Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(6): 2701-2704
Received: 16-09-2018
Accepted: 18-10-2018

Ch Chandra Sekhar
ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, Telangana, India

MVS Naidu
Department of Soil Science & Agricultural Chemistry, S.V. Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

T Ramprakash
Department of Soil Science & Agricultural Chemistry, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

D Balaguravaiah
Department of Soil Science & Agricultural Chemistry, S.V. Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

Correspondence
Ch Chandra Sekhar
ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, Telangana, India

Soil-site suitability evaluation for major crops grown in the central parts of Prakasam district in Andhra Pradesh, India

Ch Chandra Sekhar, MVS Naidu, T Ramprakash and D Balaguravaiah

Abstract
Seven typical pedons from central parts of Prakasam district, Andhra Pradesh, India were characterized and evaluated for their suitability to five major crops *viz.*, rice, cotton, chickpea, tobacco and sorghum. Suitability classes of these pedons ranged from moderately suitable (S2) to permanently not suitable (N2) to these crops. Pedon 7 was marginally suitable; pedons 1, 2 and 4 were temporarily not suitable while the pedons 3, 5 and 6 were permanently not suitable for rice. Pedons 5 and 7 were marginally suitable; pedons 1 and 2 were temporarily not suitable while the pedons 3, 4 and 6 were permanently not suitable for both cotton and chickpea cultivation. Pedons 3 and 7 were marginally suitable; pedons 1, 2, 5 and 6 were temporarily not suitable while the pedon 4 was permanently not suitable for tobacco crop. Pedons 3, 5, 6 and 7 were moderately suitable; pedons 1 and 2 were temporarily not suitable, while pedon 4 was permanently not suitable for growing sorghum crop. Shallow soil depth, wetness, organic carbon content, pH and $CaCO_3$ content were the limiting factors in all the pedons of the study area. Texture was found to be limiting in all the pedons except P1 and P2. In addition, alkalinity was also a limiting factor in P1 and P4. However, limitation levels of soil-site characteristics varied from crop to crop. Suitable conservation and remedial measures were suggested to improve the soil productivity on sustainable basis without deteriorating the soil quality. Potential land suitability classes were also suggested based on the possible improvement measures for these soils.

Keywords: Pedon, suitability class, limitation levels, potential land suitability

Introduction
Soil is very important natural resource and is a natural treasure for any country. However, it is finite and non-renewable. India, with its meager share of 2.5 per cent of world's land area, has to support nearly 18 per cent of the world's population (Katyal, 2012) [1]. The population of India has increased from 456 million in 1961 to 1053 million in 2000 and is projected to reach 1387 million by 2020 and 1665 million by 2050. The per capita cultivable land in India is also reported to decline from 0.34 ha in 1961 to 0.14 ha in 2010 and is projected to further decline to as low as 0.09 ha by 2050 (Lal, 2013) [2]. Judicious use of this vital natural resource influences the survival of life systems and there by socio-economic development of any country. Land suitability evaluation is the process of estimating the potential of land for land use planning (Sys *et al.* 1991) [3]. However, each plant species requires specific soil and climatic conditions for its optimum growth. Studies and information on the soil-site suitability for crops in the state of Andhra Pradesh in general and in Prakasam district in particular are very much lacking. Hence, a study has been taken up to evaluate the soil suitability for five major crops *viz.*, rice, cotton, chickpea, tobacco and sorghum on the existing Entisols, Inceptisols and Vertisols in central parts of Prakasam district, Andhra Pradesh.

Material and Methods
Description of the study area
Prakasam district in the state of Andhra Pradesh lies between 14º 57′ to 16º 17′ North latitude and 78º 43′ to 80º 25′ East longitude. The district has semi-arid monsoonic climate with distinct summer, winter and rainy seasons. Mean annual rainfall of the district is 747.07 mm, of which about 93 per cent is received during the months of April to November. The mean annual temperature recorded is 29.50°C with mean summer and mean winter temperatures of 32.33°C and 26.09°C, respectively. The maximum temperature is recorded in May that rises to 40.60°C and the minimum temperature recorded is 20.36°C in the month of January. The study area has ustic soil moisture regime and soil temperature regime is iso-hyperthermic. The natural vegetation observed in the study area comprises of species like *Acacia nilotica, Borassus flabellifer, Parthenium hysterophorus, Calotropis gigantia, Prosopis juliflora,*

Tamarindus indica, Azadirachta indica, Cassia auriculata, Ziziphus mauritiana and Cyperus rotundus etc.

