SOILS OF SRIKAKULAM

Properties and Problems

R. PRABHU PRASADINI
M. SINGA RAO

ANDHRA PRADESH AGRICULTURAL UNIVERSITY
HYDERABAD
1995

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FOREWORD

Soil is a vital natural resource. A fair knowledge of the kind of soils, their distribution, properties and problems is essential for planning developmental activities for improving the productivity and production in the field of agriculture and allied avocations. The prediction of the input requirement and the expected output, require information on soil properties and their relationship to the application of the technology.

Systematic soil survey provide the requisite information about the nature and capabilities of soils and their production constraints. No one can solve the problem without knowing this fundamental point, first. Therefore, soil constraint analysis, in addition to the information on their properties, is essential to alleviate the problems or to manage the soils or to promote increased productivity.

North coastal districts in general and Srikakulam district in particular are agriculturally highly potential in the State. Government of Andhra Pradesh and A.P. Agricultural University are giving considerable importance to the development of these districts since they have lot of untapped natural resources.

It is timely and first of its kind that scientists working in the Soil Physical Conditions Improvement Project, Hyderabad took-up survey work to find out the properties and problems of soils of Srikakulam district and the information so generated is published in the form this Bulletin.

The publication contains information on 15 selected bench mark soil profiles from different parts of the district, representing major soil series. An attempt is made to identify the soil production constraints and based on the information so collected suitable management practices were suggested to increase the productivity of these problem soils.

I wish to place on record my appreciation to the authors Dr. (Mrs) R. Prabhu Prasadini and Dr. M. Singa Rao for their effort in bringing out this publication.

The initiative taken by Sri P. Mallikarjuna Rao, Project Director, D.R.D.A., Srikakulam, in providing the financial support for this publication is very much appreciated.

This publication, I am sure will be useful to all the Government Departments, other Organisations and individuals interested in the development of agriculture and allied fields of the Srikakulam district.

Date : 27-04-1995 **M. V. RAO**

DR. I.V. SUBBA RAO
Director of Research

Andhra Pradesh Agricultural University
Rajendranagar, Hyderabad 500 030.

PREFACE

The North Coastal districts of Visakhapatnam, Srikakulam and Vizianagaram have a lot of unexploited potential for development of Agriculture and Animal Husbandry, because of the ideal climate, well distributed rainfall, rich vegetation and soils, which are amenable for management. Realising this potential, the Andhra Pradesh Agricultural University conducted a seminar on Agricultural Development of North Coastal districts in December, 1992. It was recognised, during the deliberations of this Seminar, that the soil characteristics and their management in the North Coastal districts should be worked out and documented for harnessing this invaluable natural resource, on a sustainable basis, for the development of agriculture and allied areas of activity. In tune with this felt need, a Project on the Study of Soils of Srikakulam district was initiated and the work was carried out by a team of scientists of the Andhra Pradesh Agricultural University, the results of which are incorporated in this publication. I am sure that this publication will serve as a very useful guide and document for Scientists, Administrators and Technocrats involved in the process of planning and development of Srikakulam district.

I compliment Dr. R. Prabhu Prasadini and Dr. M. Singa Rao, for their hard work in systematically carrying out this study and for their sincere efforts to bring out the publication. The Project Director, District Rural Development Agency, Srikakulam district, Sri P. Mallikharjuna Rao, I.F.S., realising the value of the information presented herein, has come forward generously to provide funds to bring out the publication in print. I thank him for his gesture in this regard. I thank Dr. K. Pandarinatha Reddy, Officer-In-Charge, Agricultural Information & Communication Centre, APAU for his effort and cooperation in bringing out this publication in an attractive form within a short period.

Mr. A. Satyanarayana, Officer Incharge, APAU Computer Centre who has done a fine job in Laser Type Setting the material presented herein, deserves appreciation.

I earnestly hope that such publications catalouging the natural resource endowments and their management will be brought out by scientists of APAU in future to help the scientists, farmers and administrators in the scientific development of agriculture in Andhra Pradesh.

Date : 25-04-1995

I. V. SUBBA RAO

ANIL C. PUNETHA, I.A.S.,
Collector & Dist. Magistrate

Srikakulam
Andhra Pradesh - 532 011

MESSAGE

I am very happy to learn that the Andhra Pradesh Agricultural University, Rajendranagar is bringing out a Bulletin on Soils of Srikakulam district. Soil is an important natural resource and any scientific data pertaining to this would be very useful for making appropriate plans for the development of area. In the context of importance being given to watershed approach under various programmes such as DPAP, Employment Assurance Scheme, IFAD etc., the information on the natural resources of the district is highly essential for formulating suitable Action Plans for sustainable development of the district. Hope this bulletin would be put to maximum use during the course of implementation of various area development projects of the district.

Date : 26-04-1995

ANIL C. PUNETHA

P. MALLIKHARJUNA RAO
Project Director

District Rural Development Agency
Srikakulam-532 011.

MESSAGE

I am very happy to know about the Bulletin on Soils of Srikakulam District being broughtout by Andhra Pradesh Agricultural University. In view of the scientific approach envisaged in various area development programmes such as DPAP, Employment Assurance Scheme et., the data on important natural resource like soil is very much essential. The contents of the book are highly useful for formulation of suitable action plans under various rural development programmes of the district. I appreciate the efforts of the Soil Scientists, Andhra Pradesh Agricultural University in bringing out this booklet.

Date : 26-04-1995

P. MALLIKHARJUNA RAO

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INTRODUCTION

Location

Srikakulam district is the border district of Andhra Pradesh with Orissa and lies in the North Eastern end of Andhra Pradesh state (Figure 1). It is located between the Northern latitudes of 18^{o} 20' and 19^{o} 10' and between Eastern longitudes of 83^{o} 25' and 84^{o} 50'. It is bounded on the North by the state of Orissa, on the East by the Bay of Bengal and on the West by Vizianagaram district. The district has a long coastline of about 150 km. The district is divided into 37 mandals for administrative purpose. The difference between the mean annual summer temperature and mean winter temperature is less than 5^{o}C and soil temperature regime for the district is isohyperthermic. Of these 37 mandals, 31 mandals fall under the North Coastal Zone and 6 mandals under the High Altitude and Tribal Area Zone.

Climate

The district is characterized by humid to sub-humid climatic conditions. The climate is characterised by high humidity nearly all the year round, oppressive summer and good seasonal rainfall. The average annual rainfall of the district is 1068 mm. The rainfall during the monsoon period from June to October amounts to about 79 per cent of it with September as the rainiest month. The relative humidity is higher in the coastal parts of the district. The mean maximum and minimum temperatures in the district range from 27.7^{o} to 34.6^{o}C and 17.7^{o} to 27.3^{o}C, respectively.

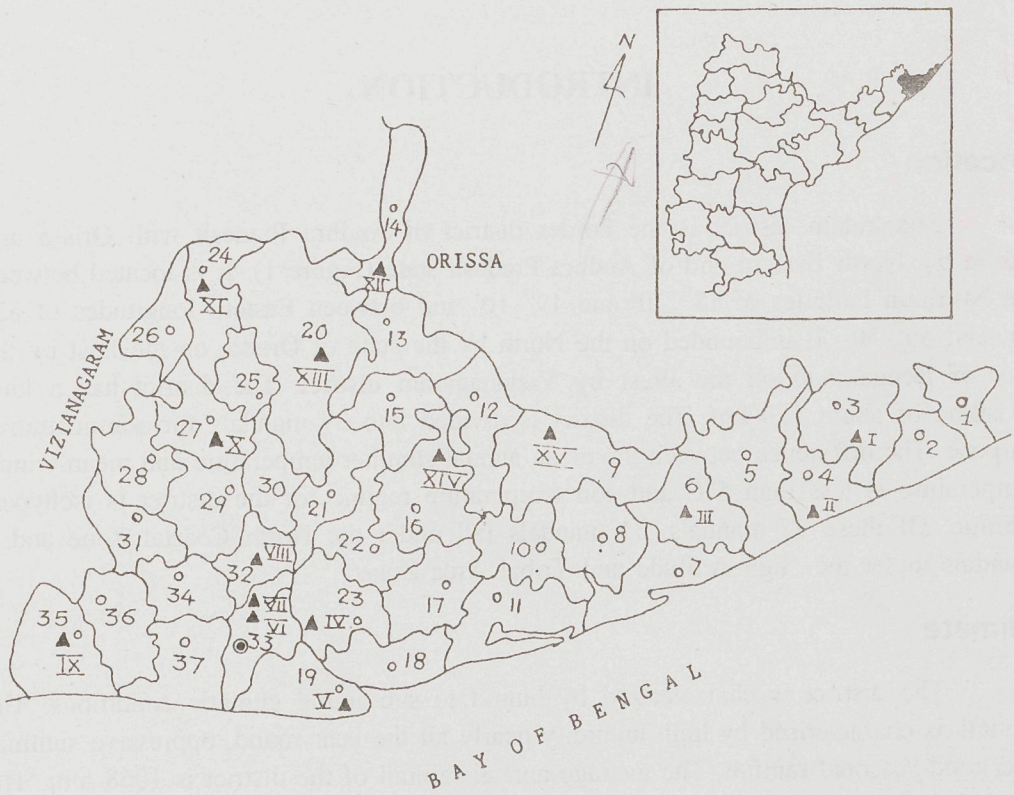
Rivers

The chief rivers in the district are the Nagavali, Vamshadhara, Suvarnamukhi, Vegavathi, Gomukhi, Champavathi and Bahuda.

Topography

The district may roughly be divided into two geographical divisions viz., the hilly region and the plains.

