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Characterisation and Classification of Mined and Unmined Gypsiferous Black Soil

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ABSTRACT. *An investigation was made to characterise and classify mined and unmined gypsiferous black soils distributed in parts of Coimbatore district, Tamil Nadu, India, based on their morphological, physical and chemical characteristics. The study revealed many significant differences between mined and unmined soils. The mined soils were dark yellowish brown and the unmined soils were dark greyish brown in colour. Eventhough both soils were fine textured and calcareous, the mined soils contained coarse fractions in the form of gypsum crystals. The unmined soils possessed vertic characters viz., presence of slickensides in subsoil and development of surface cracks but the vertic properties were absent in mined soils. Mined soil differed from unmined soil by their physico-chemical properties. Among the soil properties, clay%, coarse sand%, gypsum content, CEC and exchangeable Ca were significantly different. The mined soils were classified under USDA Soil Taxonomy as fine, montmorillonitic, isohyperthermic, Vertic Ustorthents and the unmined soils were grouped as very fine, montmorillonitic, isohyperthermic, Typic Haplusterts.*

INTRODUCTION

Gypsiferous black soil is distributed in parts of Coimbatore and Tiruchirapalli districts, Tamil Nadu State, India. Gypsum is mined from these soils for use in industrial purposes. Because of the mining the lands have degraded and the pedogenesis is greatly altered. An attempt has been made in the present investigation to characterise and identify the constraints of the mined and unmined soils for effective suitable amleorative measures on the degraded mined soils.

MATERIALS AND METHODS

The study area covering an area of 20,368 ha lies between 10°30' and 11°00' N latitude and 77°05' and 77°18' E longitude in Coimbatore district, Tamil Nadu State, India. The area is exceptionally dry and the rainfall is scanty. The mean annual precipitation is about 690 mm distributed over 45 rainy days. The mean air temperature ranges from 18.2°C to 35.3°C. The soil temperature and soil moisture regimes of the study area are isohyperthermic and ustic respectively (Eswaran *et al.*, 1990). Six pedons were opened, three in mined soils (P_1, P_2 and P_3) and three in unmined soils (P_4, P_5 and P_6). The pedons were studied in detail for their morphological characteristics and described according to Soil Survey Staff (1990). The soils were classified taxonomically (Soil Survey Staff, 1992). Physical and chemical analyses of the soils were determined in duplicate using standard procedures (Piper, 1966; Jackson, 1971).

RESULTS AND DISCUSSION

Morphology

The salient morphological features of mined and unmined soils are presented in Appendix 1. The mined soils are very deep, calcareous and have low permeability which results in poor drainage. These soils are associated with uneven land topography as they are dumped haphazardly during mining and the uncontrolled erosion further dissects the area. The unmined soils are similar to mined soils in their depth, calcareousness and low permeability. But these soils occur on very gentle sloping lands where erosion is slight and land dissection is absent. The unmined soils are moderately well drained.

The mined soils showed variations in soil colour. The colour of the surface soil ranged from yellowish brown (10 YR 5/4) to brown (7.5 YR 5/4). The sub-surface colour varied from very dark gray (10 YR 3/1) to brown (7.5 YR 5/4). In case of unmined soils, sufficient amount of uniformity was found from the surface down to the subsurface layers containing gypsum. The uniform colour of unmined soils might be due to soil development process (Dudal and Bramao, 1965). Gypsum crystals were distributed right from the surface to bottom layers in the mined soils. In unmined soils, gypsum crystals occurred only below a depth of 102 cm. The size of gypsum crystals also varied in mined and unmined soils. Gypsum crystals were less than 1 cm in diameter in mined soils while these were 5-10 cm in diameter in unmined soils.

The unmined soils showed a gradual transition from A to C horizon. Distinct horizonation is lacking due to haploidization by argillopedoturbation. Presence of shining pressure faces and intersecting slickensides are the results of high shrink and swell potential of these soils. The mined soils did not exhibit the presence of slickensides.