Methodology

After thoroughly traversing through the district, seven typical pedons were selected for study from two land forms (uplands and plains) in central parts of the district. Morphological characteristics of these pedons were described in the field by following the procedures outlined by Soil Survey Division Staff (2000) [4]. Horizon-wise soil samples were collected from these typifying pedons and analyzed for their physical, physico-chemical and chemical properties following the standard procedures and were classified according to Soil Taxonomy (Soil Survey Staff, 1999) [5]. Then, these pedons were evaluated for their suitability, for major crops grown in the study area, using limitation method regarding number and intensity of limitations (Sys *et al.* 1991) [3].

Landscape and soil requirements for the selected crops were matched with generated data at different limitation levels *viz.*, no (0), slight (1), moderate (2), severe (3) and very severe (4). The number and degree of limitations suggested the suitability classes of pedons for the crops under study (Sys *et al.* 1991) [3]. The potential land suitability (Table 3) sub-classes were also determined after considering the improvement measures to correct these limitations (Sys *et al.* 1991) [3].

Results and Discussion

Details of the selected pedons and relevant soil characteristics are given in the Table 1. Site characteristics and weighted means of soil characteristics of the studied profiles are given in the Table 2. These soils are developed from granite-gneiss and calcareous gneiss. The type and degree of limitations of soils under study for the major five crops are presented in Table 3. The soils with no limitations or only four slight limitations are grouped under highly suitable class (S1); soils with more than four slight limitations, and/or with more than three moderate limitations are grouped under moderately suitability class (S2); soils with more than three moderate limitations, and/or one or more severe limitations are grouped under marginally suitable (S3) class; soils with very severe limitations which can be corrected are grouped under N1 (currently not suitable); the soils with very severe limitations which can not be corrected are grouped under unsuitable class N2 (Sys *et al.* 1991) [3]. This method also identifies the dominant limitations restricting the crop growth and is shown with the sub-class symbol such as climatic (c), topographic (t), wetness (w), physical soil characteristics (s), soil fertility (f) and soil salinity/alkalinity (n). The suitability classes and sub-classes are decided by the most limiting soil characteristics (Table 3).

Pedon 1, which is grouped under Typic Haplustepts, is found to be temporarily not suitable for all the five crops *viz.*, rice, cotton, chickpea, tobacco and sorghum. The major limitations are wetness, soil physical characteristics (soil depth), $CaCO_3$ content and soil fertility characteristics (pH and organic carbon) and alkalinity. pH is the major limiting factor for all the five crops. $CaCO_3$ content is severe limiting factor for tobacco. Organic carbon content and soil depth are also major limiting factors, for all the five crops. Organic carbon status in these soils can be improved by the application of farmyard manures, green manuring and inclusion of legumes in the crop rotations which also help in reducing adverse effects of high $CaCO_3$ content and high pH of these soils.

Pedon 2 is grouped under Typic Haplusterts which is temporarily not suitable for all the five crops *viz.*, rice, cotton, chickpea, tobacco and sorghum. These soils showed limitations *viz.*, wetness (drainage), physical soil characteristics (depth), $CaCO_3$ content and soil fertility characteristics (pH and organic carbon). Pedon 3, which is grouped under Lithic Ustorthents, is moderately suitable for sorghum, marginally suitable for tobacco. However, it is permanently not suitable for rice, cotton and chickpea, with the severe limitations of wetness (for rice) and soil depth. The limitations in general for crop growth include wetness (for rice), physical soil characteristics (soil depth and texture, except for sorghum), $CaCO_3$ content and soil fertility characteristics (organic carbon and pH).

Pedon 4, which is grouped under Typic Haplustepts is temporarily not suitable for rice and is permanently not suitable for other four crops viz., cotton, chickpea, tobacco and sorghum due to the very severe limitations of wetness and soil depth. The major limitations of the pedon, in general, include wetness (for rice), physical soil characteristics (soil depth and texture), $CaCO_3$ content and soil fertility characteristics such as pH and organic carbon for all the crops. Pedon 5, which is grouped under Typic Haplustepts is moderately suitable for sorghum and marginally suitable for cotton and chickpea, temporarily not suitable for tobacco and permanently not suitable for rice. The very severe limitation of wetness makes this soil permanently not suitable for rice. The limitations, in general, include wetness, physical soil characteristics (soil depth and texture), $CaCO_3$ content and soil fertility characteristics (pH and organic carbon). Similar findings were reported by Satyavathi and Suryanarayan Reddy (2004) [6] in the Telangana region of Andhra Pradesh.

