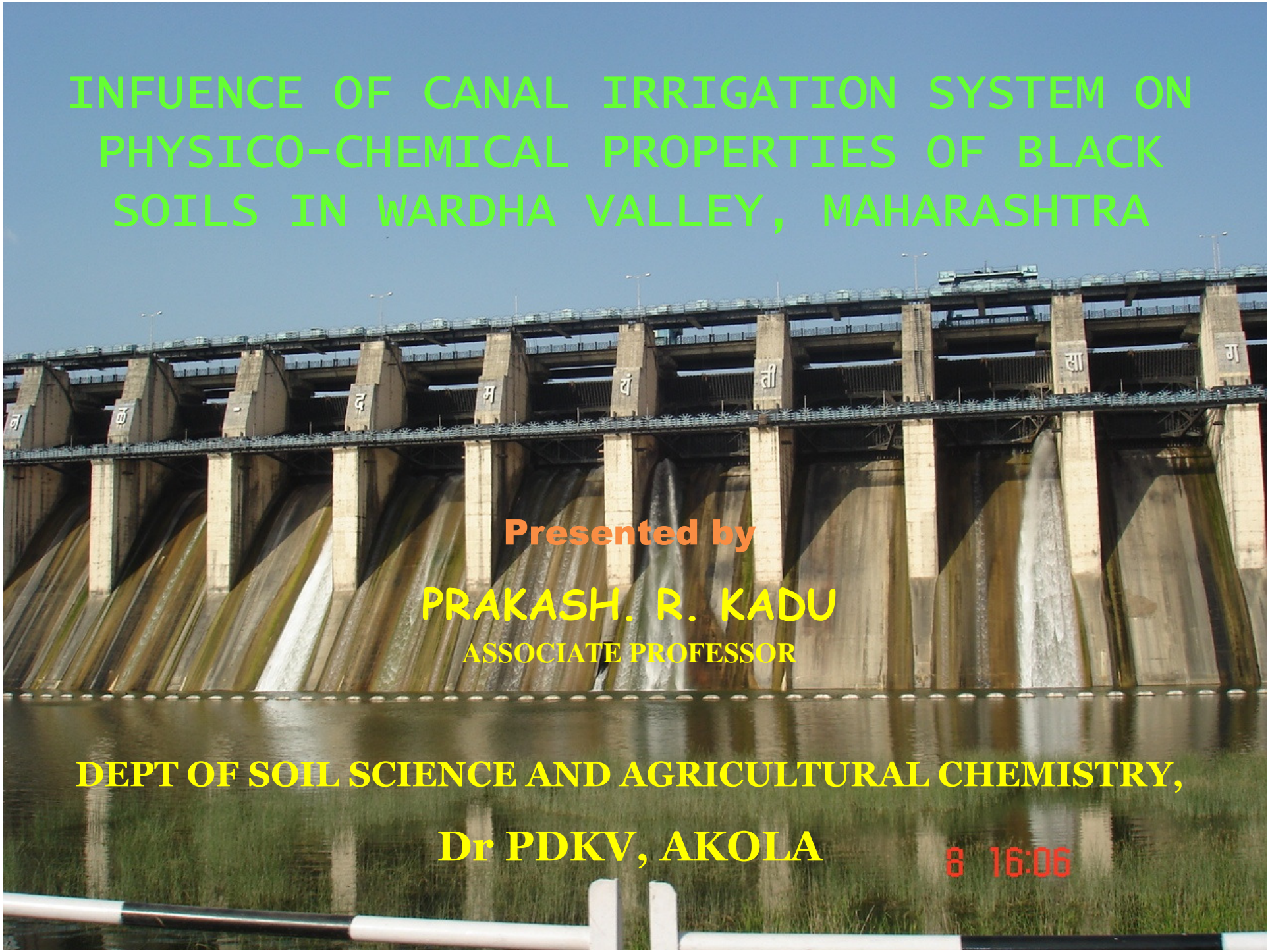
INFUENCE OF CANAL IRRIGATION SYSTEM ON PHYSICO-CHEMICAL PROPERTIES OF BLACK SOILS IN WARDHA VALLEY, MAHARASHTRA



Presented by

PRAKASH. R. KADU

ASSOCIATE PROFESSOR

DEPT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY,

Dr PDKV, AKOLA

Black soils (Vertisols and vertic intergrades) occur widely in many parts of the world, and it occupy an area of 72.9 million hectares in India, 35.5 per cent of which is in the state of Maharashatra. These soils mainly confined to the lower topographical levels and occur in most of the river valleys, one of which is the Wardha river valley. The Upper Wardha command is the part of Wardha valley covers the districts of Wardha, Amravati and Yavatmal in Vidarbha region and the canal irrigation system has been commissioned in 1997.

The natural degradation due to the aridity of the climate occurred in these soils and poor drainage caused by subsoil sodicity which may further aggravated due to irrigation as literature indicates that irrigation in Vertisols was deleterious to the properties of these soils. Establishing the cause-effect relationship is essential so that methods can be developed to restored the productivity of already degraded soils and to prevent the development of similar problem areas in future.

SITE

Wardha valley covers Wardha, Yavatmal and Amravati districts of Maharashtra

- The Upper Wardha Command Area is under irrigation since last 16 years.
- Study area :- 21° 10' to 21° 18' N latitude
  78° 5' to 78° 15' E longitude
- Climate :- Semi-arid, sub tropical,
  MAR-979 mm
- Parent Material :- Basaltic alluvium
- Moisture regime :- Ustic
- Temperature regime :- Isohyperthermic

Crops grown in command area

- **Khraif :**

  Cotton (*Gossypium sp.*)

  Sorghum (*Sorghum bicolor*)

  Tur (*Cajanas cajan*)

  Soybean (*Glycine max*)

  Mung (*Phaseolus aureus*)

- **Rabi :**

  Wheat (*Triticum sp.*)

  gram (*Cicer arietinum*)

- **Perennial :**

  Sugarcane (Saccharum oficinarum)

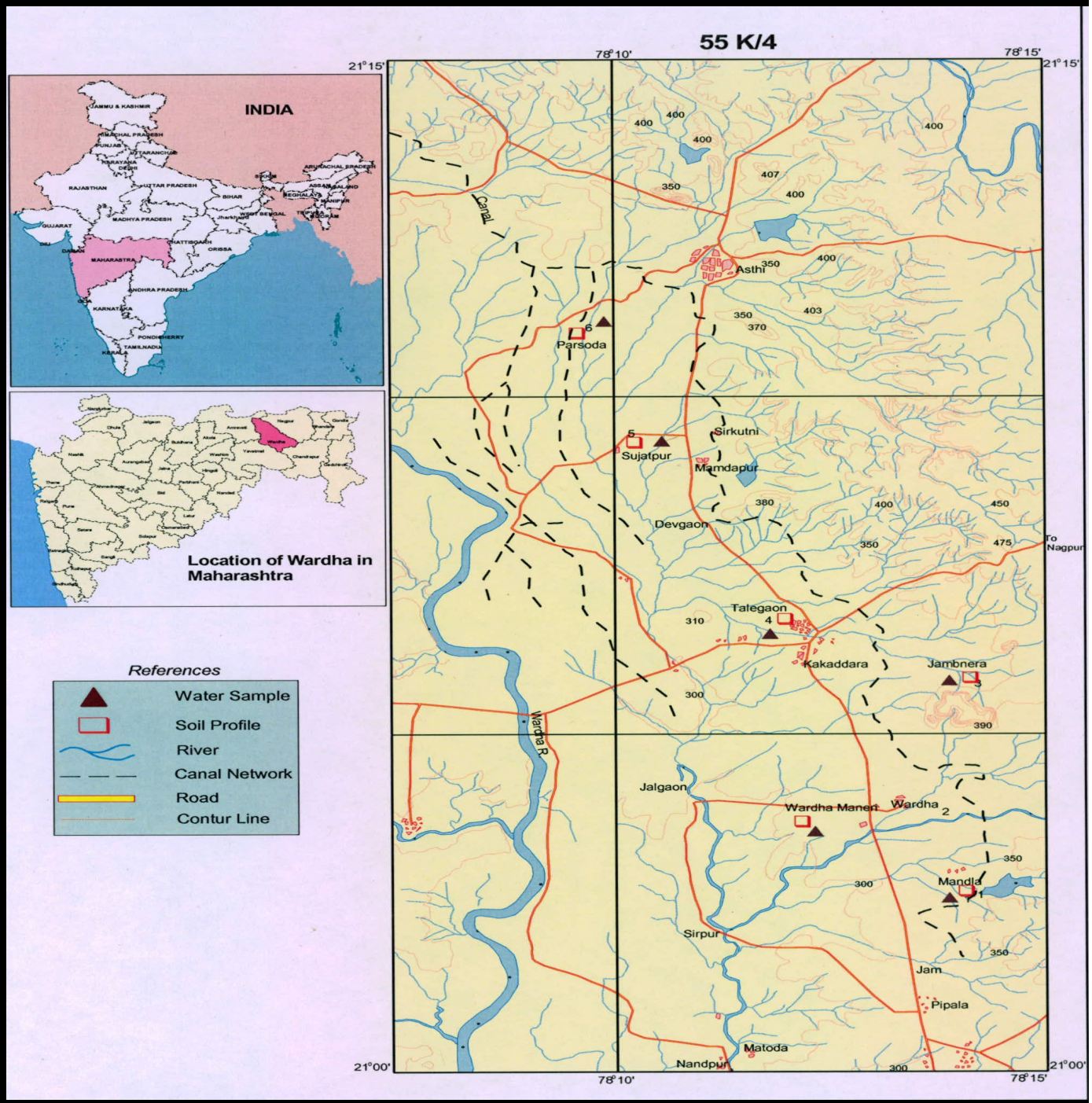
  Orchards of mandarin (*Citrus reticulate)*