FIGURE 1 : LOCATION OF PROFILE SITES STUDIED



LEGEND

◉ DISTRICT HEADQUARTERS

○ MANDAL HEADQUARTERS

▲ LOCATION OF PROFILE

I. KANCHILI
II. BARUA
III. PALASA
IV. MADAPAM
V. KALINGAPATNAM
VI. RAGOLU
VII. NAIRA
VIII. AMADALAVALASA
IX. KOSTA
X. KAGITAPALLI
XI. MADIKURU
XII. SATTIWADA
XIII. SEETHAMPETA
XIV. NOWTALA
XV. MELIAPUTTI

MANDALS

1. Ichapuram
2. Kaviti
3. Kanchili
4. Sompeta
5. Mandasa
6. Palasa
7. Vajrapukotturu
8. Nandigoan
9. Meliaputti
10. Tekkali
11. Santa bommali
12. Pathapatnam
13. Kottur
14. Bhamini
15. Hira
16. Saravakota
17. Kota Bommali
18. Polaki
19. Gara
20. Seethampeta
21. Sarubujjili
22. Jalumuru
23. Narasannapeta
24. Veeraghattam
25. Palakonda
26. Vangara
27. Regidi Amadalavalasa
28. Rajam
29. Santakaviti
30. Burja
31. G. Sigadam
32. Amadalavalasa
33. Srikakulam
34. Ponduru
35. Ranasthalam
36. Laveru
37. Etcherla

The hilly region consists of Bhamini, Seethampeta, Kotturu, Pathapatnam, Saravakota and Meliaputti mandals which are in the northern part of the district. This hilly region comes under the High Altitude and Tribal Area Zone (Agroclimatic Zone No. VII) of Andhra Pradesh. The Eastern Ghats run almost parallel to the sea coast from North-East to South-West in this region. The other 31 mandals are in the plain region which forms part of the North Coastal Zone (Agroclimatic Zone No.II) of Andhra Pradesh. The 31 mandals are : Ichapuram, Kaviti, Kanchili, Sompeta, Mandasa, Palasa, Vajrapukothuru, Nandigam, Tekkali, Santa Bommali, Kota Bommali, Jalumuru, Hiramandalam, Veeraghattam, Burja, Palakonda, Vangara, Regidi Amadalavalasa, Santakaviti, Narasannapeta, Polaki, Srikakulam, Gara, Sarubujjili, Amadalavalasa, Etcharla, G.Sigadam, Ponduru, Ranastalam, Laveru and Rajam. This region has a smooth coast line along its Eastern and Southern borders.

The altitude ranges from 0 to150 m above mean sea level in district areas of the North Coastal Zone and 300 to 600 m above mean sea level in the district areas of High Altitude and Tribal Area Zone. The district drains from the ghats to the sea.

Geology

Srikakulam district forms part of the Indian Peninsular shield comprising geologically the most ancient rocks. A major portion of the district is covered by the oldest rock formations, namely, the Archaeans.

The major rock types represented in the district are :

Archaeans.....Charnockites and granites
Lower pre-cambrians (Dharwars).....Khondalite series with kodurites

Charnockites are greasy looking massive dark granitic rocks originated from igneous rocks. Khondalites are gneissic and foliated rocks dotted with red garnets originated from sedimentary rocks. Khondalites represent sands and clays, locally magniferous and calcareous, deposited in a vast basin (Gazetteer of India, 1979).

STUDIES MADE

Profile soil samples were collected from fifteen locations in Srikakulam district of Andhra Pradesh based on soil heterogenity in consultation with the officers of Soil Testing Laboratory, Srikakulam and the Scientists of R.A.R.S., Anakapalle. The locations are Kanchili, Barua, Palasa, Madapam, Kalingapatnam, Ragolu, Naira, Amadalavalasa, Kosta, Kagitapalli, Madikuru, Sattiwada, Seethampeta, Nowtala and Meliaputti. The location of the profile sites is given in Figure 1.

Soil samples were collected horizon-wise for estimation of physical, physico-chemical and chemical properties. Bulk samples were collected, air dried, pounded with wooden pestle. The samples seived through a 2 mm sieve were used for mechanical analysis, particle density determination, physico-chemical and chemical analysis. Undisturbed samples were collected from each horizon for water retention using rings of 5 cm diameter and 1 cm height, saturated hydraulic conductivity using metal cylinders of 5 cm diatemter and 15 cm height and bulk denisty using metal cores of 10 cm diameter and 10 cm height. Infiltration studies were carried out *in situ*.

The details of methods followed are given below :

Parameter	Method	Reference
Physical properties		
Particle size distribution	International pipette	Day 1965
Bulk density	Core	Blake 1965
Particle density	—	Blake 1965
Saturated hydraulic conductivity	Constant head	Klute 1965
Infiltration	Double ring infiltrometer	Bertrand 1965
Water retention	Pressure plate apparatus	Richards 1965
Soil colour	Munsell's notation	Soil Survey Staff 1951

Physico-chemical properties		
Soil reaction (pH) (1:2.5)	Glass electrode	Jackson 1967
Electrical conductivity (1:2.5)	Digital electrical conductivity	Jackson 1967
Cation exchange capacity	Sodium saturation method	Chapman 1965
Exchangeable cations	Neutral normal ammonium acetate method	Jackson 1967
Chemical properties		
Organic carbon	Rapid titration method	Walkley and Black 1934
Available nitrogen	Alkaline permanganate method	Subbaiah and Asija 1956
Available phosphorus	Ascorbic acid method	Watanabe and Olsen 1965
Available potassium	Neutral normal ammonium acetate extraction using flame photometer	Jackson 1967
Available micronutrients	DTPA-extraction using Atomic Absorption Spectrophotometer	Lindsay and Norwell 1978
Soil classification	Soil taxonomy of U.S.D.A.	Soil Survey staff 1960
Statistical analysis	Correlation and regression	Snedecor 1961

CHARACTERISTICS OF SOILS

1. Kanchili series

Location Village: Kanchili, Mandal: Kanchili

These soils were deep and moderately drained occurring on flood plain. Basaltic alluvium forms the geology of the region. The site at the profile was nearly levelled (0-1% slope) It was an imperfectly drained land. Ground water was deeper than 10 m. Natural vegetation of the region includes palmyrah and coconut trees, grasses *etc*. The land was cultivated for groundnut crop with well irrigation.

Depth (cm)	Horizon description
0-8	Dark greyish brown (10 YR 4/2 M), brown (10 YR 5/3 D); sandy clay loam; weak, fine and angular blocky; loose, friable and slightly sticky; few very fine nodules; many mottles; moderately thick ferrans in patches; few fine roots; few fine pores; slight effervescence with dilute HCl; gradual smooth boundary.
8-17	Greyish brown (10 YR 5/2 M), pale brown (10 YR 6/3 D); clay loam; moderate, fine and sub-angular blocky; slightly hard, friable and sticky; argillans and slickensides present; few fine nodules; many mottles; moderately thick ferrans in patches; few fine roots; few very fine pores; no effervescence with dilute HCl; clear smooth boundary.
17-60	Olive brown (2.5 Y 4/4 M), pale olive (5 Y 6/3 D); clay loam; moderate, fine and sub-angular blocky; slightly hard, friable and sticky; argillans, slickensides and iron concretions present; few very fine pores; no effervescence with dilute HCl; clear smooth boundary.
60-100	Olive brown (2.5 Y 4/4 M), light yellowish brown (2.5 Y 6/4 D); clay loam; no effervescence with dilute HCl.

Table 1.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conducti-vity (cm/h)
		Sand	Silt	Clay				
0-8	0.4	70.0	8.5	21.5	Sandy clay loam	1.61	2.45	13.28
8-17	1.1	66.7	7.3	26.0	Clay loam	1.85	2.46	1.34
17-60	0.3	53.3	16.0	30.7	Clay loam	1.77	2.47	1.02
60-100	1.7	53.0	14.0	33.0	Clay loam	1.68	2.44	0.85

Table 1.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/ m depth
0-8	40.38	20.36	13.77	13.19	12.65	12.20	11.72	11.08	10.68	9.68	1.25	11.28
8-17	25.94	14.94	13.53	11.63	10.37	9.50	8.45	7.73	7.50	7.44	1.24	Medium
17-60	28.56	18.56	17.98	16.75	12.80	12.44	12.02	11.75	11.44	7.12	5.42	
60-100	32.81	17.06	16.94	15.95	14.96	14.17	13.31	12.12	12.04	5.02	3.37	

Table 1.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	2.44	2.19	1.41	0.83	0.52	0.50	0.49
Cumulative infiltration (cm)	0.20	0.38	0.85	1.29	1.81	2.06	2.31

Table 1.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+) /kg)			
				Ca	Mg	Na	K
0-8	6.86	0.16	5.38	2.91	1.82	0.33	0.12
8-17	7.46	0.11	6.28	3.24	2.42	0.39	0.10
17-60	7.56	0.20	11.96	4.39	6.42	0.59	0.21
60-100	7.58	0.16	11.96	5.01	5.77	0.68	0.20

Table 1.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-8	0.68	135	18	308	50.4	34.3	3.7	2.2
8-17	0.19	94	17	291	54.1	23.1	3.3	1.1
17-60	0.15	66	14	252	56.2	12.9	3.4	2.6
60-100	0.47	72	19	226	42.3	10.5	2.9	1.5

From the above data it is seen that these soils are neutral in reaction, non-saline and sandy clay loam to clay loam in texture. Infiltration rate was low (0.1-0.5 cm/h). Available water storage capacity of the profile was medium. Bulk density was higher in lower layers. Available nitrogen was low. Micronutrients content was above critical limits.

Classification

Order	-	Inceptisols
Sub-order	-	Ochrepts
Great group	-	Ustochrepts
Sub-group	-	Typic Ustochrepts
Family	-	Fine loamy mixed isohyperthermic Typic Ustochrepts
Series	-	Kanchili

2. Barua series

Location Village: Barua, Mandal: Sompeta

These soils were deep and well drained, occurring as transported material of sand. Transported sand material with silt forms the geology of the region. The profile site has very gentle slope and was moderately well drained and slightly eroded. Groundwater was at 4.5 to 6.0 m depth. The land was used for coconut orchard.

Depth (cm)	Horizon description
0-18	Dark brown (10 YR 3/3 M), light brownish grey (10 YR 6/2 D); sandy; single grained; loose, loose and non-sticky; fine roots; slight effervescence with dilute HCl; clear smooth boundary.
18-72	Dark brown (10 YR 3/3 M), brown (10 YR 5/3 D); sandy; single grained; loose, loose and non-sticky; many medium roots, few very fine pores; slight effervescence with dilute HCl; clear smooth boundary.
72-110	Very dark greyish brown (2.5 Y 3/2 M), light grey (2.5 Y 7/2 M); sandy; single grained; loose, loose and non-sticky; slight effervescence with dilute HCl.

Table 2.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-18	0.8	95.5	1.5	3.0	Sand	1.66	2.69	64.74
18-72	0.1	95.0	1.5	3.5	Sand	1.44	2.74	94.56
72-110	0.1	93.5	2.0	4.5	Sand	1.82	2.72	72.48

Table 2.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water	
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-18	16.46	9.99	4.30	3.83	3.26	3.03	2.88	2.63	2.43	7.56	2.26	4.37
18-72	10.94	1.71	1.54	1.02	0.91	0.85	0.78	0.75	0.71	1.00	0.78	very low
72-110	12.35	3.25	2.65	1.46	0.86	0.78	0.72	0.69	0.64	2.61	1.81	

Table 2.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	44.01	43.91	43.41	42.75	40.38	40.02	40.02
Cumulative Infiltration (cm)	3.67	7.53	22.80	44.18	84.58	104.53	124.38

Table 2.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-18	6.53	0.25	3.04	2.10	0.78	0.08	0.05
18-72	6.77	0.11	1.69	1.37	0.21	0.05	0.02
72-110	7.02	0.08	1.59	1.29	0.17	0.05	0.02

Table 2.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-18	0.65	91	5	156	11.1	13.2	0.6	1.0
18-72	0.06	59	6	123	11.0	6.0	0.5	0.4
72-110	0.04	31	6	143	10.7	5.0	0.4	0.3

These soils were light textured and very rapidly permeable. Available water storage capacity of the profile was very low. Both hydraulic conductivity and infiltration were very rapid. Soils were neutral in reaction and non-saline. Low in available nitrogen and phosphorus. Micronutreints content was above critical limits.

