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Fertility Capability Classification (FCC): A case study in rainfed soils of semi-arid Deccan plateau

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Abstract: Soil fertility capability classification (FCC) is a technical system which groups the soils according to kinds of problems they present for management. The soil fertility related constraints can be identified without testing for soil nutrients and the FCC tries to bridge the gap between pedology and soil fertility.The present study is an attempt to classify the soils of six soil series identified in a part of southern Deccan plateau. Three pedons were selected from each soil series to represent the range in characteristics of soil properties. According to FCC, the representative pedons were classified as LRdkemr^{+} (Gummagonda); Ldkmr^{+} (Pullagiri); LCdki (Chegunta); Ldkbn (Nerelapally); Cdυkbn (Avancha) and Ldkemn^{-} (Koduparthy). The presence of condition modifiers in soil moisture stress (d) and low nutrient reserve (k) indicates that all the soils are poor in soil fertility and available moisture content. The soils of Gummagonda are shallow with root restricting layer and cultivation of crops makes these soils prone to erosion. Hence, pasture development is a viable option to conserve these soils.Poor nutrient supply (k), calcareousness (b) and Alkalinity (n) are the major constraints in soils of Nerelapally and Avancha and they need to be ameliorated with suitable amendments to sustain crop production.

Keywords:*Soil fertility, Condition modifiers, Deccan plateau, Rainfed soils*

Introduction

Perception about soils for crop production capability differs among pedologists and soil fertility specialists. The pedologists place major importance on intrinsic soil properties and employ soil classification to understand the potentials and limitations of soils. Soil fertility experts mostly rely on soil test values of top 20 cm layer of soils and field experiments and attribute the differences in crop yields to variation in the surface soil properties. Quantitative pedology and soil taxonomy not accounting for dynamic soil properties and emphasis given only to permanent properties of soils for their classification, was a long standing criticism. It is argued that their application is limited in terms of their use for soil fertility management. Soil survey data helps to taxonomically group the soils and provides information on the suitability of soils for various uses, however, its utility can be increased if the taxonomic units are presented in an easy format and indicate the potential and limitations of soils in terms of fertility. To address this concern and bridge the gap between soil fertility and pedology, Fertility Capability Classification (FCC) was developed by Buol *et al*.(1975). FCC groups the soils according to the kinds of problems they present for management of their physical and chemical problems (Sanchez *et al*. 1982). The system comprises of three levels *viz*., type (texture of surface soil), sub strata type (texture of sub-surface soil) and modifiers with respect to their characteristics in the 50 cm depth of soil. Though researchers were reluctant to use it initially, it is now widely used all over the world after revisions (Sanchez *et al*. 2003).

FCC system was applied to convert the taxonomic units into fertility classes for soils of Konheri watershed in semi-arid tropical India and it was concluded that FCC can provide basic clue for fertilizer management (Jagdish Prasad 2000). Management of surface soil characteristics is relatively easier than manipulation of sub-surface layer properties especially in rainfed production systems (Adhikary *et al*. 2010). Though FCC doesn't include soil test

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values for available nutrients it can be a useful approach to evaluate the soils in rainfed and dryland farming systems where low level nutrient management is common. Several attempts have been made to evaluate soils in different agro-ecosystems based on FCC system (Rao and Jose 2003; Adhikary *et al*. 2010). The FCC class interprets the soil properties in such a way that it can be used to easily identify the soil fertility constraints for their better management. The present study is an endeavour in that direction for some rainfed soils of southern Deccan plateau.