Physical and chemical properties

Physical properties

The physical and chemical properties with statistical parameters of mined and unmined soils are given in Table 1 and 2. Mined soils contained high coarse fragments, low clay and sand content compared to unmined soils. The high coarse fragment content in mined soils was mainly due to the presence of gypsum crystals throughout the soil profile. The low clay and high sand content in mined soils were attributed to the removal in fine particles by soil erosion from the unvegetated mined areas. The results are in conformity with the findings of Dadhwal *et al.* (1992) and Bussler *et al.* (1984).

Chemical properties

The pH ranged from 7.98 to 8.30 and it showed an increasing trend through the depth due to corresponding increase in calcium carbonate and to some extent due to salt content in lower layers. The distribution of gypsum crystals right from the surface layers in mined soils has contributed the increased EC values. Organic carbon decreased with depth in both mined and unmined soils. Similar trend was reported by Soni *et al.* (1989). The calcium sulphate content in mined soils were higher when compared to unmined soils. The concentration of calcium sulphate was higher in lower layers of unmined soils. During the process of mining, lower horizons are disturbed and the soils containing high proportions of calcium sulphate are dumped on the surface. This had resulted in mined soils being enriched with calcium sulphate.

Occurrence of gypsum in soils was reported as indicative of aridity (Virmani *et al.*, 1982) and lack of thorough leaching due to low rainfall (Jewitt *et al.*, 1979). The principal agents and processes for the origin of gypsum in soils were reported as gypsiferous parent material, air borne calcium sulphate, runoff water from gypsum bearing rocks and gypsum containing ground water (Dregne, 1976). The origin of gypsum in the study area may be ascribed to the marine influence.

Table 1. **Physical and chemical properties of mined and unmined soils.**

Depth in cm	Coarse frage-ments	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Soil reaction (1:2.5)	EC dSm^{-1} (1:2.5)	Org. Carbon (%)	Calcium carbonate (%)	Gypsum (%)	CEC	Exchangeable Cations Cmol (p+) kg^{-1}				BSP (%)
												Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
PEDON 1 : JAKKARPALAYAM																
0-20	15.0	45.2	17.8	18.5	17.9	8.0	1.05	0.35	4.98	6.32	37.72	30.47	4.18	0.77	0.65	95.63
20-44	10.0	42.5	16.3	19.3	20.5	8.32	1.92	0.28	6.12	5.85	35.47	27.47	6.12	0.62	0.92	98.26
44-93	5.0	49.7	19.5	18.2	10.2	8.25	3.00	0.26	6.05	2.87	38.41	30.15	6.62	0.58	1.01	99.86
93-130	12.0	45.6	17.2	16.6	18.8	8.30	3.05	0.22	6.25	8.95	33.20	25.22	4.62	0.60	1.25	95.45
PEDON 2 : KATTAMPATTY																
0-20	15.0	50.2	13.2	18.7	16.1	8.35	0.55	0.34	7.10	8.32	40.11	28.11	7.62	0.58	1.01	93.04
20-46	10.0	37.1	15.1	25.1	21.1	8.11	1.40	0.30	5.75	6.17	26.12	16.23	5.17	0.66	0.82	87.60
46-74	12.0	48.2	12.6	18.1	20.4	8.23	1.85	0.28	6.01	6.51	37.15	25.20	6.18	0.47	0.85	88.02
74-112	15.0	49.1	15.2	18.2	16.3	8.15	2.70	0.25	5.70	7.82	38.10	25.80	6.25	0.50	0.72	87.32
112-145	8.0	39.2	15.3	23.1	21.3	8.20	3.00	0.20	5.95	5.60	27.81	19.72	4.55	0.55	0.81	92.16
PEDON 3 : KRISHNAPURAM																
0-18	5.0	36.2	16.2	23.4	22.1	8.30	3.00	0.52	7.16	5.18	24.15	16.18	5.31	0.63	0.85	95.11
18-48	7.0	41.2	18.1	22.2	17.1	8.15	2.85	0.38	4.92	6.32	34.91	25.10	6.80	0.72	0.72	95.50
48-76	12.0	36.2	19.2	23.1	21.3	8.20	1.97	0.30	5.87	5.46	26.70	17.21	5.92	0.65	0.78	91.99
76-105	8.0	37.2	18.2	24.2	19.3	8.30	3.15	0.27	6.35	3.48	27.15	18.10	4.10	0.58	0.90	87.71
105-150	10.0	36.1	19.2	24.6	18.8	8.21	2.85	0.20	5.92	6.15	25.21	17.20	4.65	0.60	0.86	92.46

(Table 1 : Cont'd).