Pedon 6, grouped under Lithic Ustorthents, is moderately suitable for sorghum, temporarily not suitable for tobacco and permanently not suitable for rice, cotton and chickpea. Wetness is the major limitation for growing rice, while soil depth is the major limitation for growing cotton and chickpea in this soil. The other limitations for growing these crops are physical characteristics (soil depth and texture), $CaCO_3$ content and soil fertility characteristics (organic carbon and pH). The pedon 7, which is classified under Typic Haplustepts, is moderately suitable for sorghum while marginally suitable for other crops *viz.*, rice, cotton, chickpea and tobacco. The limitations are wetness (drainage), physical soil characteristics (soil depth and texture), $CaCO_3$ content, soil fertility characteristics (organic carbon and pH) and alkalinity.

The pedon 7 is marginally suitable, pedons 1, 2 and 4 are temporarily not suitable and pedons 3, 5 and 6 are permanently not suitable for rice cultivation. Studies conducted by Leelavathi *et al.* (2010) [7] and Selvaraj and Naidu (2013) [8] also revealed that the soils of Yerpedu and Renigunta mandals in Chittoor district, respectively were marginally suitable (S3) for growing rice. The pedons 5 and 7 are marginally suitable; pedons 1 and 2 are temporarily not suitable, while the pedons 3, 4 and 6 are permanently not suitable for growing cotton crop. Patil *et al.* (2010) [9] and Garhwal *et al.* (2013) [10] also reported that soils in Lendi watershed of Chandrapur district in Maharashtra and Sirohi district in Rajasthan, respectively were moderately suitable (S2) for cotton cultivation.

The pedons 5 and 7 are marginally suitable, the pedons 1 and 2 are temporarily not suitable, while pedons 3, 4 and 6 are permanently not suitable for chickpea crop. Studies by Garhwal *et al.* (2013) [10] also revealed that the soils of Sirohi district of Rajasthan were marginally suitable (S3) for chickpea crop. Pedons 3 and 7 are marginally suitable; pedons

1, 2, 5 and 6 are temporarily not suitable, while the pedon 4 was permanently not suitable for growing tobacco. The pedons 3, 5, 6 and 7 are moderately suitable; pedons 1 and 2 are temporarily not suitable, while the pedon 4 is permanently not suitable for growing sorghum. Geetha Sireesha and Naidu (2013) [11] also reported that the soils of Banaganapalle mandal in Kurnool district of Andhra Pradesh were marginally suitable for growing sorghum.

Major limitations observed in the study area are wetness (drainage), soil depth, $CaCO_3$ content, organic carbon content and pH in all the pedons. Poor drainage and water holding conditions can be improved by soil conservation measures, growing leguminous crops in rotation and application of organic manures. Soils with shallow depth can be improved by deepening of soil by ridging, deep ploughing / breaking up the soil crust or contour bunding and contour farming and / or adoption of careful soil and water management practices. Organic carbon content in these soils can be improved by incorporation of crop residues or application of farm yard manure / compost / press mud or green manuring with legumes and / or inclusion of legumes in crop rotation. The high pH of these soils can be reduced by application of organic manures and soil amendments like sulphur / press mud / spent wash.

High calcium carbonate content is found in all the pedons which leads to fixation of P and Zn that can limit crop production. Application of organic manures such as FYM or compost or vermicompost or green manuring with legumes reduce the P and Zn fixation in soil by formation of organo-Zn and organo-P complexes. The acids produced during decomposition of these organic manures also solubilize $CaCO_3$ and decrease its content in the soil. Soil texture is found to be a limiting factor in pedons 3, 4, 5, 6 and 7. Heavy textured soils can be improved by cultivation with precautions against further damage like bunding / adoption of broad bed and furrow method of cultivation. Agronomic measures like crop rotation / mixed cropping / growing leguminous crops in rotation or application of organic manures or organic mulches, which add organic matter to the soil, not only improve the drainage condition of the soils but also reduce runoff and soil erosion. Alkalinity is found to be a limiting factor in the pedons 1 and 7. Alkalinity (high ESP) in the soils can be reduced by addition of gypsum or green manuring with dhaincha, which reduce the alkalinity problem there by increasing availability of nutrients to the crops.