Materials and Methods

The study area, Thimmajipet mandal is a part of Mahabubnagar district in Telangana and lies between 16º 35' 13" to 16º 44' 31" N latitudes and 78º 07' 37" to 78º 18' 36" E longitudes. The elevation varies from 434 to 662 m above MSL.The soils occur on three major landforms *viz*., piedmont, alluvial plain and valley.The climate is semi-arid tropical and mean annual rainfall varies from 450 to 550 mm. Rainfed agriculture is pre-dominant and about 10 per cent of the areas are irrigated with bore well water. Major crops grown during *monsoon* season are cotton (*Gossypium hirsutum*), maize (*Zea mays*) followed by pigeon pea (*Cajanus cajan*). In winter or post-monsoon seasongroundnut (*Arachis hypogaea*) occupies the major area. The length of the growing period is 90-120 days.

Detailed soil survey was conducted to study the soils for their morphological characteristics in the field. Soil correlation exercise resulted in six soil series and three pedons from each soil series were selected for laboratory analysis. Particle - size analysis was carried out using hydrometer method (Gee and Bauder 1986); Soil pH and electrical conductivity (EC) were measured with 1:2 soil:water ratio (Whitney 1998). Organic carbon (OC) was determined by Walkley and Black (1934) method. $CaCO_3$ equivalent (%) was determined by Piper method (1966). Cation exchange capacity (CEC) and exchangeable cations were estimated by standard procedures (Schollenberger and Simon 1945; Sumner and Miller 1996). Exchangeable sodium percentage (ESP) was estimated as the ratio of exchangeable sodium to CEC. FCC version 4 (Sanchez *et al*. 2003) was used to classify the soils based on surface and sub-surface soil properties. The first category-type/ sub-strata type indicates top soil and sub-soil texture. The second one – condition modifiers were identified to indicate soil characteristics. The superscripts + or – were used to express the magnitude of condition modifiers.

Result and discussion

The identified soil series are Gummagonda (*Lithic Ustorthents*); Pullagiri (*Typic Haplustepts*); Chegunta (*Typic Rhodustalfs*); Nerelapally (*Vertic Haplustepts*); Avancha (*Sodic Haplusterts*) and Koduparthy (*Typic Ustifluvents*). The descriptive statistics of the soil properties used to develop FCC are given in Table 1 and 2 for surface and sub-surface, respectively. The weighted mean values of considered soil properties for three pedons from each soil series is given in Table 3. The strata or sub-strata type used were (i) loamy top soil, 'L' (ii) rock or other hard root restricting layer within 50 cm, 'R' (iii) clayey sub soils, 'C' (iv) sandy sub-soil 'S'. The condition modifiers appropriate for the soils under study were (i) soil moisture stress, 'd' indicating dry season longer than three months and ustic or xeric soil moisture regime; (ii) low nutrient reserves, 'k' with sum of bases <10 cmol (p^+) kg^{-1} soil; (iii) high leaching potential, 'e' with low activity clay minerals; (iv) high P fixation, 'i' with hues redder than 5YR (v) gravelliness, 'r' denoting 10-15 per cent of gravels (vi) calcareousness, 'b' indicating free $CaCO_3$ within 50 cm depth. (vii) alkalinity, 'n' with high ESP (viii) cracking clays indicating vertic properties (ix) low organic carbon status, 'm'.

Table 1. Descriptive statistics of soil variables (0-20 cm depth)

Properties	Mean	Minimum	Maximum	Std Dev	SE(m)±
Sand (%)	64.6	48.8	78.5	9.01	2.12
Silt (%)	8.8	1.1	14.4	4.64	1.09
Clay (%)	26.6	16.8	41.2	7.22	1.70
pH	7.7	6.1	9.4	1.11	0.26
EC (dS m^{-1})	0.3	0.0	1.3	0.36	0.09
$CaCO_3$ (%)	5.3	2.7	9.2	2.32	0.55
SOC (g kg^{-1})	7.8	4.3	16.6	3.10	0.73
Ca [c mol (p+) kg^{-1}]	5.2	0.4	14.5	4.78	1.13
Mg [c mol (p+) kg^{-1}]	2.8	0.2	8.8	2.92	0.69
Na [c mol (p+) kg^{-1}]	1.9	0.1	6.9	2.37	0.56
K [c mol (p+) kg^{-1}]	1.4	0.5	3.5	0.79	0.19
CEC [c mol (p+) kg^{-1}]	14.5	3.9	32.7	9.59	2.26
ESP	9.8	1.0	26.7	8.51	2.01