Depth in cm	Coarse frage-ments	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Soil reaction (1:2.5)	EC dSm^{-1} (1:2.5)	Org. Carbon (%)	Calcium carbonate (%)	Gypsum (%)	CEC	Exchangeable Cations Cmol (p+) kg^{-1}				BSP (%)
												Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
PEDON 4 : JAKKARPALAYAM																
0-16	1.0	55.12	15.3	17.8	10.2	7.98	0.43	0.45	3.72	0.21	42.4	30.2	6.1	0.37	0.62	87.95
16-20	0.0	57.85	15.8	15.1	9.6	8.15	1.45	0.43	3.75	0.34	43.2	31.5	5.7	0.48	2.68	93.43
40-65	0.0	62.18	14.2	15.4	7.3	8.21	2.20	0.35	4.00	0.49	47.5	33.6	7.7	0.45	2.85	93.89
65-102	0.0	66.50	13.5	10.2	9.0	8.30	2.90	0.35	4.42	0.67	53.3	36.8	10.2	0.56	3.35	99.24
PEDON 5 : KATTAMPATTY																
0-22	1.0	56.1	16.8	15.3	32.5	8.17	0.58	0.48	3.45	0.0	43.7	31.1	7.3	0.46	0.68	90.48
22-45	0.0	59.7	17.5	14.5	34.3	8.15	0.72	0.46	3.72	0.44	45.6	34.2	6.9	0.50	2.81	97.39
45-55	0.0	63.3	14.8	11.7	36.5	8.21	1.65	0.43	4.81	0.49	49.2	35.3	9.4	0.48	3.10	98.13
55-94	0.0	52.6	16.2	15.2	31.1	8.30	1.75	0.43	4.85	0.57	40.1	28.5	7.2	0.42	2.29	95.79
94-135	0.0	34.2	21.7	22.3	21.8	8.35	2.70	0.40	5.01	0.80	28.3	15.2	6.3	0.38	2.10	84.73
PEDON 6 : KRISHNAPURAM																
0-23	2.0	48.2	14.3	19.4	27.5	8.00	0.62	0.52	4.01	0.15	40.2	27.3	7.6	0.51	1.82	92.61
23-56	0.0	57.7	15.9	14.8	32.3	8.05	1.55	0.49	4.21	0.38	49.7	30.5	9.2	0.48	2.25	85.37
56-108	0.0	62.5	12.2	13.3	35.5	8.11	2.10	0.49	5.46	0.64	50.3	30.7	9.4	0.49	2.61	86.08
108-152	0.0	55.3	12.4	15.2	30.7	8.15	2.53	0.45	5.72	0.81	46.7	29.5	8.4	0.55	3.21	89.21
152-200	0.0	33.5	16.5	26.1	20.5	8.10	3.15	0.40	5.85	2.92	26.5	15.6	5.2	0.55	3.02	91.96

Table 2. Range and mean values of soil properties with 't' values.

Sl. No.	Soil Properties	Mined Soil		Unmined Soil		't'
		Range	Mean	Range	Mean	
1.	Coarse fragments (%)	5.0-15.0	10.28	1.0-2.0	0.29	1.393[NS]
2.	Clay (%)	36.1-50.2	42.69	33.5-66.5	54.63	2.960**
3.	Silt (%)	12.6-19.5	16.65	12.2-21.7	15.51	0.832[NS]
4.	Fine sand (%)	18.1-25.1	20.95	10.2-26.1	16.16	1.309[NS]
5.	Coarse sand (%)	16.1-22.1	18.64	7.3-36.5	24.20	4.069**
6.	Soil reaction (1:2.5)	8.0-8.4	8.22	7.98-8.35	8.16	0.037[NS]
7.	EC (dSm^{-1})	0.55-3.15	2.31	0.43-3.15	1.74	0.320[NS]
8.	Organic carbon (%)	0.20-0.52	0.30	0.35-0.52	0.44	0.025[NS]
9.	CaCO3 (%)	4.92-7.16	6.01	3.45-5.85	4.58	0.257[NS]
10.	CaCO4 (%)	2.87-8.95	6.07	0.15-2.92	0.64	3.437**
11.	CEC Cmol (p+) kg^{-1}	26.12-40.11	32.30	26.5-53.5	43.43	2.500*
12.	Exch. Ca Cmol (p+) kg^{-1}	16.18-30.47	23.01	15.6-36.8	21.29	2.150*
13.	Exch. Mg Cmol (p+) kg^{-1}	4.10-7.62	5.58	5.2-10.2	7.61	0.482[NS]
14.	Exch. K Cmol (p+) kg^{-1}	0.47-0.77	0.61	0.37-0.56	0.48	0.025[NS]
15.	Exch. Na Cmol (p+) kg^{-1}	0.65-1.25	0.87	0.62-3.35	2.39	0.316[NS]
16.	BSP	87-32-99.86	92.87	85.37-99.24	91.88	1.648[NS]