Table 1: Details of selected pedons and their relevant soil characteristics

Pedon No.	Location	Depth (cm)	Physical characteristics (s)				Fertility characteristics (f)					Salinity and alkalinity (n)	
			Texture			$CaCO_3$ (%)	CEC (cmol(p^+) kg^{-1} soil)	BS (%)	Sum of basic cations (cmol (p^+) kg^{-1} soil)	pH (1:2.5) H_2O	OC (g kg^{-1})	ECe (dSm^{-1})	ESP
			Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)								
			--------% of <2 mm soil--------										
		Fine, smectitic, isohyperthermic Typic Haplustept											
P1	Gundlasamudram	0.00-0.11	37.79	15.12	47.09	10.54	50.12	86.07	42.78	9.35	0.65	0.06	14.68
		0.11-0.20	37.99	19.15	42.86	10.90	52.09	87.04	43.78	9.53	0.58	0.06	14.51
		0.20-0.32	37.72	13.02	49.26	11.86	53.85	86.41	44.55	9.56	0.39	0.05	14.52
		Fine, smectitic, isohyperthermic Typic Haplustert											
P2	Vallaipalem	0.00-0.08	50.70	14.52	34.78	10.37	14.35	61.95	8.33	9.86	0.36	0.82	0.49
		0.08-0.32	48.11	13.04	38.85	11.16	31.72	63.21	18.63	9.88	0.26	1.32	0.57
		0.32-0.47	48.52	11.28	43.20	11.34	40.37	62.47	25.12	9.86	0.22	1.32	0.54
		0.47-0.64	41.32	13.20	45.48	11.45	46.07	84.83	40.76	10.00	0.23	0.95	1.65
		0.64-0.81	36.17	16.55	47.28	11.72	43.38	88.75	37.22	9.87	0.19	1.38	1.43
		0.81-1.10	35.26	17.73	47.01	11.86	33.87	88.84	28.97	9.82	0.16	1.26	1.54
		Fine-loamy, smectitic, isohyperthermic Lithic Ustorthent											
P3	Pedda alavalapadu	0.00-0.09	55.96	9.74	34.30	5.42	16.16	81.56	12.98	7.68	0.58	0.05	1.11
		0.09-0.20	40.33	23.32	36.35	6.86	36.58	92.78	32.58	7.86	0.43	0.06	0.63
		Fine, mixed, isohyperthermic Typic Haplustept											
P4	Vijayalaxmipuram	0.00-0.10	62.61	11.54	25.85	14.52	10.05	85.37	8.14	10.48	0.58	0.04	3.38
		0.10-0.28	44.74	20.12	35.14	15.26	14.49	82.40	11.52	10.44	0.39	0.04	2.21
		0.28-0.43	41.07	22.62	36.31	17.64	16.26	80.38	12.67	10.09	0.34	1.04	1.66
		Fine-loamy, smectitic, isohyperthermic Typic Haplustept											
P5	Rajupalem	0.00-0.13	77.33	6.85	15.82	10.35	15.87	85.34	14.53	8.31	0.97	0.06	3.65
		0.13-0.33	60.48	14.75	24.77	10.71	17.28	86.51	15.86	8.09	0.63	0.06	4.11
		Fine-loamy, smectitic, isohyperthermic Lithic Ustorthent											
P6	Gangapalem	0.00-0.10	64.35	9.14	26.51	10.12	17.03	87.18	15.82	7.91	0.19	0.09	4.52
		0.10-0.20	61.16	9.48	29.36	11.54	17.38	91.19	15.94	8.02	0.14	0.20	4.72
		Fine, smectitic, isohyperthermic Typic Haplustept											
P7	Bakkireddipalem	0.00-0.10	68.78	7.65	23.57	8.66	10.05	85.47	8.17	7.65	0.26	0.27	4.18
		0.10-0.26	58.38	8.68	32.94	7.53	9.14	80.74	6.72	7.63	0.21	0.22	7.22
		0.26-0.46	51.94	9.17	38.89	8.92	28.12	65.47	17.49	7.92	0.18	0.36	3.27

Table 2: Site characteristics and weighted means of soil characteristics of the selected profiles

Pedon	landform	Wetness (w) Drainage	Soil depth (cm)	$CaCO_3$ (%)	Apparent CEC (cmol (p^+) kg^{-1} clay)	BS (%)	pH (1:2.5)	OC (g kg^{-1})	ECe (dSm^{-1})	ESP
P1	Upland	Well drained	32	11.14	111.76	52.07	12.13	0.57	0.06	14.68
P2	Plain	Imperfectly drained	110	11.40	79.90	77.06	9.87	0.33	1.22	1.65
P3	Upland	Well drained	20	6.21	76.55	87.93	7.78	0.40	0.06	1.11
P4	Upland	Well drained	43	15.92	41.92	82.38	10.46	0.47	0.39	3.38
P5	Upland	Well drained	33	10.57	81.80	86.04	8.20	0.81	0.06	4.11
P6	Upland	Well drained	20	10.83	61.72	89.18	7.97	0.17	0.15	4.72
P7	Plain	Moderately well drained	46	8.38	50.36	75.12	7.64	0.23	0.29	7.22