Classification

Order - Entisols

Sub-order - Psamments

Great group - Ustipsamments

Sub-group - Typic Ustipsamments

Family - Coarse sandy mixed isohyperthermic Typic Ustipsamments

Series - Barua

3. Palasa series

Location Village: Palasa, Mandal: Palasa

These soils were moderately deep and moderately well drained, occurring on gently sloping flood plain. The profile site was very gently sloping flood plain with poor drainage. Groundwater was at 7.5-9.0 m depth. Runoff was slow with slight erosion hazard. There was a cashew orchard in the region but the profile site was a wasteland.

Depth (cm)	Horizon description
0-20	Reddish yellow (5 YR 4/6 M), reddish yellow (7.5 YR 7/8 D); clay loam; moderate, fine and sub-angular blocky; loose, friable and non-sticky; few fine roots; few fine pores; slight effervescence with dilute HCl, gradual irregular boundary.
20-40	Reddish yellow (5 YR 4/6 M), reddish yellow (5 YR 6/8 D); clay; strong, fine and sub-angular blocky; hard, firm and slightly sticky; common medium nodules; moderately thick ferrans broken; slicken sides present; common fine roots; few very fine pores; slight effervescence with dilute HCl; clear smooth boundary.
40-80	Red (2.5 YR 4/6 M), red (2.5 YR 5/6 D); clay; strong, fine and sub-angular blocky; very hard, firm and slightly sticky; common medium nodules; moderately thick ferrans broken; slickensides present; few fine roots; few very fine pores; slight effervescence with dilute HCl; clear smooth boundary.
80-100	Reddish yellow (5 YR 4/6 M), reddish yellow (5 YR 6/6 D); clay; moderate, fine and sub-angular blocky; slightly hard, friable and slightly sticky; iron concretions present; strong effervescence with dilute HCl.

Table 3.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-20	2.3	54.3	12.7	33.0	Clay loam	1.67	2.62	0.54
20-40	1.0	45.3	12.0	42.7	Clay	1.53	2.70	0.60
40-80	1.0	44.0	10.0	46.0	Clay	1.47	2.71	0.30
80-100	3.3	41.4	8.3	50.3	Clay	1.52	2.69	0.31

Table 3.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-20	26.60	19.52	14.98	12.93	11.02	10.16	9.67	9.51	9.33	10.19	3.40	11.94
20-40	33.43	20.67	17.52	14.23	13.93	13.08	12.16	11.83	11.40	6.12	1.87	Medium
40-80	29.45	23.90	21.87	19.55	18.32	17.51	16.59	16.02	15.46	6.41	4.28	
80-100	47.96	25.78	23.90	21.38	19.04	17.72	16.44	16.24	16.10	7.80	2.39	

Table 3.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	0.73	0.68	0.52	0.41	0.33	0.31	0.31
Cumulative infiltration (cm)	0.06	0.12	0.29	0.50	0.82	0.98	1.14

Table 3.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-20	6.11	0.10	6.28	3.00	2.90	0.09	0.10
20-40	6.30	0.20	6.28	2.41	3.60	0.08	0.05
40-80	6.98	0.26	11.96	5.11	6.61	0.12	0.05
80-100	7.03	0.19	11.96	5.50	6.21	0.13	0.08

Table 3.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-20	0.40	188	11	196	33.3	28.7	0.9	0.6
20-40	0.47	219	23	168	22.4	22.6	1.8	1.1
40-80	0.39	245	16	190	18.9	20.6	2.1	0.5
80-100	0.29	260	11	224	19.6	18.9	1.9	2.3

The data show that these soils were medium textured at surface but finer textured in lower horizons. Bulk density was highest (1.67 g/cc) at surface. Infiltration rate was slow. Available water storage capacity of the profile was medium. These soils were slightly acidic in reaction and non-saline, low in organic carbon and available nitrogen. Micronutreints content was above critical limits.

Classification

Order	-	Inceptisols
Sub-order	-	Ochrepts
Great group	-	Ustochrepts
Sub-group	-	Typic Ustochrepts
Family	-	Fine mixed isohyperthermic Typic Ustochrepts
Series	-	Palasa

4. Madapam series

Location Village: Madapam, Mandal: Narsannapeta

These soils were deep and well drained, occurring on gently sloping river sand. Vegetation includes acacia, palmyrah trees *etc*. The profile site was with very gentle slope. The land was used for cashew orchard.

Depth (cm)	Horizon description
0-35	Dark yellowish brown (10/YR 4/4 M), yellowish brown (10YR 5/4 D); sandy; single grained; loose, loose and non-sticky; few roots; blackish pockets; slight effervescence with dilute HCl; clear boundary. The top (0-5 cm) layer of this horizon was darker in colour than the lower part.
35-110	Brown (7.5 YR 5/4 M), yellow (10 YR 7/6 D); sandy; single grained; loose,loose and non-sticky; no effervescence with dilute HCl.

Table 4.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-35	0.5	95.5	2.0	2.5	Sand	1.63	2.58	32.52
35-110	0.4	94.5	2.5	3.0	Sand	1.31	2.62	40.98

Table 4.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-35	16.03	5.07	4.46	3.80	3.29	2.95	2.56	2.02	1.66	3.41	1.95	6.23
35-110	17.99	5.57	4.15	1.85	1.18	0.92	0.80	0.68	0.54	5.03	4.94	Low

Table 4.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	115.30	158.70	56.30	53.10	51.00	50.97	50.91
Cumulative infiltraion (cm)	9.61	22.84	41.61	68.16	119.16	114.6	170.15

Table 4.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-35	6.96	0.15	2.52	1.94	0.17	0.21	0.07
35-110	7.01	0.05	2.09	1.23	0.44	0.20	0.12

Table 4.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-35	0.49	132	6	246	10.6	14.2	0.5	1.1
35-110	0.11	42	6	123	9.2	5.0	0.4	0.3

These soils were light textured and very rapidly permeable. Both infiltration rate and hydraulic conductivity were very rapid. Available water storage capacity of the profile was low. Soils were neutral, non-saline and poor in fertility. Micronutrients content was above critical limits.

Classification

Order	-	Entisols
Sub-order	-	Psamments
Great group	-	Ustipsamments
Sub-group	-	Typic Ustipsamments
Family	-	Coarse sandy mixed isohyperthermic Typic Ustipsamments
Series	-	Madapam

5. Kalingapatnam series

Location Village: Kalingapatnam, Mandal: Gara

These soils were deep, moderately well drained occurring on gently sloping land. The profile site was with gentle slope. The ground water was deeper than 9 m. Cropping pattern followed in the region was paddy, paddy-groundnut or chillies or ragi. The crop in the field was groundnut, irrigation source was borewell.

Depth (cm)	Horizon description
0-15	Olive brown (2.5 Y 4/4 M), yellow (2.5 Y 7/6 D); silty loam; angular blocky; hard, firm and sticky; black mottles; many roots; few fine pores; slicken sides present; no effervescence with dilute HCl; clear boundary.
15-38	Brown and dark brown (10 YR 4/4 M), pale yellow (2.5 Y 7/4 D); loamy; sub-angular blocky; hard, firm and sticky; reddish and blackish mottles; few fine roots, no effervescence with dilute HCl; clear boundary.
38-110	Dark yellowish brown (10 YR 4/4 M), pale yellow (2.5 Y 7/4 D); loamy; sub-angular blocky; hard, firm and sticky; black mottles; few fine pores; no effervescence with dilute HCl.

Table 5.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-15	0.4	39.0	46.5	14.5	Silty loam	1.76	2.54	0.11
15-38	3.3	60.0	21.0	19.0	Loam	1.70	2.56	0.09
38-110	0.8	63.0	15.0	22.0	Loam	1.64	2.58	0.07

Table 5.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available Water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-15	35.56	24.09	22.24	21.06	19.78	18.65	17.92	17.24	16.55	7.54	1.99	19.36
15-38	37.79	24.30	22.48	19.30	17.96	17.00	16.00	15.63	15.15	9.15	3.58	High
38-110	37.67	24.31	21.01	14.72	13.28	12.31	11.53	11.11	10.75	13.56	16.01	

Table 5.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	14.60	1.90	1.26	0.21	0.21	0.21	0.21
Cumulative infiltration (cm)	1.22	1.38	1.80	1.91	2.12	2.23	2.34

Table 5.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-15	8.20	0.38	14.95	6.86	6.47	1.29	0.29
15-38	8.37	0.44	11.76	5.08	5.01	1.32	0.30
38-110	8.21	0.38	13.95	6.50	5.84	1.41	0.15

Table 5.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-15	0.40	199	30	364	25.6	17.3	2.3	1.0
15-38	0.24	144	6	302	11.5	15.3	1.3	0.8
38-110	0.25	72	6	291	10.1	14.3	1.2	0.9

These soils were medium textured with high silt content (46.5%) in surface layer. Sand content increased sharply from surface to next horizon. Hydraulic conductivity was very low and infiltration rate was slow. Available water storage capacity of the profile was very high. The soil was moderately alkaline in reaction and non-saline. Low in organic carbon and available nitrogen. Micronutrients content was above critical limits.

Classification

Order	-	Inceptisols
Sub-order	-	Ochrepts
Great group	-	Ustocherpts
Sub-group	-	Vertic Ustochrepts
Family	-	Fine loamy mixed isohyperthermic Vertic Ustochrepts
Series	-	Kalingapatnam

6. Ragolu series

Location Village: Ragolu, Mandal: Srikakulam

These soils were deep and moderately well drained occurring on gently sloping piedmont. Basalt forms geology of the region. The profile site was a piedmont with rolling topography and very gentle slope. Water table was at 7.5-9.0 m depth. The field was moderately well drained with moderate erosion hazard. The cropping pattern followed in the region was paddy-jowar-pulse. The field was cultivated for paddy in *kharif* and groundnut in *rabi* with tank irrigation. Vegetation of the region includes acacia, palmyrah *etc*. The profile was collected in field no. 6 of Agricultural Research Station Farm, Ragolu.