NS - Not significant   * - Significant at $P = 0.05$ ** - Significant at $P = 0.01$

Exchangeable properties

Both the mined and unmined soils registered high CEC values. However, the CEC was high in unmined soils compared to mined soils due to high clay contents in unmined soils. The results on the exchangeable cations clearly indicated that in both mined and unmined soils, the cation concentrations followed the order: Ca>Mg>Na>K. The soils are highly base saturated upto 99 percent.

Soil classification

Soils were classified according to Soil Taxonomy (Soil Survey Staff, 1992). Three mined soil pedons, *viz.*, P_1, P_2 and P_3 were grouped as fine, montmorillonitic, isohyperthermic, Vertic Ustorthents. The unmined soil pedons, P_4 and P_6 were classified as very fine, montmorillonitic, isohyperthermic. Typic Haplusterts and P_5 pedon was classified as fine, montmorillonitic, isohyperthermic, Typic Haplusterts.

P_1 and P_3 pedon showed only 'A' horizons while P_2 pedon exhibited lithological discontinuity without diagnostic horizons. Hence, they were grouped under Entisol order. In suborder level, mined soil pedons were grouped under Orthents, since they did not qualify for any of the suborders of Entisol. The study area has ustic moisture regime, and therefore the soils were grouped in Ustorthents. The presence of wedge shaped aggregates with more than 15 cm thick horizon led the soils to be grouped under sub group Vertic Ustorthents. The soil temperature regime was isohyperthermic. The clay content in control section was more than 30 percent but less than 60 percent and hence the textural class was grouped as fine texture. The chemical composition and CEC of the soil indicated the dominance of "montmorillonite" mineralogy.

The unmined soil pedons P_4, P_5 and P_6 were classified under Vertisol order since all the pedons had more than 30 percent clay in all the horizons, slickensides in the subsoil horizons and surface cracks which open and close periodically. The cracks of 1 cm wide were found down to 50 cm depth in all the pedons for more than 90 cumulative days in a year hence they were grouped under "Usterts" suborder. The great group was "Haplusterts" since the soils could not be classified under any other great groups of Usterts. The sub group was Typic Haplusterts as the soils could not meet the requirements of other subgroups under Haplusterts. P_4 and P_6 pedons were very fine in texture since they contain more than 60 percent clay in control section and P_5 pedon had only $< 60\%$ clay. Therefore, it was grouped under fine textural class. Mineralogy and temperature regimes were similar as that of mined soil pedons.

CONCLUSIONS

The mined soils in comparison to the unmined soils exhibited differences in soil properties. The mined soils were dark yellowish brown and the unmined soils were dark greyish brown in colour. Eventhough both soils were fine textured and calcareous, the mined soils contained coarse fractions in the form of gypsum crystals. The unmined soils possessed vertic characters *viz.*, presence of slickensides in subsoil and development of surface cracks, but the vertic properties were absent in mined soils. Electrical conductivity was higher in mined soils due to the presence of soluble gypsum. The clay contents, CEC and exchangeable Ca were higher in unmined soils and lower in mined soils, whereas calcium sulphate and coarse sand contents were higher in the mined soils and lower in unmined soils. The mined soils were classified as fine, montmorillonitic, isohyperthermic, Vertic Ustorthents and the unmined soils were grouped as very fine. montmorillonitic, isohyperthermic, Typic Haplusterts.