Table 2. Descriptive statistics of soil variables (20-50 cm depth)

Properties	Mean	Minimum	Maximum	Std Dev	SE(m)±
Sand (%)	62.8	45.4	78.8	10.02	2.59
Silt (%)	9.3	2.7	13.3	3.69	0.95
Clay (%)	27.9	9.5	43.7	9.38	2.42
pH	8.1	6.1	9.4	1.10	0.28
EC (dS m^{-1})	0.4	0.0	1.3	0.44	0.11
$CaCO_3$ (%)	5.6	2.7	9.0	2.00	0.52
SOC (g kg^{-1})	6.1	3.3	9.3	1.55	0.40
Ca [c mol (p+) kg^{-1}]	6.0	0.3	14.8	4.90	1.26
Mg [c mol (p+) kg^{-1}]	3.3	0.2	7.9	2.81	0.72
Na [c mol (p+) kg^{-1}]	2.9	0.1	8.7	3.33	0.86
K [c mol (p+) kg^{-1}]	1.6	0.4	3.5	0.82	0.21
CEC [c mol (p+) kg^{-1}]	17.0	4.3	33.9	10.05	2.59
ESP	12.8	1.2	25.7	9.90	2.56

In Gummagonda soils, condition modifiers identified were soil moisture stress (d), low nutrient reserve (k), high leaching potential (e), low OC status(m) and gravelliness (r^+) and the FCC class was LRdkemr$^+$.Pullagiri soils had condition modifiers as soil moisture stress (d), low nutrient reserve (k), low organic carbon (m) and gravelliness (r^+) and the FCC class was Ldkmr$^+$. In Chegunta soils, condition modifies were soil moisture stress (d), low nutrient supplying power (k), high leaching potential (e) and thus FCC class was Ldke for pedon and Ldk for Pedon2. Pedon 3 comprises of d, k and i condition modifiers and C sub-strata type because of clayey top soil and accordingly FCC class assigned was LCdki.

Nerelapally possess condition modifiers as moisture stress (d), low nutrient reserve (k), calcareousness (b) and alkalinity (n). Hence, the FCC class was Ldkbn. In soils of Avancha, condition modifiers identified were soil

moisture stress (d), cracking clay (v), low nutrient supply (k), calcareousness (b) and alkalinity (n). The FCC class was Cdvkbn for all three pedons. The pedon of Koduparthy soils vary to great extent due to lithological discontinuity. Pedon 1 was classified as Ldkemn^{-} according to FCC class and the condition modifiers were soil moisture stress (d), low nutrient supply (k), high leaching potential (e), low organic carbon (m) and moderate alkalinity (n^{-}). Suitable modifiers for pedon 2 were d,k and e and sub-strata type S was assigned to indicate sandy top soil and classified as LSdke. Pedon 3 was classified as CSdkn and it indicates clayey surface soils underlain by sandy sub-surface layer.

It is observed that condition modifiers is soil moisture stress (d) and low nutrient reserve (k) found a place in the FCC class of all the soils. It indicates the soils are poor in fertility and low in available water. In soils of Koduparthy, lithological discontinuity compounds this problem where sandy layer facilitates leaching of nutrients to lower depth along with percolating water. These soils lack capacity to support root anchorage as they have single grain structure and poor aggregate stability. The accumulation of base cations due to leaching in the sub-surface layer enhances the development of sub-soil sodicity with the presence of $CaCO_3$. It induces deficiency of micronutrients and phosphorus by forming Ca-P compounds (Jagdish Prasad 2000). They have low CEC due to sandy texture and kaolinitic clay (Jawahar *et al*. 1999) and irregularly distributed OC due to lithological discontinuity.

