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Characterization and Classification of Pigeon Pea Growing Soils and their Land Suitability for Hot Semiarid Deccan Plateau, India

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ABSTRACT

Background: Semiarid lands possess limitations of climate such as low and erratic rainfall, long dry spell, high potential evapotranspiration and lesser length of growing period which directly influence the yield and productivity of crop along with the soil properties. Pigeon pea, being one of the most dominant pulse crops cultivated in the semiarid Deccan plateau, an understanding on the soils where pigeon pea is mainly grown and the evaluation of their land suitability was found to be essential.

Methods: Land resource inventory at 1:10,000 scale was carried out in Mahabubnagar Rural mandal, Mahabubnagar district, Telangana state of South Deccan plateau to characterize the major pigeon pea growing soils and their land suitability evaluation.

Result: When the entire study area was evaluated for its suitability, majority of the area (32.79%) was marginally suitable, followed by moderately suitable area (16.24%) with moderate to severe limitations of nutrient availability, rooting conditions, gravelliness and texture and a very small area of 5.55 per cent was found to be highly suitable towards the crop. Out of the 18 soil series identified, only five were the major pigeon pea soils which were mostly marginally suitable (S3) with limitations of nutrient availability, slope, effective root depth and texture. Though the climatic characteristics of the area were highly favourable to the crop classified under the highly suitable class (S1), rooting conditions, nutrient availability and slope were the major limitations towards the cultivation and productivity of pigeon pea.

Key words: Characterization, Classification, Deccan plateau, Pigeon pea, Semiarid.

INTRODUCTION

India ranks first in the area and production of pigeon pea or red gram (*Cajanus cajan* L.) in the world. It is one of the important pulse crops in the semiarid tropics of India. In Telangana, pigeon pea is grown in an area of 2.75 lakh ha. In Mahabubnagar district, pigeon pea is cultivated in a total area of 82,000 ha, out of which *Kharif* season covers an area of 66,000 ha. Being the major *Kharif* pulse crop of the country, the variations in rainfall and soil characteristics determine the crop productivity (Sehgal, 1991). An understanding of potentials and constraints of the soils is essential to evaluate the suitability of the soils towards pigeon pea to increase its productivity. This involves characterizing the major soils of the study area, where crop is grown. Low productivity in pigeon pea has resulted from climatic aberrations, poor soil fertility and management practices and various socio-economic constraints (Sankar *et al.*, 2007).

Several studies reported land suitability evaluation for different legume crops such as chickpea (Meena *et al.*, 2012); pigeon pea (Hegde *et al.*, 2018) and groundnut (Savalia and Gundalia, 2009 and 2010). Pigeon pea is recognized as highly resistant to drought and thrives well in areas with 650 cm of rainfall and requires warm, moist weather during germination (30-35°C), 20-25°C during active growth,15-18°C for flowering and pod setting and 35-40°C at maturity (Naidu *et al.*, 2006). Very deep, well drained soils of sandy loam to clay loam texture, pH 6.0-7.5, free from soluble salts (EC<1.0 dSm^{-1}), ESP (<10) and erosion hazards (slope<3%) are found to be highly suitable for growing pigeon pea (Naidu *et al.*, 2006). The semiarid conditions prevailing in the study area, resulting in the climatic variations of mean annual rainfall and temperature could affect the performance of crop (Sankar *et al.*, 2007). Hence, it becomes necessary to characterize the soils, in which the crop is grown to evaluate and identify the suitable areas to grow pigeon pea. Thus this study was carried out with the objectives 1) to characterize the major pigeon pea-growing soils of the area 2) to evaluate soil site suitability towards pigeon pea in the study area.

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MATERIALS AND METHODS

Description of the study area

The study area Mahabubnagar Rural mandal belongs to AESR 7.2: North Telangana Plateau, hot, moist, semiarid agro-eco-sub region; lies between 77° 49′ 43.133″ to

77° 59′ 33.183″ E longitudes and 16° 38′ 31.415″ to 16° 46′ 21.897″ N latitudes. Total area of the mandal is 14,497 ha, with an average annual rainfall of 613.3 mm, average temperature ranges between 16°C and 34°C and length of dry period is 31 weeks. The total potential evapotranspiration (PET) of the area is about 1806.3 mm, which is much higher than the amount of rainfall received in the area.