Depth (cm)	Horizon description
0-17	Dark brown (10 YR 3/3 M), pale olive (5 Y 6/3 D); clay loam; moderate, medium and sub-angular blocky; hard, friable and slightly sticky; coarse fragments of 2-10 mm occur to about 7% by volume; moderately permeable; few fine roots; common fine pores; no effervescence with dilute HCl; clear smooth boundary.
17-55	Brown and dark brown (10 YR 4/3 M), pale olive (5 Y 6/3 D); clay loam; moderate, medium and angular blocky; hard, firm and slightly sticky; prominent pressure faces present; coarse fragments (2-10 mm) occur to about 5% by volume; moderately slow permeability; few fine roots; common fine pores; no effervescence with dilute HCl; gradual wavy boundary.
55-100	Yellowish red (5 YR 4/8 M), reddish yellow (7.5 YR 6/6 D); clay loam; strong, coarse and angular blocky; hard, firm and slightly sticky; intersecting slickensides present; moderately slow permeability; coarse fragments of 2-5 mm size occur to about 3% by volume; very few very fine roots; few fine pores; no effervescence with dilute HCl; gradual wavy boundary.
100-125	Yellowish red (5 YR 4/8 M), reddish yellow (7.5 YR 6/6 D); sandy clay loam; strong, coarse and angular blocky; hard, firm and slightly sticky; common fine faint mottles; intersecting slickensides; coarse fragments of 2.5 mm size upto 1% by volume; very fine very few roots; few fine pores; no effervescence with dilute HCl.

Table 6.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-17	5.1	67.3	8.7	24.0	Clay loam	1.67	2.59	2.12
17-55	7.1	63.0	11.7	25.3	Clay loam	1.69	2.57	2.34
55-100	34.5	65.5	9.5	25.0	Gravelly clay loam	1.79	2.56	12.42
100-125	19.8	70.0	6.0	24.0	Sandy clay loam	1.76	2.57	19.08

Table 6.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-17	[illegible]	21.29	18.67	16.17	15.28	13.60	13.08	12.83	12.55	8.74	2.51	13.95
17-55	38.57	24.64	22.76	20.82	19.83	19.08	18.05	17.02	16.66	7.98	5.12	Medium
55-100	25.64	18.69	16.45	13.75	12.67	12.17	11.72	11.25	10.85	7.84	6.32	
100-125	28.55	15.99	14.85	13.43	12.58	12.11	11.72	11.40	10.96	5.03	2.21	

Table 6.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	3.63	3.38	0.13	0.12	0.11	0.11	0.11
Cumulative infiltration (cm)	0.30	0.58	0.62	0.68	0.79	0.84	0.89

Table 6.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C (cmol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-17	7.71	0.33	14.95	8.35	6.09	0.36	0.12
17-55	7.88	0.48	14.95	8.04	6.09	0.63	0.16
55-100	7.90	0.46	16.14	8.28	7.15	0.46	0.21
100-125	7.93	0.21	9.57	4.41	4.50	0.47	0.16

Table 6.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-17	0.22	190	59	235	32.3	15.8	2.9	3.0
17-55	0.21	160	39	280	15.5	12.9	1.6	2.4
55-100	0.17	130	34	382	8.9	10.1	1.0	4.5
100-125	0.14	98	16	392	6.9	10.2	0.7	3.7

The soils were medium textured. Infiltration rate was very slow. Available storage capcity of the profile was medium.

Classification

Order	-	Inceptisols
Sub-orders	-	Ochrepts
Great group	-	Ustochrepts
Sub-group	-	Vertic Ustochrepts
Family	-	Fine loamy mixed isohyperthermic Vertic Ustochrepts
Series	-	Ragolu

7. Naira series

Location Village: Naira, Mandal: Srikakulam

These soils were deep and moderately well drained occurring on gently sloping piedmont. The profile site was with gentle slope and moderate erosion hazard. Natural vegetation of the region includes acacia, palmyrah *etc*. The profile was collected from the College Farm of Agricultural College, Naira.

Depth (cm)	Horizon description
0-15	Dark yellowish brown (10 YR 4/4 M), light yellowish brown (10 YR 6/4 D); loamy sand; moderate, medium and sub-angular blocky; loose, loose and non-sticky; many roots; few fine pores; no effervescence with dilute HCl; clear boundary.
15-50	Brown and dark brown (7.5 YR 4/4 M), yellowish brown (10 YR 5/8 D); sandy clay; strong, medium and sub-angular blocky; hard, firm and sticky; few roots; few fine pores; no effervescence with dilute HCl; clear boundary; fine kankar tightly packed with soil around it. This was a compact layer.
50-100	Brown and dark brown (7.5 YR 4/4 M), strong brown (7.5 YR 5/6 D); sandy clay; moderate, medium and sub-angular blocky; hard, firm and sticky; few roots; few fine pores; no effervescence with dilute HCl; kankar tightly packed with soil around it.

Table 7.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-20	2.61	89.3	6.0	4.7	Loamy sand	1.63	2.61	7.68
20-50	1.70	65.0	6.7	28.3	Sandy clay	1.80	2.58	0.18
50-100	16.30	66.7	4.0	29.3	Sandy clay	1.77	2.57	0.25

Table 7.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water rentention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-20	13.05	6.32	5.98	5.48	5.03	4.59	4.11	3.59	3.28	3.04	0.99	7.44
20-50	29.30	18.13	15.21	12.13	10.98	10.43	9.76	9.42	9.12	6.09	3.29	Low
50-100	29.88	18.10	16.49	15.36	14.50	14.08	13.60	13.22	12.92	3.57	3.16	

Table 7.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	10.34	8.46	8.60	7.01	6.01	5.90	5.81
Cumulative infiltration (cm)	0.86	1.57	4.44	7.95	13.96	16.91	19.8

Table 7.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-20	6.53	0.09	2.99	1.52	1.04	0.10	0.08
20-50	6.04	0.12	7.97	4.01	3.02	0.23	0.15
50-100	7.16	0.14	13.55	7.31	5.70	0.29	0.12

Table 7.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-20	0.21	104	9	146	19.4	27.5	0.9	0.8
20-50	0.19	255	22	146	36.7	31.2	1.9	0.7
50-100	0.23	108	6	168	11.7	20.0	0.9	0.6

These soils were coarse textured (loamy sand) at surface but deeper layers were fine (sandy clay) in texture. The lower layers of the profile were compacted due to illuviated clay. Sand content decreased steeply and clay content increased steeply from surface to second horizon. Lower layers recorded high bulk density and hydraulic conductivity was slow in these layers though it was moderately rapid in surface layer. Infiltration rate was moderate. Available water storage capacity of the profile was low.

These soils were neutral in reaction, non-saline and poor in fertility. Micronutrients content was above critical limits.

Classification

Order	-	Alfisols
Sub-order	-	Ustalfs
Great group	-	Haplustalfs
Sub-group	-	Udic Haplustalfs
Family	-	Fine loamy mixed isohyperthermic Udic Haplustalfs
Series	-	Naira

8. Amadalavalasa series

Location Village: Amadalavalasa, Mandal: Amadalavalasa

These soils were deep and moderately well drained formed from basaltic alluvium occurring on very gently sloping piedmont. The site of the profile was a plain land with very gentle slope. It was a well drained land with moderate erosion hazard. Water table was 12-15 m deep. Vegetation of the region includes acacia, palmyrah *etc.* The field was cultivated for mesta as rainfed crop. The profile location was Agricultural Research Station Farm, Amadalavalasa.

Depth (cm)	Horizon description
0-15	Strong brown (7.5 YR 5/6 M), light yellowish brown (10 YR 6/4 D); sandy loam; moderate, medium and sub-angular blocky; slightly hard, firm and slightly sticky; coarse fragments of 5-15 mm size occur to about 5% by volume; common fine roots; common very fine pores; moderately permeable; no effervescence with dilute HCl; clear smooth boundary.
15 - 30	Strong brown (7.5 YR 5/6 M), reddish yellow (7.5 YR 6/6 D); sandy clay loam; moderate, medium and sub-angular blocky; slightly hard, firm and sticky; pressure faces present; coarse fragments of 2-10 mm size upto 5% by volume; moderately slow permeability; common very fine roots; common very fine pores; no effervescence with dilute HCl; gradual smooth boundary.
30-68	Strong brown (7.5 YR 5/6 M), reddish yellow (7.5 YR 6/6 D); sandy clay loam; strong, coarse and angular blocky; hard, firm and sticky; pressure faces present; coarse fragments of 2-10 mm size upto 2-3% by volume; slowly permeable; very few very fine roots; common very fine pores; no effervescence with dilute HCl; clear wavy boundary.
68-100	Strong brown (7.5 YR 5/6 M), reddish yellow (7.5 YR 6/8 D); sandy clay loam; moderate, medium and sub-angular blocky; hard, firm and slightly sticky; pressure faces present; coarse fragments of 10-35 mm size upto 10% by volume; slow permeability; few very fine roots; many fine pores; slight effervescence with dilute HCl.

Table 8.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-15	0.9	80.0	8.5	11.5	Sandy loam	1.62	2.56	0.90
15-30	0.9	70.0	5.0	25.0	Sandy clay loam	1.61	2.52	0.36
30-68	2.1	76.0	3.0	21.0	Sandy clay loam	1.76	2.50	0.17
68-100	18.5	75.0	3.5	21.5	Sandy clay loam	1.90	2.52	0.13

Table 8.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-15	16.07	9.38	6.97	5.53	4.90	4.54	4.25	3.95	3.60	5.78	1.40	13.46
15-30	26.61	16.65	14.18	11.58	10.55	10.21	9.82	9.25	8.92	7.73	1.87	Medium
30-68	31.23	14.24	13.83	12.81	11.55	11.72	9.61	8.26	6.92	7.32	4.90	
68-100	31.96	17.13	13.58	12.91	12.11	11.20	9.92	8.71	7.85	9.28	5.29	

Table 8.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	15.10	13.23	6.15	2.77	2.12	2.12	2.12
Cummulative infiltratiion (cm)	1.26	2.36	4.41	5.80	7.92	8.98	10.04

Table 8.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-15	5.44	0.09	9.57	4.09	4.01	0.35	0.10
15-30	5.81	0.07	15.02	7.52	6.01	0.30	0.04
30-68	6.60	0.24	13.15	6.41	6.02	0.24	0.09
68-100	6.75	0.15	16.14	8.03	7.03	0.21	0.11

Table 8.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-15	0.21	181	18	168	26.3	40.9	1.4	1.3
15-30	0.33	212	13	134	18.7	41.3	1.4	2.8
30-68	0.32	229	9	235	17.6	45.3	1.6	0.8
68-100	0.26	176	30	246	15.7	48.7	1.4	1.5

These soils were light (sandy loam) in texture at surface but medium (sandy clay loam) textured in lower layers. Sand content decreased and clay content increased steeply from surface to second horizon. Lower layers recorded high values of bulk density (1.76 and 1.90 g/cc) and hydraulic conductivity was slow in these layers.