Soils of Gummagonda are shallow with root limiting hard rock. They occur mostly on moderately sloping piedmonts and dominant surficial water movement leads to erosion of fine soil particles to lower topographic positions and increases the gravelliness of the soils (Rao and Jose 2003). Hence, poor nutrient supply and low available water content due to limited depth are major limiting factors for crop production in these soils. Pasture development could be viable option to restrict the soil erosion and to conserve the soils from degradation. Limitations in Chegunta soils are low water availability and poor nutrient supplying capacity. However, these soils have sufficient clay (>20%, Table 3) in the 50 cm and thus take care in nutrient management with assured supplemental irrigation can make these soils productive.

Calcareousness and alkalinity due to high pH and ESP are major limitations in soils of Nerelapally and Avancha (Table 3). High level of Ca and Na causes micronutrient deficiency. The high clay content of these soils reduces the workability when they are wet and dry (Jagdish Prasad 2000). Though leaching is a difficult process due to high clay content, suitable amendment like gypsum or organic manures need to be used to reduce the alkalinity threat (Table 4). Though soil application of gypsum may not be advocated due to calcareousness, foliar spray of micronutrients can correct their deficiency.

Conclusion

The soils were grouped by characteristics that make them similar for fertility management. Soil moisture stress and low nutrient content were identified as major constraints for all the soils, however, the soils occurring in the valley need not always be under soil moisture stress as the high clay content in these soils increases water holding capacity. Soil depth and erosion are limitations for crop cultivation in Gummagonda soils. Management of sub-soil sodicity and calcareousness are of major importance for soils of Nerelapally and Avancha. The study indicates that transforming the quantitative pedological data into fertility class by FCC can provide information on limitations and potentials of soils for planning better management of soils. Condition modifiers can serve as drivers for selection of appropriate management for increasing the soil productivity apart from indicating soil characteristics.

Table 3. Relevant Weighted Mean values of soil properties for fertility capability classification