Soil survey and mapping

The detailed soil survey of the mandal was carried out in the year by using remote sensing data products from Sentinel 2 merged at the scale of 1:10,000 in conjunction with the topo sheets. A total of 114 soil profiles were studied in detail for all their morphological and physical characteristics. Based on these, the soils were grouped into 18 different soil series and mapped into 66 mapping units, which are phases of soil series. The soils were classified according to the keys to soil taxonomy (Soil Survey Staff, 1999).

Soil sampling and laboratory analysis

Horizon-wise soil samples were collected and analyzed using standard procedures for soil morphological, physical and chemical parameters. Cation exchange capacity (CEC) and other soil chemical parameters were determined using standard analytical techniques (Jackson, 1958).

Soil site suitability evaluation

Soil-site suitability for pigeon pea was evaluated based on the criteria given by Naidu *et al.* (2006). The mapping units were designated as S1 (Highly suitable), S2 (Moderately suitable with moderate limitations); S3 (Marginally suitable with severe limitations) and N (Currently not suitable).

RESULTS AND DISCUSSION

Characterization and classification of the major pigeon pea growing soils in the study area

Among the 18 soil series identified in the mandal, five series were the major pigeon pea growing soils. These soils include the series Gajulapet (GA), Manikonda1 (MA1), Manikonda2 (MA2) Potanpalle2 (PO2) and Kodur series (KO).

Morphological characteristics

The depth varied from shallow to very deep among the major soils. Gajulapet soils were shallow (25-50 cm), Manikonda1 soils were moderately shallow (50-75 cm), Manikonda2 and Potanpalle2 soils were deep (100-150 cm) and Kodur soils were very deep (>150 cm). The dominant soil colour was having a hue of 10 YR in all the soils series with its value ranging from 3 to 5 and chroma varying from 1 to 4 except Gajulapet. Gajulapet soils were dark brown (7.5 YR4/3 M), in the surface and yellowish red (5 YR4/6 M) in the subsurface. Soil colour depends on the mineral composition and changes in soil coating (Schaetzl and Anderson, 2005). Dominant soil texture was sandy clay loam, which resulted due to the process of soil formation and the dominant structure was moderate subangular blocky which was well developed due to high clay content (Verma *et al.*, 2012). Soil consistency varied from firm, friable, slightly sticky to very sticky, non plastic to very plastic. With increase in clay content, soil consistency also increased as evident from Table 1 and 2. Soil consistency is influenced by the clay content of the soil (Sarkar *et al.*, 2001), organic matter and soil texture (Wani *et al.*, 2016).

Physico-chemical characteristics

Clay increase was evident in all the soils indicating the process of clay illuviation (Sarkar *et al.*, 2002). In Manikonda2 and Potanpalle2 soils, there was a clay increase towards the depth which later decreased at the deeper layers due to the influence of parent material and also the less active pedogenic processes. Surface pH varied from slightly acid (6.19) in Manikonda1 soils to moderately alkaline (8.06) in Manikonda2 soils. Surface CEC was low (9.77 cmol (+) kg^{-1}) in MA1 to 18.76 cmol (+) kg^{-1} in MA2 soils. These low CEC values indicate the dominance of low activity clays. In general, CEC followed a similar trend of clay content in soils. Base saturation was very high (100%) in the MA2 and PO2 series, which could be due to higher Ca^{+} occupying exchange sites on the colloidal complex (Sireesha and Naidu, 2013). Exchangeable sodium percentage (ESP) was recorded in all the soils, however it was <10%, posing no hindrance to growing pigeon pea. Calcium carbonate equivalent was not recorded in GA and MA1 soils.