Infiltration rate was moderate and available water storage capacity of the profile was medium. The soils were moderately acidic in reaction and non-saline. Low in organic carbon and available nitrogen. Micronutreints content was above critical limits.

Classification

Order	-	Alfisols
Sub-order	-	Ustalfs
Great group	-	Haplustalfs
Sub-group	-	Udic Haplustalfs
Family	-	Fine loamy mixed isohyperthermic Udic Haplustalfs
Series	-	Amadalavalasa

9. Kosta series

Location Village: Kosta, Mandal: Ranasthalam

These soils were deep and well drained occurring on gently sloping lands. Water table was deeper than 10 m. Cultivated for groundnut and horsegram as rainfed crops. Vegetation of the region includes palmyrah trees, grasses *etc.* Mango and cashew orchards were also there in the region.

Depth (cm)	Horizon description
0-10	Strong brown (7.5 YR 5/6 M), brownish yellow (10 YR 6/6 D); sandy loam; weak; medium and sub-angular blocky; loose, loose and non-sticky; few roots; few fine pores; no effervescence with dilute HCl; clear boundary.
10-35	Red (2.5 YR 4/6 M), yellowish red (5 YR 5/8 D); sandy clay loam; weak, medium and sub-angular blocky; slightly hard, very friable and slightly sticky; few fine pores; no effervescence with dilute HCl; diffused boundary.
35-100	Red (2.5 YR 4/8 M), red (2.5 YR 5/8 D); sandy clay; weak, medium and sub-angular blocky; hard, firm and sticky; common pores; more gravelly than the upper layers and few stones were also present; no effervescence with dilute HCl. It was a compact layer.

Table 9.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-10	7.8	87.5	2.0	10.5	Sandy loam	1.52	2.62	16.42
10-35	7.8	68.7	3.3	28.0	Sandy clay loam	1.43	2.67	24.32
35-100	18.5	65.0	5.0	30.0	Sandy clay	1.98	2.67	2.84

Table 9.2 : Water retention and available water

Soil depth (cm)	Water content in saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-10	13.88	6.31	5.90	4.89	4.38	4.12	3.85	3.41	3.09	3.22	0.49	9.48
10-35	25.31	18.40	11.09	9.32	8.48	8.12	7.68	7.59	7.27	11.13	3.98	Low
35-100	28.65	11.94	10.77	9.43	8.23	7.84	7.48	7.09	6.88	3.89	5.01	

Table 9.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	11.16	7.50	1.93	1.06	1.06	1.06	1.06
Cumulative infiltration (cm)	0.93	1.56	2.20	2.73	3.79	4.32	4.85

Table 9.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-10	7.05	0.24	4.78	2.76	0.94	0.39	0.09
10-35	5.14	0.07	4.18	2.67	0.50	0.11	0.12
35-100	5.39	0.09	4.78	2.25	1.73	0.13	0.10

Table 9.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-10	0.15	124	16	146	26.4	33.3	1.0	0.8
10-35	0.17	176	9	123	9.1	38.3	1.2	0.9
35-100	0.19	212	29	213	7.1	28.0	1.6	1.0

These soils were light (sandy loam) textured at surface. Sand content decreased and clay content increased steeply from the surface to second horizon. The bottom (35-100 cm) layer was a compact layer with very high bulk density (1.98 g/cc). Hydraulic conductivity in this layer was comparatively lower than the upper horizons. Infiltration rate was moderately slow. Available water storage capacity was low. Surface horizon

was neutral in reaction. Soil was non-saline, low in organic carbon and available nitrogen. Micronutrients content was above critical limits.

Classification

Order	-	Alfisols
Sub-order	-	Ustalfs
Great group	-	Rhodustalfs
Sub-group	-	Udic Rhodustalfs
Family	-	Fine loamy mixed isohyperthermic Udic Rhodustalfs
Series	-	Kosta

10. Kagitapalli series

Location Village: Kagitapalli, Mandal: Regidiamadalavalasa

These soils were very shallow, poorly drained occurring on plains. Highly weathered basalt or granitic rock forms the geology of the region. The site of the profile was a very gently sloping land with imperfect drainage. The runoff was slow with moderate erosion hazard.

Depth (cm)	Horizon description
0-11	Dark yellowish brown (10 YR 4/4 M), pale brown (10 YR 6/3 D); sandy loam; weak, coarse and angular blocky; soft, loose and slightly sticky; few fine nodules; moderately thick ferrans in patches; common fine roots; very fine pores; slight effervescence with dilute HCl; clear smooth boundary.
11-47	Brown and dark brown (7.5 YR 4/4 M), reddish yellow (7.5 YR 6/6 D); sandy loam weak, coarse and angular blocky; soft very friable and slightly sticky; few fine nodules; iron concretions and mottles present; thick ferrans in patches; few fine roots; few fine pores; slight effervescence with dilute HCl; gradual smooth boundary.
47-51	Brown and dark brown (7.5 YR 4/4 M), light yellowish brown (10 YR 6/4 D); sandy loam; weak, coarse and angular blocky; slightly hard, friable and slightly sticky; few medium nodules; cutans broken in distribution; iron concretions present; slight effervescence with dilute HCl.

Table 10.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-11	3.8	87.3	1.4	11.3	Sandy loam	1.72	2.56	15.12
11-47	3.7	77.0	6.0	17.0	Sandy loam	1.73	2.56	9.84
47-51	38.4	75.5	6.5	18.0	Gravelly sandy loam	1.68	2.55	23.22

Table 10.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-11	20.32	11.63	7.28	5.54	4.45	3.89	3.66	3.51	3.42	8.21	1.55	5.67
11-47	19.30	9.68	8.91	6.92	5.80	5.28	4.78	4.28	4.03	5.65	3.52	Low
47-51	29.75	20.01	15.74	14.31	13.28	12.48	11.88	11.43	11.13	8.88	0.60	

Table 10.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	3.00	2.82	2.17	2.17	2.11	2.11	2.11
Cumulative infiltration (cm)	0.25	0.49	1.21	2.[illegible]	4.41	5.47	6.53

Table 10.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-11	6.69	0.10	2.61	1.32	1.01	0.10	0.0[illegible]
11-47	6.51	0.07	3.91	2.32	1.27	0.13	0.0[illegible]
47-51	6.48	0.11	5.87	3.43	2.03	0.14	0.0[illegible]

Table 10.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	[illegible]	Cu	Zn
0-11	0.31	178	13	252	14.0	20.4	1.0	1.1
11-47	0.28	169	8	140	13.8	32.1	0.9	[illegible].9
47-51	0.21	210	7	268	13.0	31.0	0.8	0.8

These soils were light textured (sandy loam) with gravelly bottom (47-51 cm) layer. Hydraulic conductivity was rapid and infiltration rate was moderate. Available water storage capacity was low. Soils were neutral in reaction and non-saline. Low in organic carbon and available nitrogen. Micronutrients content was above critical limits.

Classification

Order	-	Entisols
Sub-order	-	Orthents
Great group	-	Ustorthents
Sub-group	-	Typic Ustorthents
Family	-	Coarse loamy mixed isohyperthermic Typic Ustorthents
Series	-	Kagitapalli

11. Madikuru series

Location Village: Madikuru, Mandal: Veeraghattam

These soils were deep and moderately well drained occurring on very gently sloping plains. Basaltic alluvium forms the geology of the region. The profile site was a nearly levelled flood plain with imperfect drainage. The runoff was slow with very slight erosion hazard. Water table was deeper than 10 m. The field was cultivated for paddy in *kharif* and groundnut in *rabi*. Cracks of about 1 cm width remained open for more than 150 days throughout the profile.

Depth (cm)	Horizon description
0-10	Very dark greyish brown (2.5 Y 3/2 M), greyish brown (2.5 Y 5/2 D); clay, moderate, fine and sub-angular blocky; loose, friable and slightly sticky; few very fine nodules; few fine roots; slight effervescence with dilute HCl; gradual smooth boundary; white encrustations were found on peds.
10-40	Very dark greyish brown (2.5 Y 3/2 M), pale olive (5 Y 6/3 D); clay; strong, fine and sub-angular blocky; slightly hard, friable and sticky; few fine nodules; moderately thick ferrans in patches; slight effervescence with dilute HCl; clear smooth boundary.
40-100	Very dark greyish brown (2.5 Y 3/2 M), greyish brown (2.5 Y 5/2 D); clay; strong, fine and sub-angular blocky; slightly hard, firm and sticky; few fine nodules; thin ferrans in patches; prominent slickensides; iron and lime concretions present; few fine pores; slight effervescence with dilute HCl; clear smooth boundary.

Table 11.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-10	0.8	47.0	15.0	38.0	Clay	1.17	2.52	0.12
10-40	0.5	40.6	18.0	42.0	Clay	1.47	2.51	0.12
40-100	1.2	51.3	13.4	35.3	Clay	1.56	2.61	0.09

Table 11.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-10	45.69	34.06	32.31	29.64	27.54	25.10	22.98	21.08	19.52	12.82	1.50	15.5
10-40	42.83	32.17	30.81	28.61	26.48	25.80	24.05	22.08	20.73	10.08	4.45	High
40-100	38.65	30.39	28.43	25.45	23.15	22.08	20.78	19.46	18.18	10.25	9.60	

Table 11.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	negligible						
Cumulative infiltration (cm)	negligible						

Table 11.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-10	7.32	0.69	19.13	8.39	10.28	0.09	0.17
10-40	7.35	0.55	18.93	8.16	10.11	0.27	0.20
40-100	7.61	0.37	17.04	7.98	8.37	0.40	0.20

Table 11.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutreints (kg/ha)			Available micronutreints (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-10	1.03	185	31	333	13.6	2.1	16.3	2.7
10-40	0.66	172	23	338	9.8	1.7	14.1	2.0
40-100	0.44	203	14	324	7.1	1.6	11.8	2.3

These soils were fine textured. Hydraulic conductivity was very slow and infiltration rate was negligible. Available water storage capacity of the profile was high. Soil was neutral in reaction and non-saline. Low in available nitrogen. Micro-nutrients content was above critical limits. Due to high clay content (montmorillonitic clay) workability was limited both when wet and dry.

Classification

Order	-	Vertisols
Sub-order	-	Usterts
Great group	-	Chromusterts
Sub-group	-	Typic Chromusterts
Family	-	Fine montmorillonitic isohyperthermic Typic Chromusterts
Series	-	Madikuru

12. Sattiwada series

Location Village: Sattiwada, Mandal: Bhamini

These soils were very deep and moderately well drained occurring on gently sloping land. The profile site was one kilometre away from foot hills. Water table was deeper than 15 m. This region was under rainfed cultivation, cultivated for groundnut, redgram or ragi in *khari*, [illegible] and mango orchards horsegram and tapioca crops were also cultivated. The crop in the field was tapioca.