Pedon	Depth (cm)	Sand	Silt	Clay	pH	EC dS m^{-1}	$CaCO_3$ (%)	OC g kg^{-1}	Bases [c mol (p+) kg^{-1}] Ca	Mg	Na	K	CEC [c mol (p+) kg^{-1}]	ESP	Colour (moist)
		----------%----------													
Gummagonda 1	0-20	75.2	3.2	21.6	6.37	0.045	3.24	5.8	1.2	0.3	0.2	0.8	4.5	4.5	7.5YR4/4
Gummagonda 2	0-20	78.1	4.7	17.2	6.42	0.051	3.51	6.1	1.4	0.5	0.1	0.5	4.3	2.3	7.5YR3/4
Gummagonda 3	0-20	71.4	10.2	18.4	7.20	0.063	3.29	5.2	1.6	0.6	0.2	0.5	6.7	3.0	7.5YR3/4
Pullagiri 1	0-20	67.8	1.3	30.9	7.02	0.281	4.34	6.9	2.1	1.4	0.3	1.1	11.7	2.6	7.5YR3/4
	20-50	65.1	4.5	30.4	7.35	0.201	4.41	6.0	2.6	1.6	0.3	1.7	12.1	2.5	7.5YR3/3
Pullagiri 2	0-20	70.2	1.4	28.4	7.83	0.113	3.22	5.6	1.9	1.1	0.2	0.9	11.5	1.7	7.5YR4/4
	20-50	68.1	2.7	29.2	7.81	0.125	3.71	5.0	2.4	1.3	0.2	0.7	12.1	1.7	7.5YR3/4
Pullagiri 3	0-20	64.2	5.4	30.4	6.61	0.220	3.16	6.7	2.5	1.0	0.1	0.8	10.4	1.0	7.5YR3/3
	20-50	65.1	4.7	30.2	6.68	0.235	3.70	5.2	2.8	1.2	0.1	0.9	10.2	10.2	7.5YR4/4
Chegunta 1	0-20	65.4	10.9	23.7	7.20	0.092	3.23	8.3	1.5	0.5	0.2	1.4	4.2	4.7	7.5YR3/4
	20-50	59.4	8.9	31.7	6.80	0.125	3.65	8.5	2.5	0.7	0.2	1.2	6.20	1.20	2.5YR3/6
Chegunta 2	0-20	67.0	12.8	20.2	6.10	0.004	2.72	6.7	2.5	1.1	0.2	1.1	13.4	1.2	7.5YR4/4
	20-50	63.5	11.2	25.3	6.10	0.004	2.74	6.3	3.0	1.3	0.1	1.2	14.3	1.3	5YR3/6
Chegunta 3	0-20	61.8	11.0	27.2	6.10	0.058	3.23	6.5	3.0	1.2	0.2	1.3	14.8	2.1	7.5YR3/4
	20-50	53.9	12.1	34.0	6.70	0.085	4.41	5.9	3.2	1.1	0.2	1.2	15.2	1.4	2.5YR3/6
Nerelapally 1	0-20	55.4	13.0	31.6	8.61	1.314	7.01	16.6	9.4	4.2	4.1	2.3	24.3	16.9	10YR4/1
	20-50	54.9	13.1	32.0	9.02	0.965	7.83	9.3	9.6	4.8	5.1	2.6	23.7	21.8	10YR4/1
Nerelapally 2	0-20	64.9	10.9	24.2	9.40	0.211	4.45	7.9	8.8	4.6	5.2	1.4	19.5	26.7	10YR4/1
	20-50	60.5	12.4	27.1	9.37	0.168	4.10	4.3	8.5	4.3	5.1	1.3	20.8	25.7	10YR4/1
Nerelapally 3	0-20	65.3	12.5	22.2	8.72	0.459	9.23	7.4	9.9	6.1	4.8	1.8	20.7	23.2	10YR4/3
	20-50	63.8	10.8	25.4	8.80	0.421	9.03	6.4	10.2	6.3	5.0	1.8	20.7	23.8	10YR4/2
Avancha 1	0-20	55.2	8.2	36.6	8.85	0.692	8.56	13.1	14.5	8.8	6.9	2.1	32.7	21.1	10YR3/2
	20-50	55.3	7.6	37.1	9.23	0.853	7.78	7.8	13.5	7.5	8.3	1.9	32.2	24.0	10YR3/2
Avancha 2	0-20	48.8	10.0	41.2	8.56	0.771	7.43	6.5	10.5	7.9	3.9	1.8	28.4	15.0	10YR4/1
	20-50	45.4	10.9	43.7	9.06	1.310	6.55	5.2	11.9	7.2	7.4	2.4	33.9	19.0	10YR3/1
Avancha 3	0-20	54.4	13.5	32.1	8.89	0.716	7.96	7.5	13.4	6.9	5.2	2.1	30.9	16.8	10YR4/2
	20-50	51.7	13.3	35.0	9.00	1.116	7.71	5.6	14.8	7.9	8.7	2.4	33.1	23.5	10YR3/1
Koduparthy 1	0-20	78.5	1.1	20.4	8.41	0.005	6.75	4.3	0.4	0.2	0.4	0.6	5.0	11.2	10YR4/4
	20-50	78.8	4.0	17.2	8.51	0.005	6.21	3.3	0.3	0.6	0.5	0.4	4.3	10.4	7.5YR3/4
Koduparthy 2	0-20	70.1	13.1	16.8	8.70	0.447	6.25	7.1	0.4	0.2	0.3	0.5	3.9	7.7	10YR4/4
	20-50	78.7	10.7	10.6	8.84	0.321	4.95	6.1	0.5	0.2	0.2	1.3	4.3	6.1	7.5YR4/4
Koduparthy 3	0-20	49.4	14.4	36.2	8.32	0.003	8.54	12.2	8.4	3.9	2.1	3.5	14.8	14.3	10YR3/3
	20-50	77.5	13.0	9.5	8.33	0.006	7.62	6.7	4.0	2.8	2.1	3.5	12.4	19.3	7.5YR4/4