Soil classification

The soils were classified based on soil taxonomy (USDA). The temperature and moisture regimes are isohyperthermic and ustic respectively in the study area. Gajulapet and Manikonda1 series were classified as *Alfisols*, with argillic sub-surface horizon and hence keyed out to *Haplustalfs* at great group level and to *Typic Haplustalfs* at sub-group level. Manikonda2 and Potanpalle2 series were classified as *Inceptisols* order and as *Haplustepts* at great group level. Manikonda2 series was keyed out as fine-loamy, smectitic, superactive, *Typic Haplustepts* and Potanpalle2 series was a member of fine-loamy, smectitic, superactive, *Aquic Haplustepts*, as redox depletions with chroma of 2 or less and also aquic conditions for some time in normal years (or artificial drainage) were observed in one or more horizons within 75 cm of the mineral soil surface. The particle size class was fine-loamy as the particles in the fine-earth fraction,18 to less than 35 per cent (by weight) of clay and mineralogy class was smectitic due to the dominant smectite minerals by weight, than any other single kind of clay mineral. The CEC class was superactive due to a higher CEC: clay ratio of 0.60 or more. Kodur series was classified as a member of fine-loamy, smectitic, superactive, isohyperthermic family of *Vertic Haplustepts.* Due to the presence of pressure faces in a layer 15 cm or more thick that has its upper boundary within 125 cm of the mineral soil surface these soils were classified as *Vertic Haplustepts*.

Land suitability evaluation

The soils of the study area were classified to 18 soil series

Table 1: Morphological characteristics of major pigeon pea growing soils in the study area.

Horizon	Depth (cm)	Boundary	Moist colour	Texture	Structure	Consistency	Gravel (%)	Roots	Pores
				Gajulapet series					
Ap	0-18	c s	7.5YR 4/3	vgscl	2 M sbk	h fr ss sp	45	c m	
Bt1	18-34	g s	5YR 4/6	egscl	2 M sbk	fi ms mp	70	f f	
Cr	34-54								
				Manikonda1 series					
Ap	0-17	a s	10 YR 3/4	g sl	1 M sbk	sh vfr s0 p0	20	f vf	c m
Bt1	17-42	g s	10 YR 3/4	g scl	2 M sbk	fr ss sp	35	f vf	c f
Bt2	42-70	-	10 YR 3/4	g scl	2 M sbk	fr ss sp	30		c f
Cr									
				Manikonda2 series					
Ap	0-29	c s	10 YR 4/2	scl	1 F sbk	l vfr ms vp		c f	c f
Bw1	29-59	c w	10 YR 4/2	scl	2 M sbk	fr ms vp		f vf	f f
Bw2	59-87	c s	10 YR 4/2	scl	2 M sbk	fr ms mp		f vf	f f
Bw3	87-135	c s	10 YR 4/2	scl	3 M sbk	fr ms mp			f f
Bw4C	135+		10 YR 5/4	vg scl	2 M sbk	fr ms mp	70		f f
Cr									
				Potanpalle2 series					
Ap	0-13	a s	10 YR 3/3	sl	1 M sbk	sh fr ms mp	15	m vf, m f	m f
Bwk1	13-43	g s	10 YR 4/2	scl	2 M sbk	fr ms mp	15	c f	c f
Bwk2	43-72	g s	10 YR 4/2	scl	2 M sbk	fr ms mp		f f	c f
Bwk3	72-96	g s	10 YR 4/2	scl	2 M sbk	fr ms mp		f f	c f
Bwk4	96-125		10 YR 4/2	scl	2 M sbk	fr ms mp			c f
				Kodur series					
Ap	0-13	c s	10 YR 4/2	scl	2 M sbk	h fr ms mp		m vf, m f	m c
Bw1	13-30	g s	10 YR 3/2	scl	3 M sbk	h fi vs vp		m vf, m f	m f
Bw2	30-56	g s	10 YR 3/1	scl	2 M sbk	fi vs vp		f f	m f
Bw3	56-91	g s	10 YR 3/1	gscl	2 M sbk		30	f f	m f
Bw4	91-122	g s	10 YR 4/2	cl	2 M sbk				m f
Bw5	122-148		10 YR 4/2	cl	2 M sbk				m f

c: clear; g: gradual; s: smooth; w: wavy; g: gravelly; vg: very gravelly; eg: extremely gravelly; scl: sandy clay loam; sl: sandy loam, sc: Sandy clay, M: Medium, F: Fine; sbk: subangular blocky; h: hard; sh: slightly hard; fr: friable; fi: firm; s0: non sticky; ss: slightly sticky; ms: moderately sticky; vs: very sticky; p0: non plastic; sp: slightly plastic; mp: moderately plastic; vp: very plastic; cm: common medium; cvf: common very fine; cf: common fine; ff: few fine; fvf: few very fine; mf: many fine; mvf: many very fine.