Depth (cm)	Horizon description
0-12	Yellowish red (5 YR 4/6 M), reddish yellow (5 YR 6/8 D); sandy; structureless; loose, very friable and non-sticky; many fine roots; no effervescence with dilute HCl; clear boundary.
12-50	Yellowish red (5 YR 4/6 M); reddish yellow (5 YR 7/8 D); sandy loam; sub-angular blocky; loose, friable and slightly sticky; few fine roots; no effervescence with dilute HCl; clear boundary.
50-80	Yellowish red (5 YR 4/8 M), reddish yellow (5 YR 6/8 D); sandy loam; sub-angular blocky; loose, friable and non-sticky; very few fine roots; few fine pores; no effervescence with dilute HCl; clear boundary.
80-100	Yellowish red (5 YR 4/6 M), yellowish red (5 YR 5/8 D); sandy clay loam; sub-angular blocky; loose, friable and slightly sticky; worm channels and insect burrows; sand pockets; many pores; few fine roots; no effervescence with dilute HCl.

Table 12.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-12	0.4	92.7	3.3	4.0	Sand	1.54	2.60	7.20
12-50	2.9	82.7	4.7	12.6	Sandy loam	1.48	2.63	2.10
50-80	1.7	88.5	2.0	9.5	Sandy loam	1.55	2.69	7.34
80-100	1.5	77.0	4.0	19.0	Sandy clay loam	1.63	2.67	2.42

Table 12.2 : Water rentention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-12	15.80	10.38	5.33	3.87	3.21	2.86	2.45	2.05	1.81	8.57	1.58	12.72
12-50	30.98	15.17	12.50	10.82	9.44	8.60	7.51	6.61	6.45	8.72	4.90	Medium
50-80	22.01	9.10	8.25	6.98	6.12	5.48	4.65	3.45	3.15	5.95	2.77	
80-100	31.11	18.35	12.46	11.13	9.92	9.24	8.52	8.08	7.70	10.65	3.47	

Table 12.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	13.81	8.41	2.91	2.12	2.12	2.12	2.12
Cumulative infiltration (cm)	1.15	1.85	2.82	3.88	6.00	7.06	8.12

Table 12.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+) /kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-12	6.56	0.07	3.49	1.65	1.42	0.20	0.12
12-50	6.53	0.06	3.59	1.86	1.37	0.23	0.07
50-80	6.78	0.08	9.96	5.79	3.40	0.44	0.17
80-100	6.83	0.09	7.38	3.56	2.91	0.57	0.24

Table 12.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-12	0.25	133	12	179	13.0	21.5	0.7	1.2
12-50	0.25	173	6	201	13.7	31.6	0.8	1.3
50-80	0.22	78	15	134	14.2	28.9	0.9	1.6
80-100	0.24	143	22	179	15.3	36.1	1.0	0.9

These soils were light textured and clay content increased with depth. Infiltration rate was moderate. Available water storage capacity of the profile was medium. Soil was neutral in reaction and non-saline. Low in organic carbon and

available nitrogen. Medium in available P and K. Micronutrients content was above critical limits.

Classification

Order	-	Inceptisols
Sub-order	-	Ochrepts
Great group	-	Ustochrepts
Sub-group	-	Typic Ustochrepts
Family	-	Coarse loamy mixed isohyperthermic Typic Ustochrepts
Series	-	Sattiwada

13. Seethampeta series

Location Village: Seethampeta, Mandal: Seethampeta

These soils were very deep and poorly drained occurring on gentle slopes. Vegetation includes casuarina, tamarind, eucalyptus *etc.* It was cultivated for sunflower and ragi. Cracks of 1 cm width remained open for more than 150 days in a year throughout the profile. The profile was collected from the Agricultural Research Station Farm, Seethampeta.

Depth (cm)	Horizon description
0-20	Dark brown (10 YR 3/3 M), brown and dark brown (10 YR 4/3 D); clay; angular blocky; hard, very firm and sticky; slickensides and well developed cracks; few sand pockets; few roots; few fine pores; strong effervescence with dilute HCl; clear boundary.
20-70	Brown and dark brown (10 YR 4/3 M), brown (10 YR 5/3 D); clay; sub-angular blocky; hard, very firm and sticky; slickensides and well developed cracks; very small black kankar, few sand pockets; few roots; violent effervescence with dilute HCl; diffused boundary.
70-100	Brown and dark brown (10 YR 4/3 M), brown (10 YR 5/3 D); clay; sub-angular blocky; hard, very firm and sticky; slickensides and cracks; calcitic kankar with violent effervescence with dilute HCl; soil showed strong effervescence with dilute HCl.

Table 13.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		sand	silt	clay				
0-20	0.8	45.3	14.7	40.0	Clay	1.38	2.48	0.41
20-70	1.0	30.0	19.0	51.0	Clay	1.55	2.46	0.31
70-100	1.1	44.0	10.0	46.0	Clay	1.53	2.45	0.13

Table 13.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/mdepth
0-20	60.81	38.03	36.73	33.27	30.09	28.66	26.38	24.44	23.19	13.54	3.74	19.68
20-70	62.15	40.11	37.63	33.82	31.43	29.55	27.93	26.65	24.98	12.65	9.80	High
70-100	55.91	35.14	33.98	30.08	27.58	25.93	23.88	21.86	20.60	13.38	6.14	

Table 13.3 : Infiltration rate and cummulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	61.37	24.92	8.15	4.16	2.78	2.45	2.40
Cumulative infiltration (cm)	5.11	7.19	9.91	11.99	14.77	16.00	17.2

Table 13.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-20	7.80	0.49	26.30	13.13	11.30	1.70	0.17
20-70	7.90	0.44	29.89	14.52	12.82	1.78	0.22
70-100	8.07	0.46	29.89	14.49	13.09	1.72	0.24

Table 13.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-20	0.43	163	28	380	13.7	1.8	15.4	2.6
20-70	0.32	130	9	257	9.8	1.5	12.6	1.7
70-100	0.28	58	12	235	8.6	1.5	11.6	1.5

These soils were fine textured. Hydraulic conductivity was slow and infiltration rate was moderate. Available water storage capcity was high. Soil was slightly alkaline in reaction and non-alkaline but ESP was below 15. Low in organic carbon and available nitrogen and high in available phosphorus and potassium. Micronutrients content was above critical limits. Due to high clay content workability was limited both when wet and dry.

Classification

Order - Vertisols

Sub-order	-	Usterts
Great group	-	Chromusterts
Sub-group	-	Typic Chromusterts
Family	-	Fine montmorillonitic isohyperthermic Typic Chromusterts
Series	-	Seethampeta

14. Nowtala series

Location Village: Nowtala, Mandal: Saravakota

These soils were deep and moderately well drained occurring on very gently sloping piedmont lands. Weathered basalt forms the geology of the region. The profile site was a slopy hill area with poor drainage. Runoff was medium with moderate erosion hazard. Groundwater was deeper than 20 m. Vegetation of the region includes teak, cashew, mango *etc*. The field was used for teak plantation.

Depth (cm)	Horizon description
0-12	Brown and dark brown (7.5 YR 4/4 M), light yellowish brown (10 YR 6/4 D); sandy; weak, fine angular blocky; loose, friable and non-sticky; many medium nodules; about 3% coarse gravel by volume; many medium roots; many fine pores; slight effervescence with dilute HCl; abrupt wavy boundary.
12-45	Reddish yellow (5 YR 4/6 M), reddish yellow (5 YR 6/6 D); clay loam; moderate, fine and angular blocky; hard, firm and sticky; many fine nodules; abundant fine prominent mottles; thin ferrans in patches; slickensides present; many fine roots; common very fine pores; slight effervescence with dilute HCl; clear smooth boundary.
45-70	Reddish yellow (5 YR 4/6 M), reddish yellow (5 YR 6/6 D); clay loam; moderate fine and angular blocky; hard, firm and sticky; many very fine nodules; abundant fine prominent mottles; thin ferrans in patches; slickensides present; many very fine roots; common very fine pores; slight effervescence with dilute HCl; clear smooth boundary.
70-115	Reddish yellow (5 YR 4/6 M), reddish yellow (5 YR 6/6 D); clay loam; weak, very fine and angular blocky; slightly hard, firm and slightly sticky; few very fine nodules; few very fine roots; many medium pores; strong effervescence with dilute HCl.

Table 14.1 : Mechanical composition bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-12	2.8	91.3	1.7	7.0	Sand	1.58	2.52	10.74
12-44	1.4	65.0	8.5	26.5	Clay loam	1.59	2.53	0.92
44-70	0.9	66.7	10.3	23.0	Clay loam	1.63	2.51	0.78
70-115	1.3	69.0	7.0	24.0	Sandy clay loam	1.55	2.50	0.58

Table 14.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-12	18.99	9.80	9.12	7.24	5.63	4.65	3.55	3.02	2 67	7.13	1.35	19.93
12-44	31.74	21.40	17.02	15.15	14.03	13.19	12.58	11.80	11.40	10.00	4.99	High
44-70	39.80	23.24	16.83	12.68	10.85	10.18	9.49	8.87	8.58	14.66	6.21	
70-115	44.57	25.65	18.93	13.97	11.75	10.85	10.33	9.98	9.78	15.87	11.07	

Table 14.3 : Infiltration rate and cummulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	16.51	15.70	12.50	8.98	8.00	7.90	7.90
Cummulative infiltration (cm)	1.38	2.69	7.86	12.35	20.35	24.30	28.25

Table 14.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-12	6.73	0.08	4.18	2.86	1.11	0.04	0.02
12-44	6.46	0.10	7.17	4.73	2.01	0.08	0.03
44-70	6.62	0.08	7.17	4.82	2.03	0.08	0.03
70-115	6.85	0.08	7.17	4.71	2.10	0.09	0.03

Table 14.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-12	0.46	112	11	190	13.6	16.2	0.5	0.8
12-44	0.39	150	16	175	21.3	18.7	0.4	0.7
44-70	0.15	122	17	196	23.6	23.5	0.6	0.6
70-115	0.09	131	16	196	17.32	25.1	0.8	0.5

These soils were light (sandy) textured at surface but medium textured in lower layers. Sand content decreased and clay content increased steeply from surface to second horizon. Hydraulic conductivity decreased suddenly from surface to lower horizons. Available water storage capacity was high. Infiltration rate was moderately

rapid. Soil was neutral in reaction and non-saline. Organic carbon and available nitrogen were low and available phosphorus and potassium were medium. Micronutrients content was above critical limits.