Table 4. FCC class of soils and their interpretation

Pedon	Taxonomic classification	FCC Unit	Description	Interpretation
Gummagonda P1	Loamy, mixed, hyperthermic Lithic Ustorthents	LRdkemr^{+}	Gravelly shallow coarse loamy soils with underlying rock. Dry soils with low water and nutrient holding capacity. Low cation exchange capacity	Moisture is limiting during dry season unless soil is irrigated. Germination problems are experienced if first rains are sporadic
P2		LRdkemr^{+}		
P 3		LRdkemr^{+}		
Pullagiri P1	Fine-loamy, mixed, hyperthermic Typic Haplustepts	Ldkmr^{+}	Gravelly coarse loamy at surface and fine loamy sub-surface soils with ustic soil moisture regime. Good water holding capacity. Poor nutrient supply with P fixation capacity.	CEC is low and poor nutrient supply along with low soil moisture limits crop yield. Erosion prone soils need conservation measures and optimum fertilizer application.
P2		Ldkmr^{+}		
P3		Ldkmr^{+}		
Chegunta P1	Fine-mixed, hyperthermic Typic Rhodustalfs	Ldke	Sandy clay loam texture at surface and sub-surface. Dry soils with poor water and nutrient holding capacity and low cation exchange capacity at surface.	Poor nutrient supply limits crop yield. Split application of fertilizer or better fertility management practices with irrigation can improve productivity.
P2		Ldk	Sandy clay loam texture at surface and sub-surface. Dry soils with poor water and nutrient holding capacity	Care in fertilizer management is required since soils have poor nutrient supplying power
P3		LCdki	Sandy clay loam at surface and sandy clay at sub-surface with high P fixation capacity and low nutrient holding capacity.	Requires high levels of P fertilizer or special P management practices
Nerelapally P1	Fine loamy, mixed, hyperthermic Vertic Haplustepts	Ldkbn	Sandy loam texture at surface and sub-surface texture with ustic soil moisture regime and poor nutrient status. Soils with calcareousness and sodicity which limits crop productivity.	High levels of sodium. Potential deficiency of micronutrients. Requires special management practices for calcareousness and alkalinity including use of gypsum and drainage provision.
P2		Ldkbn		
P3		Ldkbn		
Avancha P1	Fine, smectitic, hyperthermic Sodic Haplusterts	Cdvkbn	Shrink-swell soils with clay at surface and sub-surface. Dry soils with calcareousness, sodicity and low productivity.	Tillage is difficult when too dry or too moist. Potential deficiency of P and micronutrients. Soils can be highly productive if carefully managed for alkalinity and drainage.
P2		Cdvkbn		
P3		Cdvkbn		
Koduparthy P1	Sandy, mixed, hyperthermic, Typic Ustifluvents	Ldkemn^{-}	Sandy clay loam at surface and sandy loam at sub-surface with ustic soil moisture regime and low cation exchange capacity and incipient alkalinity.	High infiltration and poor water holding capacity and low nutrient supplying power. Requires gypsum amendment for arresting the development of sodicity.
P2		LSdke	Sandy loam at surface and loamy sand at sub-surface with high rate of infiltration. Poor nutrient supplying power with very low cation exchange capacity	Very high infiltration rate and leaching of nutrients. High rate of fertilizer application is required with shallow and medium rooted crops suitable.
P3		CSdkn	Sandy clay at surface and sand at sub-surface with poor nutrient supplying power and sodicity.	High infiltration rate and nutrient leaching limits the crop production with alkalinity. Requires gypsum amendment with high level of fertilizer

*P1, P2 and P3 indicate pedons 1, 2 and 3, respectively.

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