 4/1 M) clay; strong, coarse, angular blocky with prominent intersecting slickensides; firm, very sticky and very plastic; 7 to 10 per cent lime nodules; slightly effervescent;

Pedon described by the core group N.G. Godse, N.K. Barde, M. Jayaraman and H.S. Shankaranarayana; C.R. Shivaprasad associated. April 17, 1979.

quartz fragments; very strongly alkaline (pH 9.2); clear, wavy boundary.

- C 104-120 cm --- Dark greyish brown (10YR 4/2 M) clay; moderate, coarse, angular blocky; firm, very sticky and very plastic; 15 per cent lime nodules; strongly effervescent; quartz fragments; very strongly alkaline (pH 9.2).

Type location : 10°56' N, 78°56' E; about 1 km east of Annappanpettai near Jambukolam, Papanasam taluk, Thanjavur district, Tamil Nadu.

Range in characteristics : The A horizon is 80 to 100 cm thick. Its colour is in hue 10YR, value 3 to 4 and chroma 1 to 1.5. Its texture ranges from clay loam to clay. Lime nodules are present. The structure is strong, subangular and angular blocky. Intersecting slickensides are common in the lower part of the horizon. The C horizon is also in hue 10YR, value 3 to 4 and chroma 2 or less. It is also clayey in texture. The soils develop cracks during dry season.

Geographic setting : Kalathur soils are formed in alluvium on nearly level to very gently sloping Cauvery delta plain in Thanjavur district of Tamil Nadu at an elevation of 80 m above MSL. The climate is semiarid tropical with mean annual temperature of 26.8°C and mean annual rainfall of 870 mm. The estimated MAST is 27.8°C. The difference between MSST and MWST is 3.3°C.

Geographically associated soils : Kalathur soils are associated with Adanpur soils which belong to Vertic Ustropepts.

Drainage and permeability : Moderately well drained with slow to very slow permeability.

Use and vegetation : Cultivated mainly to rice and occasionally to green gram and black gram.

Natural vegetation comprises of *Acacia spp.* and grasses.

Distribution and extent : Extensive in the Cauvery delta plain, Thanjavur district, Tamil Nadu.

Series proposed : State Soil Survey and Land Use Planning Organisation, Tamil Nadu.

Interpretation : Kalathur soils are important in the delta area. They are liable to stagnation of rainy water. The subsoils are sodic and ESP increases with depth. Adapted crops like rice, green gram and black gram are raised. Rice is the main crop in sodic phases.

Interpretative grouping :

- | | |
|------------------------------|------------------|
| i) Land capability sub-class | III _s |
| ii) Irrigability sub-class | 3 _s |
| iii) Productivity potential | Medium |

Soil Series : KALATHUR

Classification : Udorthentic Pellustert

Analysis at: NBSS & LUP,
Regional Centre,
BangaloreLocation : District Tanjavur,
Tamil Nadu

Sampling Date : April 17, 1979

Horizon	Depth (cm)	Size class and particle diameter (mm)								Coarse fragments >2 mm % of whole soil
		Total			Sand					
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	
← % of <2 mm →										
Ap	0-14	43.4	17.9	38.7	3.7	7.8	13.4	13.0	5.5	4
A12	14-49	38.6	16.3	45.1	4.0	7.1	12.0	11.1	4.4	10
A13	49-87	27.1	16.5	56.4	2.0	5.0	8.7	7.8	3.6	9
AC	87-104	22.6	18.7	58.7	2.0	3.8	6.8	6.4	3.6	11
C	104-120	24.1	17.6	58.3	22.6	4.2	7.1	6.5	3.7	12

Depth (cm)	Organic carbon %	Carbonate as CaCO ₃ <2 mm %	pH (1:2.5) H ₂ O	E.C. (1:2.5) H ₂ O dSm ⁻¹
0-14	0.90	8.2	9.1	0.23
14-49	0.29	8.4	9.7	0.46
49-87	0.21	8.5	9.4	0.80
87-104	0.21	9.0	9.2	0.90
104-120	0.11	10.4	9.2	0.97

Depth (cm)	Extractable bases					CEC NaOAc pH 8.2	Exchangeable sodium %	Ratio CEC/Clay
	Ca	Mg	Na	K	Sum			
← c mol(p ⁺)kg ⁻¹ →								
0-14	21.1	15.9	2.4	0.4	39.8	38.9	6	1.01
14-49	15.0	17.4	12.3	0.5	45.2	43.9	28	0.97
49-87	9.0	26.2	19.9	0.5	55.6	54.1	37	0.96
87-104	14.3	21.0	25.0	0.5	60.8	57.9	43	0.99
104-120	14.4	19.8	25.5	0.5	60.2	52.8	48	0.91

Analysed by : V.A.K. Sarma, P. Krishnan and S.L. Budihal.

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