MATERIALS AND METHODS

- **Field Study :** 15 soil Pedons were studied
  12 water samples were collected
  Six representative pedons data is presented here
  Pedon 1, 4, 5 and 6 – Irrigated since 15 years
  Pedon 2 and 3 – Irrigated since 5 years

- **Lab Analysis :** Standard Methods (Richards, 1954;
  Jackson 1973, 1979)
  Hydraulic conductivity – USDA, 1974
  COLE – Schafer and Singer, 1976
  X-ray diffraction analysis - Jackson 1979

LOCATION MAP OF STUDY AREA




ROAD CUT NEAR WARDHA RIVER
8 16:02


LEFT BANK CANAL
8 18:19

HIGH WATER TABLE

WATERLOGGING
NEAR SUB CANAL

FORMATION OF SALT CRUST DUE TO SEEPAGE

SEEPAGE LOSSES FROM CANAL


DEEP CRACKS IN SOIL

CROP STAND IN THE STUDY AREA - WHEAT

CROP STAND IN THE STUDY AREA - GRAM

MORPHOLOGICAL PROPERTIES

Depth	: Deep to very deep (>100cm)
Color	: Dark brown to very dark gray
Texture	: Clayey
Structure	: Moderate, medium sub angular to angular blocky
Special features	: Well developed pressure faces and slickensides
Classification	: Fine, montmorillonitic, isohyperthermic family of Typic Haplusterts and sodic Haplusterts

BRIEF MORPHOMETRIC DESCRIPTION OF SOILS

Depth (cm)	Horizon	Boundry D T	Munsell colour (moist)	Texture	Structure	Consistence			Effervescence (10% dil HCl)	Concretions	Other Features
						Dry	Moist	Wet		S Q	
1	2	3	4	5	6	7	8	9	10	11	12
Pedon 1 : Mandala (Typic Haplustert)											
0-15	Ap	c s	10YR 3/3	Clay	3 c sbk	sh	fr	sssp	Slight	f c	Well developed slickensides below 60 cm depth
15-30	A	c s	10YR 3/3	Clay	2 m sbk	h	fr	sp	Slight	f c	
30-60	Bw	c w	10YR 3/2	Clay	2 m abk	h	fi	sp	Slight	m c	
60-85	Bss1	c w	10YR 3/2	Clay	2 m abk	vh	fi	svp	Violent	m c	
85-123	Bss2	-	10YR 3/1	Clay	2 m abk	vh	fi	vsvp	Violent	m m	
Pedon 2 : Wardha-maneri (Typic Haplustert)											
0-15	Ap	c s	10YR 3/3	Clay	2 m sbk	h	fr	sp	Slight	f f	Slickensides below 54 cm depth.
15-30	A	c s	10YR 3/2	Clay	2 m sbk	h	fr	sp	Slight	f f	
30-54	Bw	c w	10YR 3/1	Clay	2 m abk	h	fr	vsp	Slight	f c	
54-76	Bss1	c w	10YR 3/2	Clay	3 m abk	vh	fi	vsvp	Slight	f c	
76-126	Bss2	,-	10YR 3/1	Clay	3 m abk	vh	fi	vsvp	Strong	m m	
Pedon 3 : Jambnera (Typic Haplustert)											
0-18	Ap	c s	10YR 4/2	Clay	1 m sbk	sh	fr	sssp	Slight	f c	Slickensides below 40 cm depth
18-40	A	c w	10YR 3/3	Clay	1 m sbk	sh	fr	sssp	Slight	f c	
40-73	Bw	d w	10YR 3/2	Clay	2 m abk	sh	fi	ssp	Strong	m c	
73-120	Bss	-	10YR 3/2	Clay	2 m abk	h	fi	sp	Strong	m m	

Contd.

Depth (cm)	Horizon	Boundry D T	Munsell colour (moist)	Texture	Structure	Consistence			Effervescence (10% dil HCl)	Concretions S Q	Other Features
						Dry	Moist	Wet			
1	2	3	4	5	6	7	8	9	10	11	12
Pedon 4 : Talegaon											
0-13	Ap	c s	10YR 3/3	Clay	2 m sbk	h	fi	sp	Strong	f c	Cracks 30 to 50 mm wide ; well developed slickensides and mottles below 60 cm depth ;motels with 5YR 5/6 and 5YR 4/1 colour
13-35	A	c s	10YR 3/3	Clay	2 m sbk	vh	fi	vsp	Violent	f c	
35-60	Bw	c b	10YR 3/2	Clay	2 m abk	vh	fi	vsvp	Violent	m c	
60-100	Bss1	c w	10YR 3/2	Clay	2 m abk	vh	vfi	vsvp	Violent	m m	
100-150	Bss2	-	10YR 3/3	Clay	2 m abk	vh	vfi	vsvp	Violent	m m	
Pedon 5 : Parsoda											
0-11	Ap	c s	10YR 3/3	Clay	1 m sbk	sh	fr	sp	Strong	f c	slickensides below 33 cm depth.
11-33	Bw	g s	10YR 3/2	Clay	2 m sbk	h	fi	svp	Strong	f c	
33-86	Bss1	c l	10YR 3/2	Clay	2 m abk	vh	fi	vsvp	Violent	m m	
86-132	Bss2		10YR 3/2	Clay	2 m abk	vh	vfi	vsvp	Violent	m m	
Pedon 6 : Sujatpur											
0-20	Ap	c s	10YR 4/2	Clay	2 m sbk	h	fr	sssp	Slight	f c	Pressure faces below 37 cm depth ; slickensides below 60 cm depth
20-37	A	c s	10YR 3/2	Clay	2 m sbk	h	fr	sp	Strong	f c	
37-60	Bw	g w	10YR 3/2	Clay	2 m abk	h	fi	svp	Strong	f c	
60-100	Bss1	d w	10YR 3/1	Clay	2 m abk	vh	vfi	vsvp	Strong	m c	
100-145	Bss2	-	10YR 3/1	Clay	2 m abk	vh	vfi	vsvp	Violent	m m	

Note : Symbols used are according to Soil Survey Manual notations (Soil Survey Division Staff, 1998)

Detailed morphological descriptions of the Pedons are given in Appendix - I.