Topography (slope) (t): <5%

Flooding: F0; Climate (c): Semi-arid monsoonic

Table 3: Limitation levels of the soil characteristics in the study area and land suitability classes for the five major crops

Pedon	Crop	Wetness (w) Drainage	Physical soil characteristics (s)				Soil fertility characteristics (f)			Alkalinity (n)	Actual land suitability subclass	Potential land suitability subclass
			Texture	Coarse Fragments (vol. %)	Soil depth (cm)	$CaCO_3$ (%)	Apparent CEC (cmol (p^+) kg^{-1} clay)	pH (1:2.5)	OC (g kg^{-1})	ESP		
P1	Rice	2	0	0	3	2	0	4	3	1	N1wsfn	S3ws
	cotton	3	0	0	3	1	0	4	3	0	N1 wsf	S3ws
	chickpea	2	0	0	3	1	0	4	3	3	N1wsfn	S3ws
	tobacco	2	0	0	3	4	0	4	3	2	N1wsfn	S3ws
	sorghum	2	0	0	2	0	0	4	2	1	N1wsfn	S2ws
P2	Rice	2	0	0	0	2	0	4	3	0	N1wf	S2w
	cotton	3	0	0	0	1	0	4	2	0	N1wf	S3w
	chickpea	2	0	0	0	1	0	4	3	0	N1wf	S2w
	tobacco	2	0	0	1	4	0	4	3	0	N1wsf	S2w
	sorghum	2	0	0	0	0	0	4	2	0	N1wf	S2w
P3	Rice	4	3	0	3	2	0	1	3	0	N2wsf	N2ws
	cotton	0	1	0	4	0	0	2	1	0	N2sf	N2s
	chickpea	0	1	0	4	0	0	2	3	0	N2sf	N2s
	tobacco	0	1	0	3	3	0	3	3	0	S3sf	S3s
	sorghum	0	0	0	2	0	0	1	1	0	S2sf	S2s
P4	Rice	1	2	0	3	3	0	4	3	0	N1wsf	S3s
	cotton	4	2	0	3	1	0	4	1	0	N2wsf	N2ws
	chickpea	4	1	0	3	1	0	4	3	0	N2wsf	N2ws
	tobacco	4	1	0	3	4	0	4	3	0	N2wsf	N2ws
	sorghum	4	1	0	2	0	0	4	1	0	N2wsf	N2ws
P5	Rice	4	2	0	3	2	0	1	2	0	N2wsf	N2ws
	cotton	0	2	0	3	1	0	3	0	0	S3sf	S3s
	chickpea	0	1	0	3	1	0	3	2	0	S3sf	S3s
	tobacco	0	1	0	3	4	0	4	2	0	N1sf	S3s
	sorghum	0	1	0	2	0	0	1	0	0	S2sf	S2s
P6	Rice	4	2	0	3	2	0	1	3	0	N2wsf	N2ws
	cotton	0	2	0	4	1	0	2	2	0	N2sf	N2s
	chickpea	0	1	0	4	1	0	2	3	0	N2sf	N2s
	tobacco	0	1	0	3	4	0	4	3	0	N1sf	S3w
	sorghum	0	1	0	2	0	0	1	2	0	S2sf	S2s
P7	Rice	3	2	0	3	2	0	1	3	0	S3wsf	S3ws
	cotton	2	2	0	3	0	0	2	2	0	S3wsf	S3ws
	chickpea	1	1	0	3	0	0	2	3	1	S3wsfn	S3s
	tobacco	1	1	0	3	3	0	3	3	1	S3wsfn	S3s
	sorghum	1	1	0	2	0	0	1	2	0	S2wsf	S2s

Limitations: 0 – no slight; 1 – slight; 2 – moderate; 3 – severe; 4 – very severe

Suitability sub-classes: f-soil fertility limitations; s-physical soil limitations; w-wetness limitations; n-salinity (and/or alkalinity) limitations

Conclusion

Crop suitability of soils in the central parts of Prakasam district ranged from moderately suitable (S2) to permanently not suitable (N2) for the major crops *viz.*, rice, cotton, chickpea, tobacco and sorghum. Limitations observed in these soils for crop production were wetness, physical characteristics like soil depth and texture, high $CaCO_3$ content and fertility characteristics like high pH, low organic carbon content and alkalinity. Remedial measures are also suggested to improve these soils to achieve their potential productivity levels without deteriorating the soil quality and to sustain crop yields.

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