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Appendix 1. Salient morphological features of the mined and unmined soils.

Horizon	Depth	Matrix Colour	Texture	Structure	Consistence	Reaction	Drainage	Others
Pedon 1 : Jakkarpalayam								
A/1	0-20 cm	10 YR 5/3	cl	m 2 sbk	h fi s/p	ev	Moderate	few gypsum and calcium carbonate concretions
A/2	20-44 cm	10 YR 3/1	cl	m 3 abk	h fi s/p	ev		" "
A/3	44-93 cm	10 YR 2/1	cl	m 3 abk	fi s/p	ev		" "
A/4	93-130 cm	10 YR 2/1	cl	m 3 abk	fi s/p	ev		" "
Pedon 2 : Kattampatty								
A/1	0-20 cm	7.5 YR 5/4	cl	m 2 abk	h fi s/p	ev	Poor	few gypsum and lime concretions
A/2	20-46 cm	7.5 YR 5/2	scl	m 2 sbk	h fi s/p	ev		" "
II C_1	46-74 cm	10 YR 3/2 10 YR 3/1	cl	m 3 abk	h fi s/p	ev		" "
II C_2	74-112 cm	10 YR 3/2	cl	m 3 abk	fi s/p	ev		" "
III C_1	112-145 cm	7.5 YR 5/4	scl	m 2 sbk	fi s/p	ev		" "
Pedon 3 : Krishnapuram								
A/1	0-18 cm	10 YR 5/4 10 YR 5/3	scl	m 2 sbk	h fi s/p	ev	Poor	few lime and gypsum concretions
A/2	18-48 cm	10 YR 4/4	cl	m 2 sbk	h fi s/p	ev		" "
A/3	48-76 cm	10 YR 4/4	scl	m 2 sbk	h fi s/p	ev		" "
A/4	76-105 cm	10 YR 4/4	scl	m 2 sbk	h fi s/p	ev		" "
A/5	105-150 cm	10 YR 4/4	scl	m 2 sbk	fi s/p	ev		" "

(Appendix 1 : Cont'd).

Horizon	Depth	Matrix Colour	Texture	Structure	Consistence	Reaction	Drainage	Others
Pedon 4 : Jakkarpalayam								
A_p	0-16 cm	10 YR 3/1	cl	m s sbk	h fi vs/vp	es	Moderately well drained	surface cracks
A12	16-40 cm	10 YR 3/1	cl	c 3 abk	vh vfi s/p	es		cracks
A13	40-65 cm	10 YR 3/1	cl	c 3 abk	vfi vs/vp	es		cracks, distinct pressure faces
A14	65-102 cm	10 YR 3/1	cl	c 3 abk	vfi vs/vp	es		prominent silicken sides
A_c	102-250 cm	10 YR 4/3				Gypsum blocks mixed with soils		
Pedon 5 : Kattampatty								
A_p	0-22 cm	10 YR 4/1 10 YR 3/1	cl	m 3 sbk	h fi vs/vp	es	Moderatelywell drained	cracks
A12	22-45 cm	10 YR 3/1	cl	c 3 abk	h fi vs/vp	es		"
A13	45-55 cm	10 YR 4/2	cl	c 3 abk	h fi vs/vp	es		cracks, prominent silicken sides
A14	55-94 cm	10 YR 5/3	cl	m 3 abk	fi s/p	es		" "
A_c	94-135 cm	10YR 5/3	cl	m 2 sbk	fi s/p	es		" "
C	135-200 cm	Gypsum blocks						
Pedon 6 : Krishnapuram								
A_p	0-23 cm	10 YR 4/3 10 YR 3/2	cl	m 3 sbk	h fi vs/vp	ev	Moderately well drained	cracks
A12	23-56 cm	10 YR 3/2	cl	c 3 abk	h fi vs/vp	es		"
A13	56-108 cm	10 YR 3/1	cl	c 3 abk	vh vfi vs/vp	es		prominent silicken sides "
A14	108-152 cm	10 YR 4/4	cl	c 3 abk	vh vfi vs/vp	es		" "
A_c	152-300 cm	10 YR 4/4	cl	c 2 sbk	h fi s/p	es		few gypsum blocks