PEDON 4 TALEGAON

PEDON 5 PARSODA

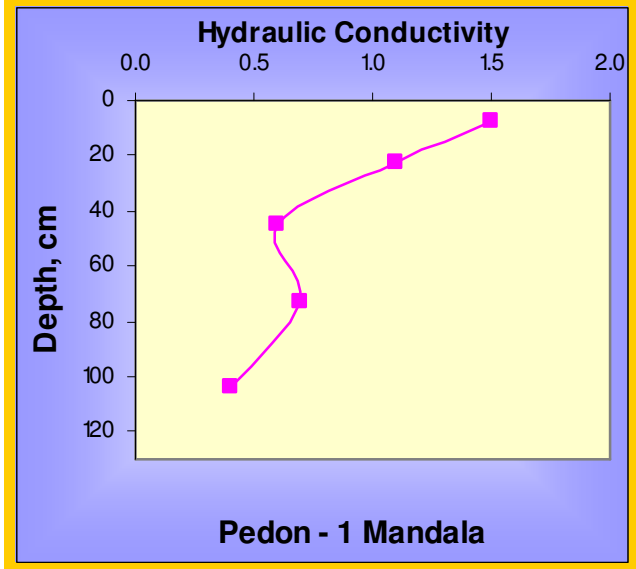
PEDON 6
SUJATPUR

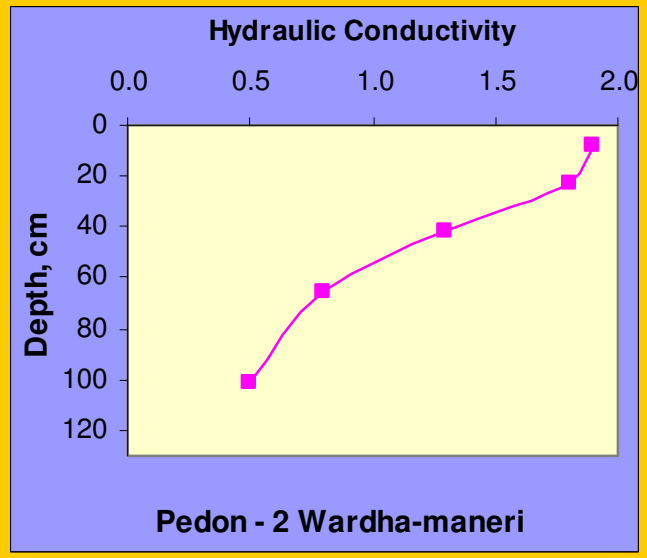
PEDON 2 WARDHA-
MANERI

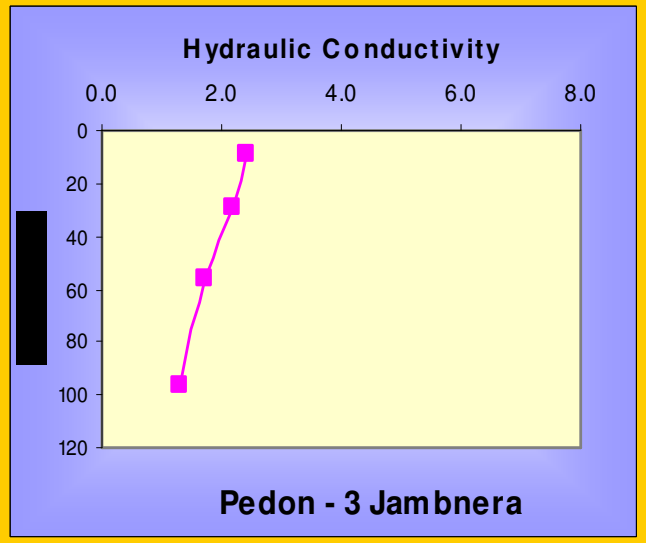
PHYSICAL PROPERTIES OF SOILS

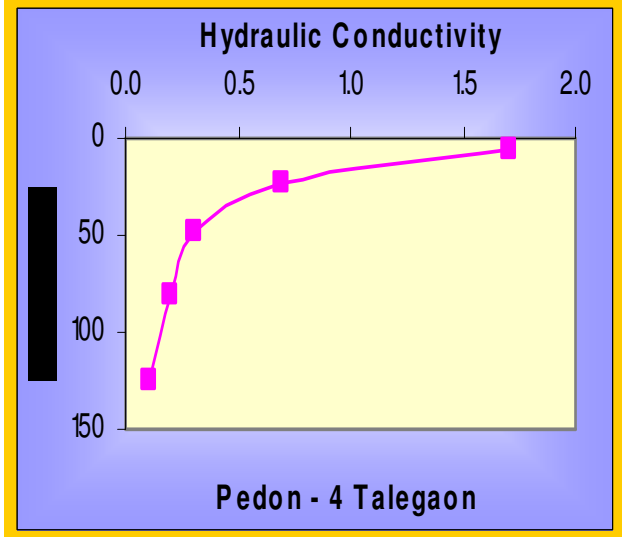
Depth (cm)	Horizon	Clay	Bulk Density (W max) (Mg m-3)	Maximum Water Holding Capacity (%)	Hydraulic Conductivity (cm hr-1)	COLE	VSP (%)	WDC (%)
Pedon 1 : Mandala								
0-15	Ap	53.7	1.36	67	1.5	0.19	68.5	15.6
15-30	A	55.8	1.34	73	1.1	0.2	72.8	17.2
30-60	Bw	57.0	1.29	73	0.6	0.23	86.1	22.1
60-85	Bss1	60.2	1.31	74	0.7	0.22	81.6	23.5
85-123	Bss2	61.7	1.26	67	0.4	0.21	77.2	22.1
Pedon 2 : Wardha-maneri								
0-15	Ap	56.5	1.42	63	1.9	0.18	64.3	18.5
15-30	A	59.5	1.28	71	1.8	0.19	68.5	17.9
30-54	Bw	62.1	1.3	66	1.3	0.23	86.1	18.6
54-76	Bss1	68.5	1.26	70	0.8	0.22	81.6	20.2
76-126	Bss2	64.2	1.34	74	0.5	0.23	86.1	21.6
Pedon 3 : Jambnera								
0-18	Ap	41.4	1.56	64	2.4	0.17	60.2	12.6
18-40	A	44.2	1.43	62	2.2	0.17	60.2	14.3
40-73	Bw	50.1	1.46	68	1.7	0.18	64.3	15.6
73-120	Bss	52.7	1.34	59	1.3	0.18	64.3	15.8
Pedon 4 : Talegaon								
0-13	Ap	52.1	1.35	72	1.7	0.17	60.2	22
13-35	A	53.4	1.33	75	0.7	0.21	77.2	19.5
35-60	Bw	58.5	1.27	75	0.3	0.19	68.5	22.3
60-100	Bss1	60.1	1.26	77	0.2	0.23	86.1	24.1
100-150	Bss2	63.9	1.23	78	0.1	0.23	86.1	25.0
Pedon 5 : Parsoda								
0-11	Ap	58.1	1.35	68	0.9	0.19	68.5	20.4
11- 33	Bw	60.6	1.34	66	0.5	0.23	86.1	25.2
33-86	Bss1	63.8	1.29	73	0.4	0.23	86.1	25.6
86-132	Bss2	65.8	1.25	72	0.1	0.27	104.8	26.8
Pedon 6 : Sujatpur								
0-20	Ap	53.4	1.38	68	0.6	0.21	77.2	22.0
20-37	A	56.7	1.41	60	0.2	0.23	86.1	21.5
37-60	Bw	62.2	1.4	78	0.1	0.25	95.3	23.8
60-100	Bss1	64.8	1.37	76	0.02	0.27	104.8	28.1
100-145	Bss2	67.2	1.32	75	0.01	0.26	100.0	26.4