Classification

Order	-	Alfisols
Sub-order	-	Ustalfs
Great group	-	Haplustalfs
Sub-group	-	Typic Haplustalfs
Family	-	Fine loamy mixed isohyperthermic Typic Haplustalfs
Series	-	Nowtala

15. Meliaputti series

Location Village: Meliaputti, Mandal: Meliaputti

These soils were moderately deep, moderately well drained occurring on valley lands. The profile site was a slopy land with very poor drainage. The water table was below 7.5 m depth. Runoff was medium with moderate erosion hazard. Vegetation of the region includes cashew, tamarind, teak and eucalyptus. The field was under rainfed cultivation.

Depth (cm)	Horizon description
0-16	Yellowish red (5 YR 4/6 M), yellowish red (5 YR 5/8 D); sandy clay loam; weak, fine and sub-angular blocky; loose, firm and non-sticky; many fine nodules, few prominent mottles; few very fine roots; many very fine pores; gravel upto 2% by volume; slight effervescence with dilute HCl; clear smooth boundary.
16-35	Yellowish red (5 YR 4/6 M), yellowish red (5 YR 4/8 D); clay; moderate, fine and sub-angular blocky; hard, firm and very sticky; many very fine nodules; few coarse prominent mottles; thin patchy ferrans; slickensides present; common fine roots; common medium pores; slight effervescence with dilute HCl; clear wavy boundary.
35-100	Red (2.5 YR 4/6 M), yellowish red (5 YR 4/8 D); clay; strong, fine and sub-angular blocky; hard, firm and very sticky; few very fine nodules; thin ferrans in patches; slickensides present; few fine roots; common medium pores; slight effervescence with dilute HCl; clear smooth boundary.

Table 15.1 : Mechanical composition, bulk density, particle density and hydraulic conductivity

Soil depth (cm)	Gravel (%)	Mechanical composition (%)			Texture	Bulk density (g/cc)	Particle density (g/cc)	Hydraulic conductivity (cm/h)
		Sand	Silt	Clay				
0-16	0.6	67.0	7.0	26.0	Sandy clay loam	1.76	2.60	1.16
16-35	0.7	66.0	28.7	35.3	Clay	1.50	2.61	0.10
35-100	1.7	57.7	8.3	34.0	Clay	1.51	2.64	0.06

Table 15.2 : Water retention and available water

Soil depth (cm)	Water content at saturation (% wt. basis)	Water retention (% wt. basis) at different tensions in bars								Available water		
		0.1	0.33	1.0	2.0	3.0	5.0	10.0	15.0	%	cm/layer	cm/m depth
0-16	36.10	15.64	13.88	11.38	9.58	8.59	8.02	7.67	7.21	8.43	2.37	13.77
16-35	38.51	22.37	18.53	17.68	16.30	15.81	15.16	14.11	13.21	5.32	2.61	Medium
35-100	39.05	23.38	21.05	15.78	15.34	14.94	14.78	14.59	14.42	6.63	8.79	

Table 15.3 : Infiltration rate and cumulative infiltration

	Time in minutes						
	5	10	30	60	120	150	180
Infiltration rate (cm/h)	13.33	13.12	4.87	4.51	3.40	2.86	2.58
Cumulative infiltration (cm)	1.11	2.20	3.82	6.08	9.48	10.91	12.2

Table 15.4 : Physico-chemical properties

Depth (cm)	pH (1:2.5)	E.C. (1:2.5) (dS/m)	C.E.C. (c mol (p^+)/kg)	Exchangeable cations (c mol (p^+)/kg)			
				Ca	Mg	Na	K
0-16	6.55	0.11	5.38	3.00	1.81	0.30	0.04
16-35	6.62	0.07	6.28	3.19	2.48	0.31	0.10
35-100	6.34	0.07	7.17	3.41	3.03	0.30	0.08

Table 15.5 : Chemical properties

Depth (cm)	O.C. (%)	Available primary nutrients (kg/ha)			Available micronutrients (ppm)			
		N	P	K	Fe	Mn	Cu	Zn
0-16	0.48	159	5	319	35.1	33.2	1.4	1.1
16-35	0.35	94	6	260	41.1	40.3	1.8	0.8
35-100	0.47	138	8	252	42.2	49.3	1.9	1.4

These soils were medium (sandy clay loam) textured at surface but lower layers were clayey. Bulk density was highest in the surface layer. Hydraulic conductivity was moderately slow in surface layer but it was very slow in lower layers. Available water storage capacity of the profile was medium. Infiltration rate was moderate. Soil was neutral in reaction and non-saline. Poor in fertility with low organic carbon, available nitrogen and available phosphorus. Micronutrients content was above critical limits.

Classification

Order	-	Inceptisols
Sub-order	-	Ochrepts
Great group	-	Ustochrepts
Sub-group	-	Typic Ustochrepts
Family	-	Fine mixed isohyperthermic Typic Ustochrepts
Series	-	Meliaputti

Correlation and Regression Analysis

Statistical analysis was carried out to obtain correlations between different soil properties and to develop regression equations for predicting soil moisture retention at 0.1, 0.33 and 15 bar tensions. Bulk density was found to have significant negative correlation with organic carbon (r = -0.415). Hydraulic conductivity was found to have significant negative correlation with clay (r = -0.476), silt (r = -0.374), clay plus silt (r = -0.521) and C.E.C. (r = -0.446) and significant positive correlation with sand (r = 0.521). C.E.C. showed significantly positive correlation with clay (r = 0.660), silt (r = 0.502), pH (r = 0.629) and significantly negative correlation with sand (r = -0.715).

Knowledge of soil water retention and its availability is important for better soil water management and crop yields. Unfortunately, soil water characteristics are difficult to measure since direct measurements are very time consuming, costly and impracticable as special equipment and trained persons are required for the purpose. Hence, methods are needed to relate easily measured soil properties to soil water retention characteristics. Keeping this in view, an attempt was made to develop prediction equations relating water retention at 0.1, 0.33 and 15 bar tensions to six soil properties *viz.*, sand, silt, clay, bulk density, organic carbon and cation exchange capacity through multiple regression equations. The equations with highest R^2 values were considered as the best prediction equations of water retention.

The R^2 values for regression equations to predict water retention at 0.1 ($w_{0.1}$), 0.33 ($w_{0.33}$) and 15 (w_{15}) bar tentions ranged from 0.36 to 0.81, 0.39 to 0.89 and 0.40 to 0.90, respectively. Highest R^2 values were observed with inclusion of all the six properties considered. However, sand (%), silt (%) and clay (%) together accounted for about 76, 81 and 82 percent variability of $w_{0.1}$, w0.33 and w_{15}, respectively and

R^2 values did not imporve to considerable extent with the inclusion of other properties in the equation. Hence, the equations that include only sand, silt and clay (given below) can be used in predicting water retention at different tensions in these soils.

$w_{0.1}$ = 45.9081 - 0.4118 sand - 0.0341 silt + 0.0125 clay.....R^2 = 0.76

$w_{0.33}$ = -6.8894 + 0.0924 sand + 0.4650 silt + 0.5107 clay.....R^2 = 0.81

w_{15} = 7.0239 - 0.0757 sand + 0.2350 silt + 0.2535 clay.....R^2 = 0.82

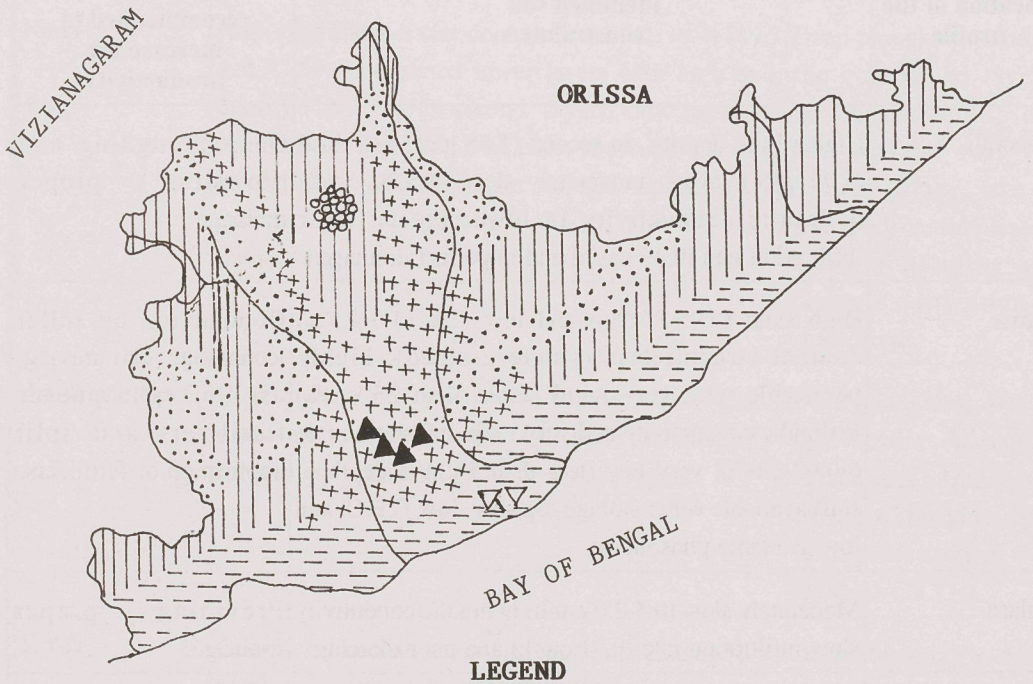
PRODUCTION CONSTRAINTS

Based on the results obtained from the study, soil related production constraints were identified. Suitable management practices were recommended based on the research work carried out on soil management to increase crop production by the Andhra Pradesh Agricultural University Institutions like Regional Agricultural Research Station, Tirupati and Agricultural Research Station, Anantapur and AICRP on Improvement of Soil Physical Conditions, Hyderabad. Depending on the availability of resources, these practices can be followed in order to increase the productivity of these soils.

Poor permeability in soils with high clay content, high sub-soil bulk density in red soils with clay base; crusting and hardening in red sandy loams; high permeability and low available water storage capacity in sandy soils were the general physical constraints. Organic carbon content was low to medium in all soils except in Madikuru in which it was high (more than 0.75 %). Organic materials like farm yard manure, plant residues, green leaf manures *etc*. should be added to the soils that are low to medium in organic carbon in order to improve the physical conditions and fertility status of the soils. Available nitrogen content was low (less than 280 kg/ha) in all the soils studied. Nitrogen should be supplied to the crops grown in these soils through chemical fertilizers and organic matter.