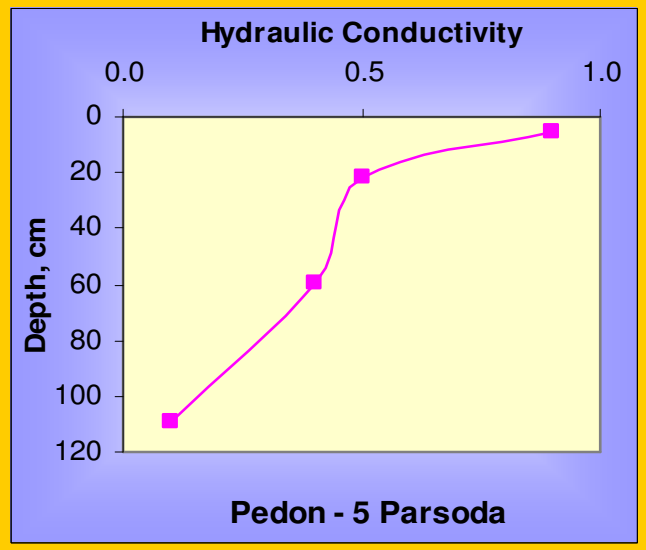
DEPTH FUNCTION OF HYDRAULIC CONDUCTIVITY

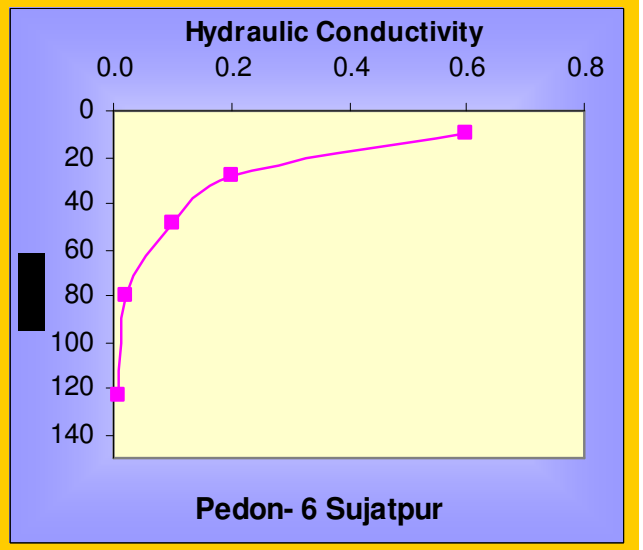












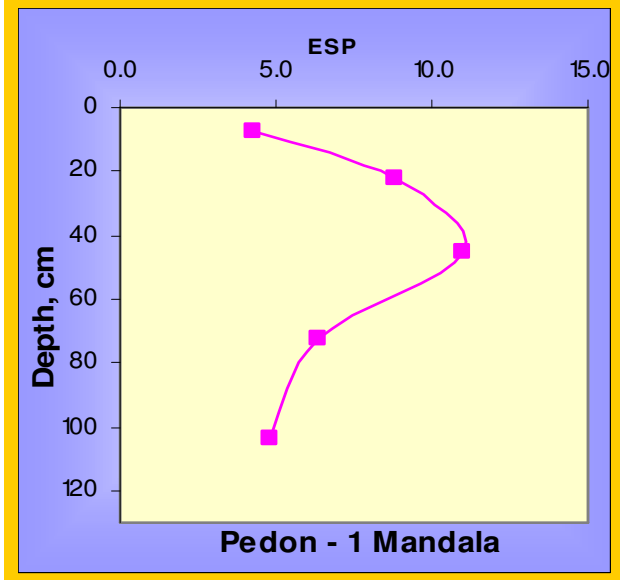
Ion Exchange Analysis Data

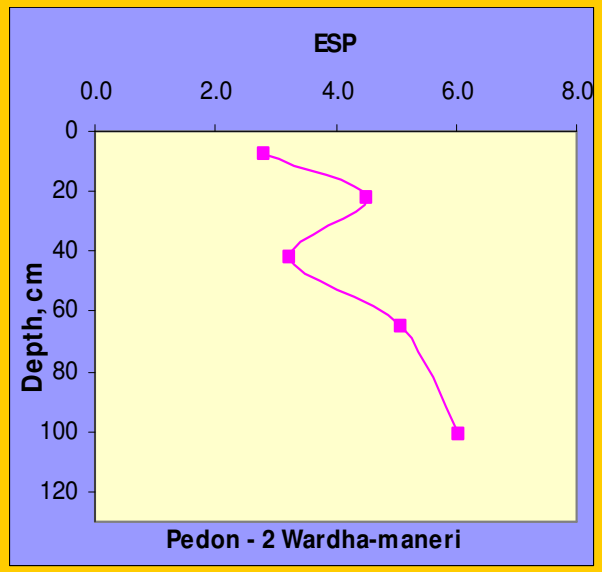
Depth (cm)	Horizon	pH	ECe (dS m^{-1})	Extractable bases					Base saturation %
				Ca	Mg	Na	K	CEC	
				<----------cmol (p^+) kg^{-1}---------->					
1	2	3	4	5	6	7	8	9	
Pedon 1 : Mandala									
0-15	Ap	8.5	0.6	32.5	14.6	2.2	0.4	51.2	97
15-30	A	8.7	0.8	30.1	15.4	4.6	0.6	52.3	97
30-60	Bw	8.6	1.0	27.9	17.1	5.8	0.7	52.9	97
60-85	Bss1	8.5	0.7	25.1	21.6	3.4	0.5	53.1	95
85-123	Bss2	8.4	0.6	24.8	23.5	2.6	0.4	53.6	96
Pedon 2 : Wardha-maneri									
0-15	Ap	8.1	0.6	38.4	11.8	1.5	0.9	53.4	98
15-30	A	8.2	0.6	36.4	12.8	2.5	0.5	55.4	94
30-54	Bw	8.2	0.7	36.1	13.1	1.8	0.6	55.9	92
54-76	Bss1	8.5	0.7	33.2	14.8	2.9	0.6	57.2	90
76-126	Bss2	8.5	0.8	29.4	16.8	3.4	0.7	56.4	89
Pedon 3 : Jambnera									
0-18	Ap	8	0.5	36.8	9.7	0.5	1.0	48.5	99
18-40	A	8.1	0.6	35.2	11.1	0.5	0.8	48.6	98
40-73	Bw	8.1	0.6	32.4	14.3	0.6	0.7	49.5	97
73-120	Bss	8.3	0.6	30.6	15.6	0.9	0.8	49.9	96
Pedon 4 : Talegaon									
0-13	Ap	8.1	0.6	29.8	16.2	1.8	0.8	49.8	98
13-35	A	8.3	0.9	28.5	16.2	4.5	0.8	50.6	99
35-60	Bw	8.5	0.9	25.4	19.7	3.4	0.9	51.7	96
60-100	Bss1	8.7	1.4	19.4	24.4	5.2	0.8	52.5	95
100-150	Bss2	8.9	1.5	16.4	26.3	7.4	0.7	52.9	96
Pedon 5 : Parsoda									
0-11	Ap	8.3	0.5	31.3	15.8	2.2	1.0	51.2	98
,11-33	Bw	8.5	0.9	30.2	16.1	4.6	1.1	52.4	99
33-86	Bss1	8.6	0.8	26.1	21.5	3.5	1.0	53.4	98
86-132	Bss2	8.8	1.5	22.5	21.3	9.1	0.9	56.6	95
Pedon 6 :Sujatpur									
0-20	Ap	8.1	1.0	30.2	18.5	4.1	1.4	55.8	97
20-37	A	8.6	1.1	29.1	18.8	4.6	1.2	55.8	96
37-60	Bw	8.6	1.2	25.2	21.5	8.4	1.3	59.6	95
60-100	Bss1	8.7	1.6	20.3	25.3	10.2	1.4	59.5	96
100-145	Bss2	8.8	1.3	18.7	27.4	8.6	1.7	59.5	95

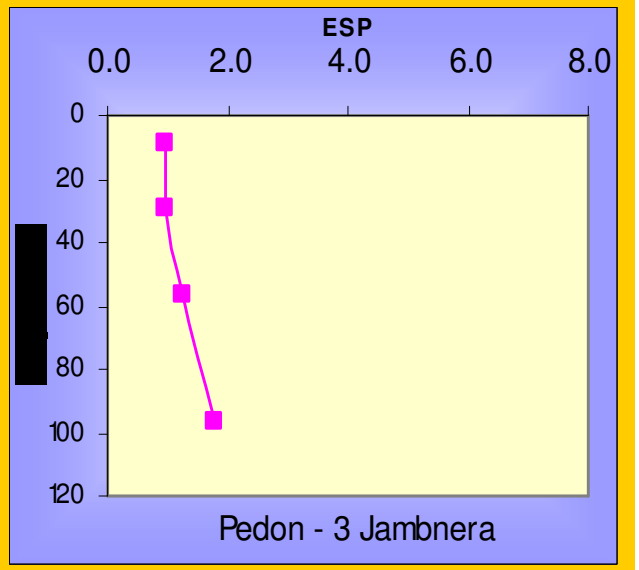
CHEMICAL PROPERTIES

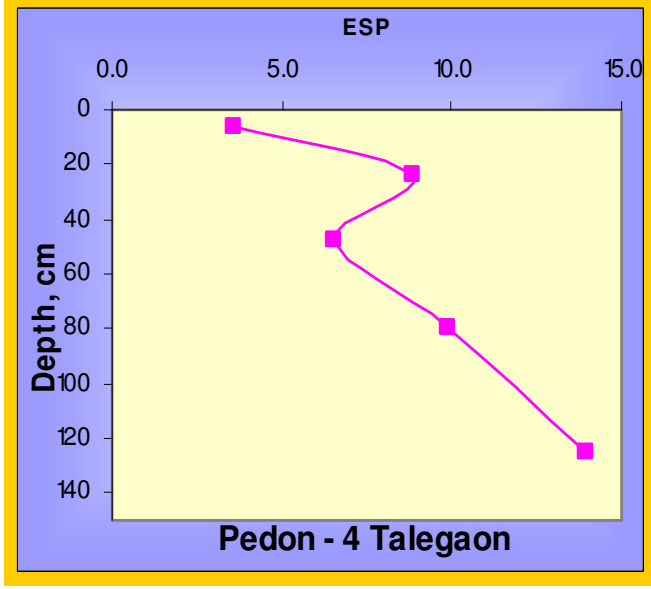
Depth (cm)	Horizon	Exchageable Na (%)	Exchangeable Mg (%)	Exchangeable Ca/Mg	SAR	HCO3/Ca
1	2	3	4	5	6	7
Pedon 1 : Mandala						
0-15	Ap	4.3	28.5	2.2	2.4	2.3
15-30	A	8.8	29.4	2.0	6.5	2.5
30-60	Bw	11.0	32.3	1.6	8.6	3.4
60-85	Bss1	6.4	40.7	1.2	5.3	3.9
85-123	Bss2	4.9	43.8	1.1	3.8	4.5
Pedon 2 : Wardha-maneri						
0-15	Ap	2.8	22.1	3.3	2.5	1.8
15-30	A	4.5	23.1	2.8	3.6	2.2
30-54	Bw	3.2	23.4	2.8	2.0	1.9
54-76	Bss1	5.1	25.9	2.2	4.2	3.7
76-126	Bss2	6.0	29.8	1.8	5.0	2.8
Pedon 3 : Jambnera						
0-18	Ap	0.9	20.0	3.8	0.6	1.6
18-40	A	1.0	22.8	3.2	0.7	1.6
40-73	Bw	1.2	28.9	2.3	0.6	2.0
73-120	Bss	1.8	31.3	2.0	1.3	2.1
Pedon 4 : Talegaon						
0-13	Ap	3.6	32.5	1.8	3.1	2.2
13-35	A	8.9	32.0	1.8	8.0	3.5
35-60	Bw	6.6	38.1	1.3	5.2	2.7
60-100	Bss1	9.9	46.5	0.8	10.2	4.4
100-150	Bss2	14.0	49.7	0.6	12.4	5.6
Pedon 5 : Parsoda						
0-11	Ap	4.3	30.8	2.0	3.6	2.5
11-33	Bw	8.8	30.7	1.9	7.3	3.5
33-86	Bss1	6.6	40.3	1.2	5.3	4.6
86-132	Bss2	16.1	37.6	1.1	14.6	15.3
Pedon 6 :Sujatpur						
0-20	Ap	7.3	33.2	1.6	6.7	3.6
20-37	A	8.2	33.7	1.5	8.2	4.3
37-60	Bw	14.1	36.1	1.2	12.0	9.0
60-100	Bss1	17.1	42.5	0.8	15.6	11.6
100-145	Bss2	14.5	46.1	0.7	14.1	9.2

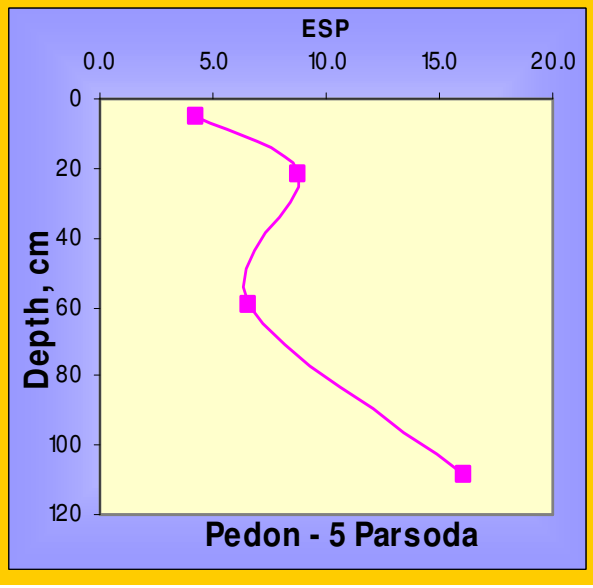
DEPTH FUNCTION OF ESP

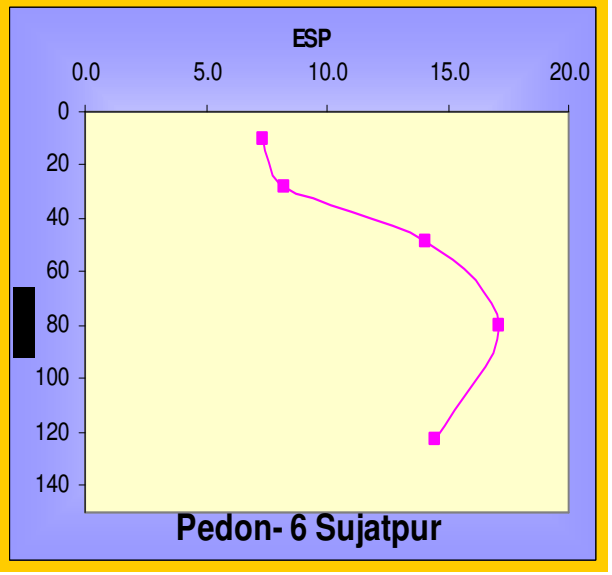












ARIDITY OF THE CLIMATE

$CaCO_3$

ESP

EMP

Ex. Ca

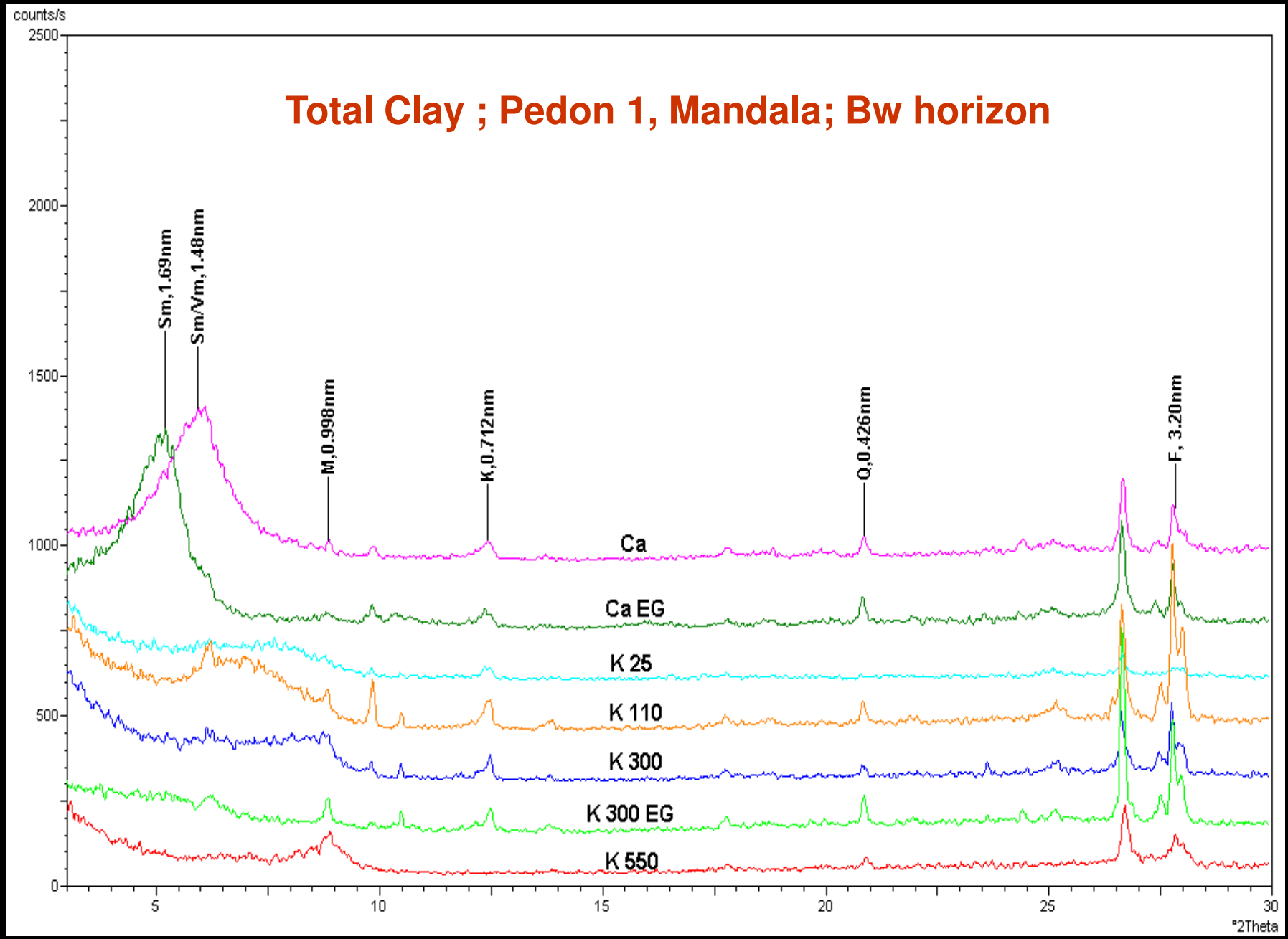
IRRIGATED SOILS

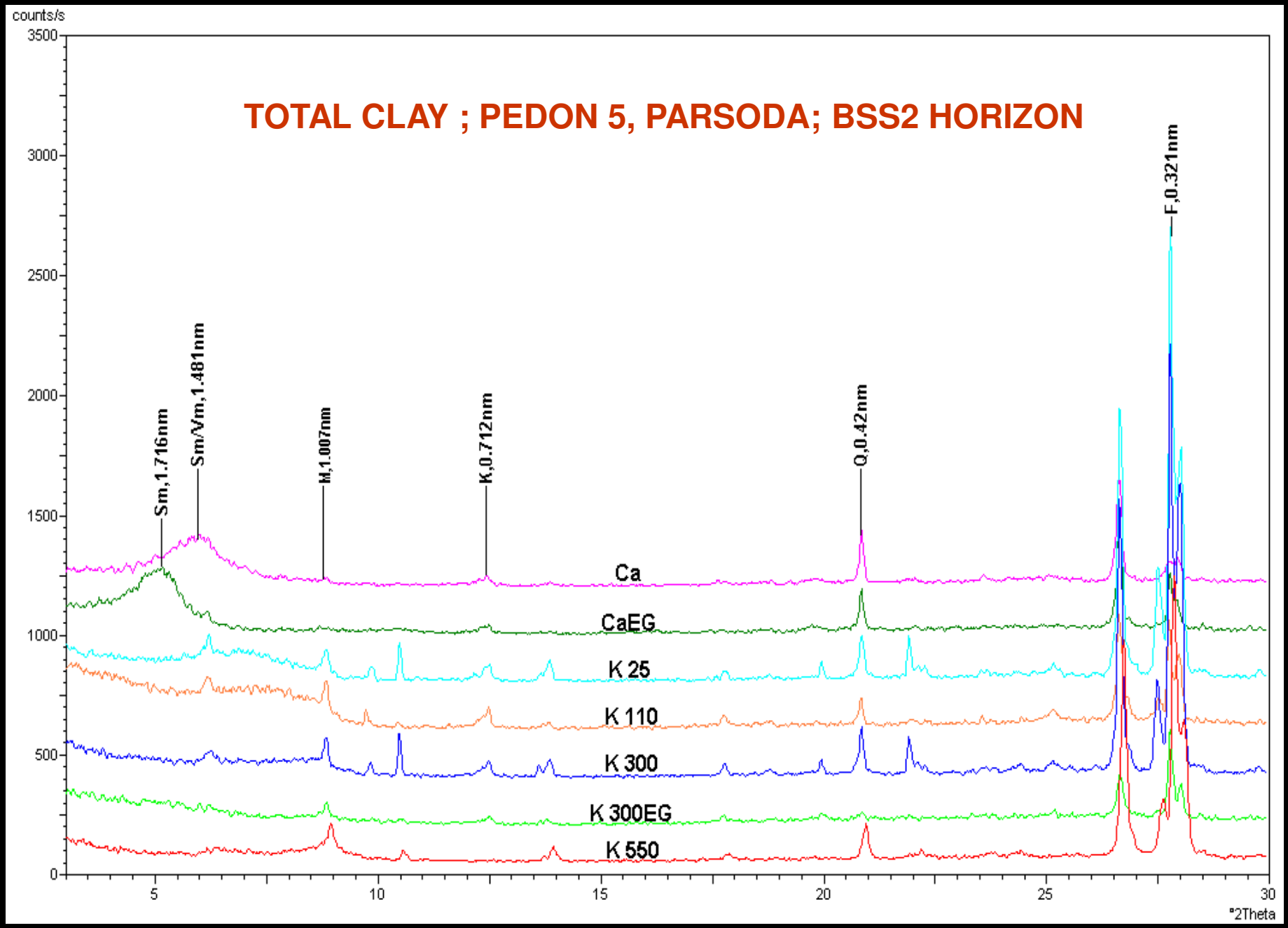
ESP

HP

SEMI-QUANTITATIVE ESTIMATES OF MINERALS IN CLAY FACTION OF SOILS

Pedon	Depth (cm)	Horizon	Clay Minerals (%)						
			Smectite	Vermiculite	Chlorite	Mica	Kaoline	Quartz	Feldspar
Mandala	35-60	Bw	67	4	1	4	5	6	12
	85-123	Bss2	67	9	3	3	5	4	9
Wardha-maneri	30-54	Bw	55	10	5	4	8	9	7
	76-126	Bss2	66	9	2	3	6	9	5
Jambnera	40-73	Bw	45	4	10	5	2	13	23
	73-120	Bss	64	3	3	2	3	7	17
Talegaon	35-60	Bw	58	4	4	2	3	20	8
	100-150	Bss2	62	6	3	5	8	8	6
Parsoda	11-33	Bw	46	4	2	3	2	8	33
	86-132	Bss2	52	3	3	2	2	13	24
Sujatpur	37-60	Bw	41	10	4	4	8	16	16
	100-145	Bss2	51	10	13	4	6	6	8


Total Clay ; Pedon 1, Mandala; Bw horizon
counts/s
2500
2000
1500
1000
500
0
Sm,1.69nm
Sm/Vm,1.48nm
M,0.998nm
K,0.712nm
Q,0.426nm
F, 3.20nm
Ca
Ca EG
K 25
K 110
K 300
K 300 EG
K 550
5
10
15
20
25
30
°2Theta


TOTAL CLAY ; PEDON 5, PARSODA; BSS2 HORIZON
counts/s
3500
3000
2500
2000
1500
1000
500
0
Sm,1.716nm
Sm/Vm,1.481nm