Identified soil constraints (Figure 2) and soil management practices recommended to increase productivity are furnished below:

FIGURE 2 : SOIL PRODUCTION CONSTRAINTS



LEGEND

High sub-soil bulk density	Red loams with clay base
High permeability	Sandy soils
Poor drainage	Alluvial soils
Crusting and hardening, low water retention, sandy surface, low C.E.C.	Red sandy loams
Slowly permeable, low workability	Black soils (in valleys)
Slightly alkaline	Problem soils
Slightly acidic	

Soil constraints and management practices

Location of the profile	Identified soil constraints	Soil management practices recommended to increase the productivity
Kanchili	Higher bulk density in second (1.85 g/cc) and third (1.77 g/cc) layers, moderately slow (0.5-20 cm/h) hydraulic conductivity in lower layers; slow infiltration rate (0.49 cm/h) and imperfect drainage	Deep ploughing and providing proper drainage.
Barua	High sand (93.5-95.5%) and low clay (3.0-4.5%) content structureless (single grained), highly permeable with very rapid (more than 25 cm/h) hydraulic conductivity and very rapid infiltration rate (40.02 cm/h), very low (less than 5 cm/m depth of soil) available water storage capacity, low C.E.C. and low available phosphorus.	Compaction by roller technology, clay mixing, use of phosphorus fertilizers and split application of fertilizers.
Palasa	Moderately slow (0.5-2.0 cm/h) hydraulic condutivity slow infiltration rate (0.31 cm/h) and poor drainage.	Providing proper drainage.
Madapam	High sand (94.5-95.5%) and low clay (2.5-3.0%) contents structureless (single grained), highly permeable with very rapid infiltration rate (50.91 cm/h), low available water storage capacity (6.23 cm/m depth of soil), low C.E.C. and low available phosphorus.	Compaction by roller technology, clay mixing, use of phosphorus fertilizers and split application of fertilizers.
Kalingapatnam	High bulk density in surface layer (1.76 g/cc), poor drainage, poor permeability with very slow (less than 0.125 cm/h) hydraulic conductivity and slow infiltration rate (0.21 cm/h), moderately alkaline pH and higher ESP values (8.63-11.22) though not in alkaline range.	Proper tillage - deep ploughing, care must be taken to decrease the alkalinity by providing proper drainage and use of good quality irrigation water.

Ragolu	Very slow infiltration rate (0.11 cm/h).	Proper tillage to improve water intake rate.
Naira	High sand and low clay contents in surface layer (89.3 and 4.7%), compacted lower layers with high bulk density (1.80 g/cc in second layer), slow hydraulic conductivity (0.18 and 0.24 cm/h in second and third layers), low available water storage capacity (7.44 cm/m depth of soil), low C.E.C. and available phosphorus.	Deep ploughing to break the compacted layers, mixing the surface and sub-surface soil by proper tillage, use of phosphorus fertilizers, contour bunding and contour cultivation in slopy areas.
Amdalavalasa	High bulk density in bottom layer (1.90 g/cc), moderately slow to slow hydraulic conductivity, moderately acidic pH (5.44 in surface layers).	Deep ploughing, use of non-acidic nitrogen fertilizers, liming to correct soil acidity (lime requirement was 784 kg/ha of $CaCO_3$).
Kosta	Compacted bottom layer with high bulk density (1.98 g/cc), moderately slow (1.06 cm/h) infiltration rate, low available water storage capacity (9.48 cm/m depth of soil), low C.E.C., crusting and hardening.	Deep ploughing to break the compacted layer, incorporation of paddy husk @ 5 t/ha or groundnut shells @ 3 t/ha.
Kagitapalli	Imperfect drainage, low available water storage capacity, low C.E.C., crusting and hardening.	Providing proper drainage, incorporation of paddy husk @ 5 t/ha or groundnut shells @ 3 t/ha.

Madikuru	Imperfect drainage, poor permeability with very slow (less than 0.125 cm/h) hydraulic conductivity and negligible infiltration rate, low workability both when wet and dry.	Providing proper drainage, working at optimum moisture contents, proper tillage to improve permeability.
Sattiwada	Sandy surface layer,low C.E.C., hardening.	Clay mixing, split application of fertilizers, incorporation of crop residues.
Seethampeta	Poor drainage slow (0.125-0.5 cm/h)hydraulic conductivity, low workability both when wet and dry.	Providing proper drainage, working the soil at optimum moisture content, proper tillage to improve permeability.
Nowtala	Poor drainage,sandy surface layer moderately slow (0.5-2.0 cm/h) hydraulic conductivity in lower layers,low C.E.C. in surface layer, hardening.	Providing proper drainage,split application of fertilizers, incorporation of crop residues.
Meliaputti	Very poor drainage,very slow (less than 0.125 cm/h) hydraulic conductivity in lower layers.	Providing proper drainage, deep ploughing to improve permeability of lower layers.

SUMMARY

The present investigation was carried out with specific objectives of studying physical and chemical properties of soils of Srikakulam district to identify soil constraints for crop production and to suggest suitable management practices to increase their productivity.

Fifteen representative soil profile samples from the district were collected for the study. They were described morphologically. Horizon-wise samples were collected from all the profiles and analysed for physical, physico-chemical and chemical properties. Soils were classified taxonomically based on the profile description and analytical data. Crop production constraints were also identified based on the results of analyses.

Srikakulam is the border district of Andhra Pradesh with Orissa. The district is characterized by humid to sub-humid climate. A major portion of the district is covered by the oldest rock formations, namely, the Archaeans. Average annual rainfall of the district is 1068 mm. The mean maximum and minimum temperatures in the district range from 27.7^{o} to 34.6^{o}C and 17.7^{o} to 27.3^{o}C, respectively.

Majority of the soils were moderately well drained and located on very gently sloping lands. Barua, Madapam, Kalingapatnam, Ragolu and Nowtala profiles were very deep (deeper than 100 cm) and the other profiles were deep (50-100 cm).

Soils varied from sandy to clayey in texture. Surface layers were coarse textured (sandy, loamy sand and sandy loam) in Barua, Madapam, Naira, Amadalavalasa, Kosta, Kagitapalli, Sattiwada and Nowtala profiles; medium (sandy clay loam, silty loam and clay loam) textured in Kanchili, Palasa, Kalingapatnam, Ragolu and Meliaputti profiles and fine (clay) textured in Madikuru and Seethampeta profiles.

Sand, silt and clay contents were found to vary from 30.0 to 95.5 per cent, 1.4 to 46.5 per cent and 2.5 to 51.0 per cent, respectively. In majority of the soils, sand content increased from surface layer to sub-surface layer. Variation in silt content was relatively less compared to variations in sand and clay contents. Steep increase in clay content from surface layer to second layer was observed in Naira (4.7-28.3 %), Amadalavalasa (11.5-25.0 %), Kosta (10.5-28.0 %) and Nowtala (7.0-26.5 %) profiles.

Bulk density varied from 1.17 to 1.98 g/cc. In majority of the soils higher bulk density values were recorded in the lower layers than the surface layers. Bulk density increased with depth in Amadalavalasa, Madikuru, Sattiwada and Seethampeta profiles, however, it decreased with depth in Palasa and Kalingapatnam profiles.

Saturated hydraulic conductivity varied from 0.66 to 94.54 cm/h. It was found to be highest in Barua (64.74, 94.56 and 72.48 cm/h) and lowest in Kalingapatnam (0.15, 0.09 and 0.07 cm/h). Hydraulic conductivity values decreased with depth in Kanchili, Kalingapatnam, Amadalavalasa, Madikuru, Seethampeta and Nowtala profiles and increased with depth in Madapam and Ragolu profiles.

Highest infiltration rate was observed in Madapam (50.91 cm/h) followed by Barua (40.02 cm/h) profile. Infiltration rate and cumulative infiltration were negligible in Madikuru soil which was clayey in texture. In general, infiltration rates were highest in the first ten minutes and decreased steeply reaching nearly constant values in two hours from the start.

Water retention at 0.1, 0.33 and 15 bar tensions varied from 1.71 to 40.11, 1.54 to 36.73 and 0.54 to 24.98 per cent, respectively and these had significant positive correlation with clay, silt, silt plus clay, organic carbon and C.E.C. and significant negative correlation with sand and bulk density. Available water content (%) varied from 1.00 to 15.87 per cent. It increased with depth in Madapam, Kalingapatnam, Amadalavalasa, Sattiwada and Nowtala profiles; decreased with depth in Kanchili, Ragolu and Meliaputti profies while in others the trend was irregular.

Available water storage capacity (cm/m depth of soil) of the profiles varied from 4.37 to 19.93. It was high (15-20) in Kalingapatnam, Madikuru, Seethampeta and Nowtala; medium (10-15) in Kanchili, Palasa, Ragolu, Amadalavalasa, Sattiwada and Meliaputti soils; low (5-10) in Madapam, Naira, Kosta and Kagitapalli soils and very low (less than 5) in Barua soil.

Surface soil reaction was 5.44 in Amadalavalasa and 8.20 in Kalingapatnam. Surface soil of Palasa was slightly acidic, and Ragolu and Seethampeta were slightly alkaline. In all the other soils surface layers were neutral (pH 6.5 to 7.5). All the soils studied were non-saline (EC of 0.06 to 0.69 dS/m) and non-sodic (ESP of 0.96 to 11.22). Cation exchange capacity ranged from 1.15 to 29.89 c mol (p^+)/kg soil. Low C.E.C. values (less than 5 c mol (p^+)/kg) were recorded in Barua, Madapam, Naira,

Kosta, Kagitapalli and Sattiwada soils. Others recorded medium to high C.E.C. values. C.E.C., in general, increased with depth.

Organic carbon content of the soils was low to medium except in Madikuru soil in which it was high (more than 0.75%). In general, organic carbon content decreased with depth except in Amadalavalasa and Kosta where it increased with depth.

All the soils studied were low in available nitrogen (less than 280 kg/ha). Available phosphorus was low in surface layers of Barua, Madapam, Naira and Meliaputti, high in surface layers of Kalingapatnam, Ragolu, Madikuru and Seethampeta and medium (10 to 24.6 kg P/ha) in surface layers of other seven soils. Available potassium was high in surface layers of Kanchili, Kalingapatnam, Madikuru, Seethampeta and Meliaputti while it was medium (112-280 kg K/ha) in surface layers of other soils. In all the soils studied, the available micronutrients (Fe, Mn, Cu and Zn) were above critical limits.

Barua, Madapam and Kagitapalli soils were Entisols; Kanchili, Palasa, Kalingapatnam, Ragolu, Sattiwada and Meliaputti were Inceptisols; Madikuru and Seethampeta were Vertisols and Naira, Amadalavalasa, Kosta and Nowtala were Alfisols.

Constraints for crop production in these soils include very rapid permeability, poor permeability in some of the soils with high clay content, high bulk density in lower layers, low organic carbon content and poor nitrogen content. Suitable management practices for improving the productivity of these soils were suggested. However, location specific on farm trials should be taken up to study the suitability and economic feasibility of these practices before adopting them on large scale.

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