M,1.007nm
K,0.712nm
Q,0.42nm
F,0.321nm
Ca
CaEG
K 25
K 110
K 300
K 300EG
K 550
5
10
15
20
25
30
°2Theta

CHEMICAL COMPOSITION OF IRRIGATION WATER

Location	pH	EC dSm^{-1}	Cations ($me\ L^{-1}$)				Anoins ($me\ L^{-1}$)				SAR	Ca/Mg Ratio	Water Quality Class
			Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4			
Mandala (Pedon-1)	7.3	0.59	4.4	1.4	1	0.5	..	3.5	2.6	1.2	0.58	3.1	C_2S_1
Kinhala (Pedon-2)	7.9	0.74	2.9	3.2	0.9	0.1	..	3.3	3.2	0.6	0.56	0.9	C_2S_1
Sujatpur (Pedon-6)	7.5	0.74	2.8	3.4	0.9	0.1	..	3.5	3.1	0.6	0.55	0.8	C_2S_1
Wardha Maneri (Well)	7.2	1.14	3.8	5.7	2	1	..	4.6	2.5	5.4	0.46	0.6	C_3S_1
Wardha Maneri (Pedon-2)	7.9	0.53	2.4	2.5	0.8	0.1	..	2.8	2.5	0.5	0.51	0.9	C_2S_1
Jambnera (Pedon-3)	7.2	0.69	3.5	3.3	0.8	0.5		3.7	2.1	2.3	0.54	1.1	C_2S_1

CORRELATION STUDIES

Sr. No.	Parameters		r
	Y	X	
1	COLE	Clay	0.78
2	COLE	CEC	0.81
3	COLE	ESP	0.87
4	COLE	SAR	0.86
5	COLE	pH	0.77
6	VSP	Clay	0.79
7	VSP	CEC	0.81
8	VSP	ESP	0.86
9	VSP	SAR	0.86
10	VSP	pH	0.77

Regression model developed using step down Regression equation explain the process causing the soils swelling

COLE = - 0.0014 + 0.0021 ESP + 0.0023 CEC + 0.0011 Clay + 0.0015 SAR.

R^2 = 0.88

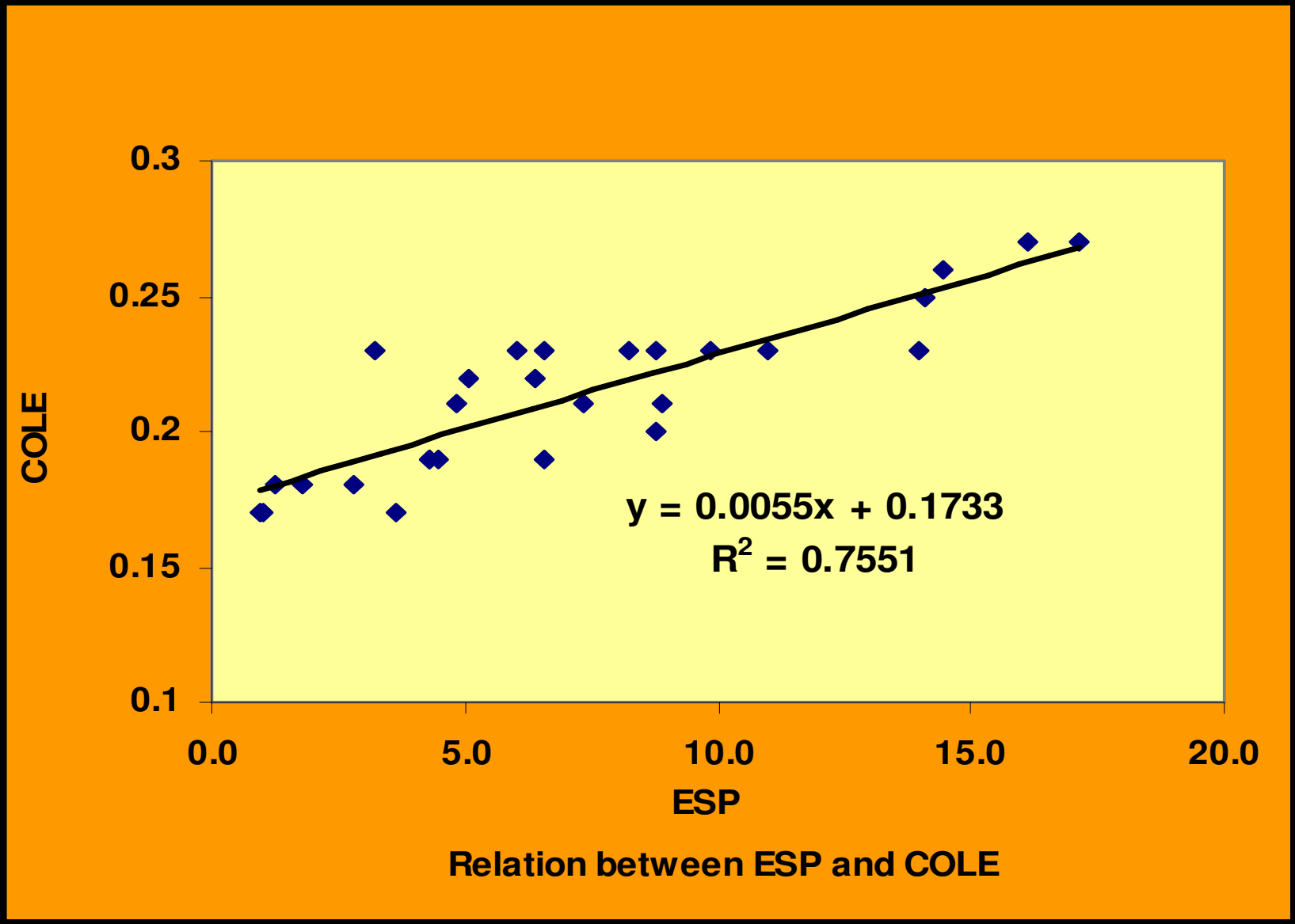
VSP = - 14.310 + 0.7370 ESP + 1.0156 CEC + 0.4927 Clay + 0.7255 SAR.

R^2 = 0.87

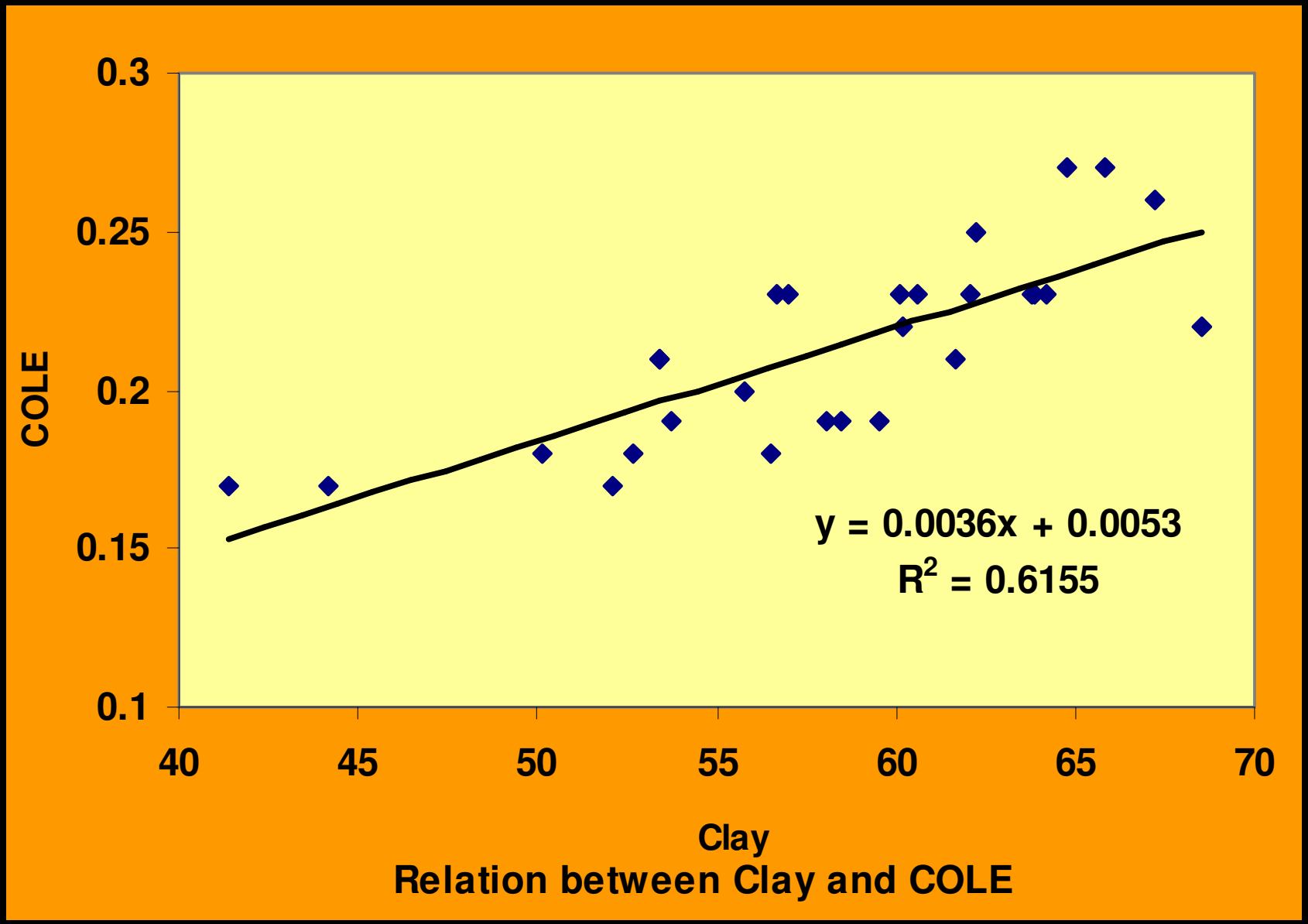
CORRELATION STUDIES

Sr. No.	Parameters		r
	Y	X	
1	Hydraulic conductivity	COLE	-0.83
2	Hydraulic conductivity	WDC	-0.87
3	Hydraulic conductivity	Exch. Ca/Mg	0.91
4	Hydraulic conductivity	ESP	-0.81
5	Hydraulic conductivity	EMP	-0.81
6	Hydraulic conductivity	ESP + EMP	-0.88
7	Hydraulic conductivity	Ca/Mg	0.91
8	Hydraulic conductivity	SAR	-0.82
9	Hydraulic conductivity	SSP	-0.87
10	WDC	ESP	0.81
11	Exchangeable sodium percentage	SAR	0.99
12	SAR	Soluble HCO_3/Ca	0.86
13	CaCO3	Exch. Ca	-0.83

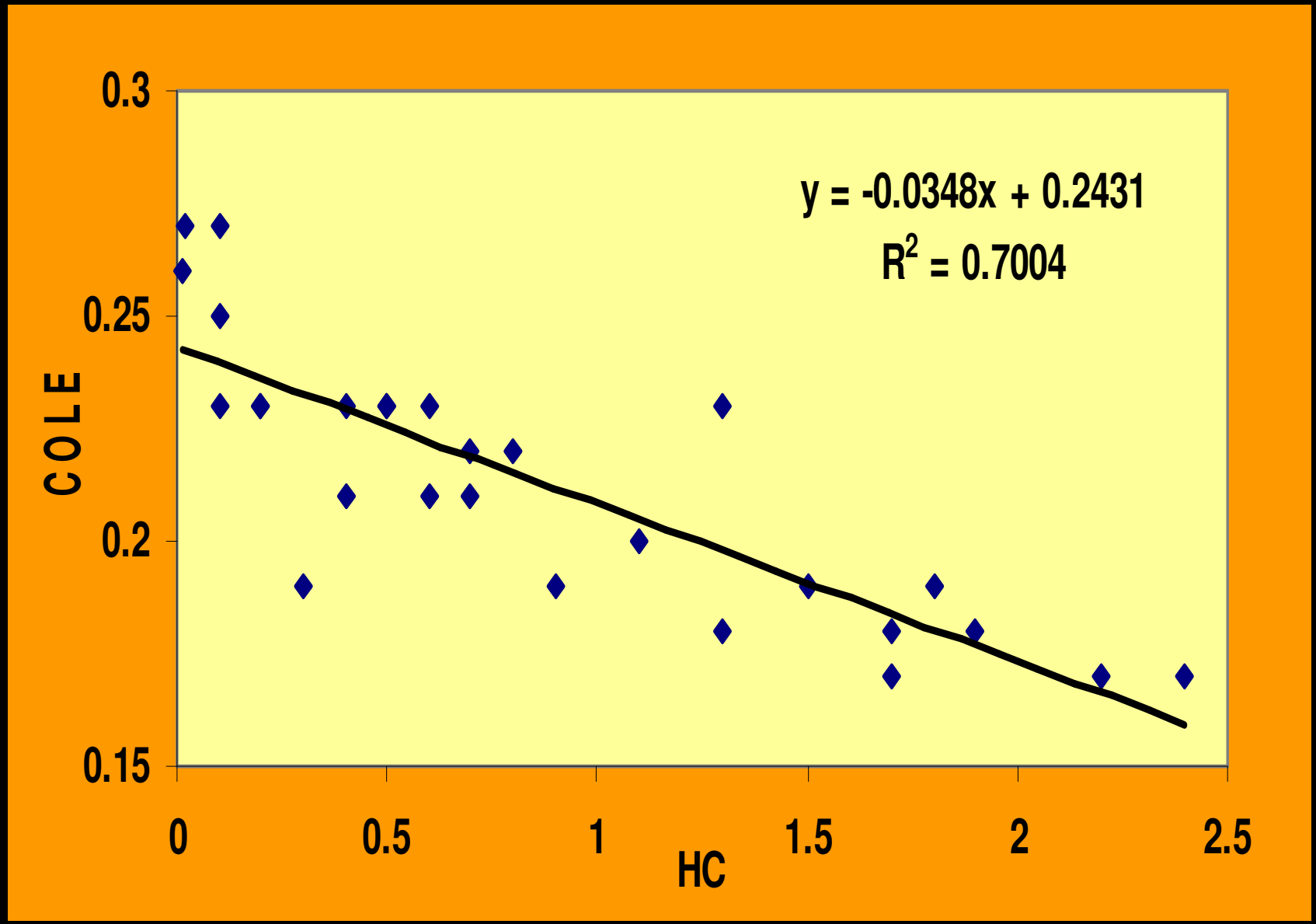
RELATION BETWEEN ESP AND COLE



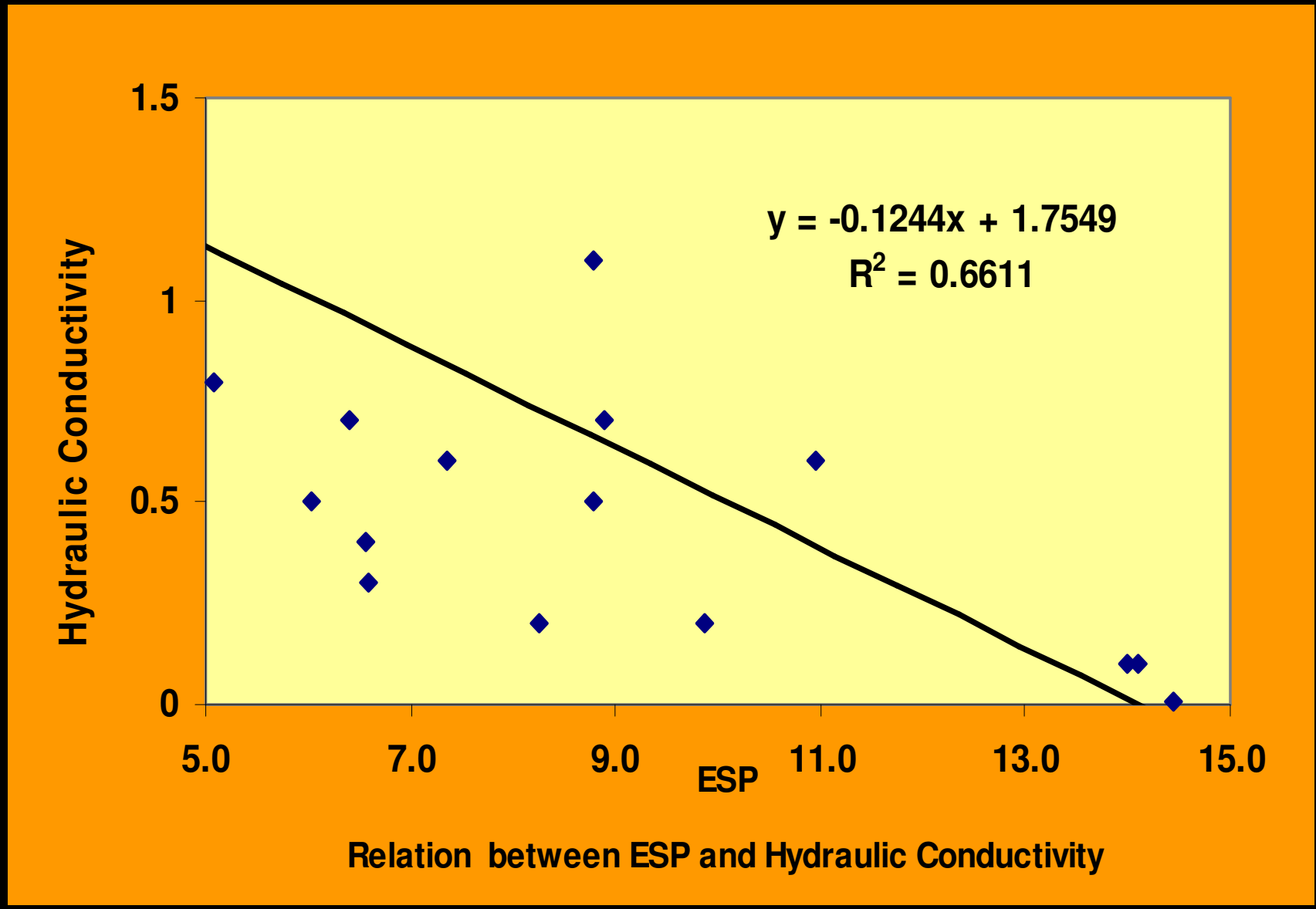
RELATION BETWEEN CLAY AND COLE



RELATION BETWEEN HYDRAULIC CONDUCTIVITY AND COLE



RELATION BETWEEN ESP AND HYDRAULIC CONDUCTIVITY



YIELD PERFORMANCE

Pedons	Yield quintal ha^{-1}		
	Cotton	Soybean	Wheat
Pedon 1-Mandala	9.6	10.2	21.3
Pedon 2- Wardha-maneri	14.9	12.6	22.6
Pedon 3- Jambnera	13.2	13.1	25.9
Pedon 4 - Talegaon	7.6	7.9	20.8
Pedon 5- Parsoda	8.3	7.4	23.6
Pedon 6- Sujatpur	6.8	5.9	22.1

CONCLUSIONS

- Due to aridity of the climate, the soluble Ca^{2+} precipitated as $CaCO_3$ which inturn increased the concentration of Na^{+} and Mg^{2+} in the subsurface soil. Furthermore, because of injudicious irrigation the water table was raised and the upward movement of Na+ initiated in the profile and caused the secondary sodification.
- The high smectitic clay, pH, CEC, ESP and SAR were responsible for high shrink-swell potential of these soils as COLE (0.17 to 0.27) and VSP (60.2 to 100 per cent) values falls in very high shrink-swell class.
- Not only the Na but also Mg is responsible for dispersion of clay and leads to blocking of small pores in the soils.

CONCLUSIONS

- The hydraulic conductivity of irrigated Vertisols of the study area is further decreased due to increase in ESP, EMP, COLE and WDC.
- The development of sodicity in upper part of the profile were observed more, where soil irrigated since 15 years than recently irrigated soils (5 to 6 years).
- The considerable yield reduction in Kharif crops was observed in the soils with irrigation since 15 years, whereas no significant difference found in Rabi crops.
- The desalinization of these soils is not possible because of very low hydraulic conductivity.

RECOMMENDATIONS

- Considering the shrink swell potential and hydraulic properties, these soils should be cultivated with irrigated crops only after providing adequate drainage
- preferably low water requiring crops and cropping sequences should be adopted with suitable irrigation layouts.
- The broad-bed and furrow technology has been found to be suitable for these Vertisols (Bharambe et al. 1999).
- Far-spaced irrigations are recommended.
- In order to improve and sustain soil productivity, organic manuring and crop residue management should be given top priority.

RECOMMENDATIONS

- The development of adverse physical conditions in these soils might possibly be prevented by surface application of gypsum before the rainy season. As the gypsum dissolves it will release enough Ca ions to prevent clay dispersion, swelling of clays and decline in hydraulic conductivity, both at the surface and up to the depth of mixing of gypsum within the soil profile (Balpande et al. 1996).
- Canal seepages should be controlled by taking lining works to avoid sodicity development in low lying areas.

Hope the smile would be continued.....