and 66 mapping units of phases of soil series. Of these, the major pigeon pea growing soils were mapped to 19 units of only five soil series which were characterized and discussed in this study. The GA and KO soils have 5 and MA1, MA2 and PO2 have 3 phases each. The details of these phases are given in Table 3 and the land suitability for pigeon pea (Fig 1) and management interventions needed in Mahabubnagar Rural mandal is given in Table 4.

The study area has a mean temperature of 27°C and rainfall of 530.8 mm during the growing season and LGP of 147 days. These confirm to the suitability of climate in the region towards pigeon pea, though the average annual rainfall was 613.3 mm, which was only moderately suitable. When the major pigeon pea growing soils were evaluated for their suitability to grow the crop, it was found that the dominant class was marginally suitable with limitations of rooting conditions, followed by texture and nutrient availability due to higher soil pH. Effective soil depth of less than 40 cm is considered as not suitable and 40-75 cm is marginally suitable class (Naidu *et al*., 2006). Gajulapet soils were shallow (25-50 cm) and Manikonda1 soils were moderately shallow (50-75 cm), where depth was the major rooting limitation. In these soils, it is better to choose shallow rooting varieties or adopt growing alternative crops. Manikonda2 soils were found to be marginally suitable with limitations of nutrient conditions especially because of the soil pH greater than 8.0 and were designated to S3n. A soil pH between 7.9 and 9.0 is marginally suitable class (Naidu *et al*., 2006). Potanpalle2 soils had two phases which were moderately suitable with limitations of erosion and nutrient availability (S2en) and the phase PO2iB2 was evaluated to marginally suitable class with limitations of nutrient availability (S3n). To manage alkalinity and thereby to improve nutrient availability, application of gypsum may be

Table 2: Physico-chemical properties of major pigeon pea growing soils in the study area.

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	pH (1: 2.5)	CEC [c mol (+) kg^{-1}]	BS by sum of cations (%)	ESP (%)	CCE	CEC/ Clay
Gajulapet series: Loamy-skeletal, mixed, active, isohyperthermic family of *Typic Haplustalfs*.										
Ap	0-18	65.82	7.70	26.48	8.05	15.54	61	2.24	0.00	0.59
Bt1	18-34	61.29	6.24	32.47	8.11	18.09	64	4.27	0.00	0.56
Cr	34-54					15.54	61	2.24	0.00	0.59
Manikonda1 series: Fine-loamy, mixed, superactive, isohyperthermic family of *Typic Haplustalfs*.										
Ap	0-17	75.48	10.42	14.10	6.19	9.77	65	0.22	0.00	0.69
Bt1	17-42	57.96	7.34	34.70	5.99	21.65	63	0.59	0.00	0.62
Bt2	42-70	53.53	11.80	34.67	7.03	21.31	74	1.00	0.00	0.61
Cr										
Manikonda2 series: Fine-loamy, smectitic, superactive, isohyperthermic family of *Typic Haplustepts*.										
Ap	0-29	65.18	12.77	22.05	8.06	18.76	100	1.55	7.08	0.85
Bw1	29-59	64.79	12.19	23.02	8.56	16.98	100	3.94	4.68	0.74
Bw2	59-87	62.89	11.09	26.02	8.59	20.00	100	3.95	4.68	0.77
Bw3	87-135	61.18	7.27	31.55	8.60	23.86	100	5.97	4.68	0.76
Bw4C	135+	64.13	12.16	23.71	8.84	22.42	100	5.73	10.92	0.95
Cr										
Potanpalle2 series: Fine-loamy, smectitic, superactive, isohyperthermic family of *Aquic Haplustepts*.										
Ap	0-13	68.65	13.09	18.26	7.71	15.10	100	0.20	2.68	0.83
Bwk1	13-43	54.40	15.87	29.73	8.02	20.76	100	0.47	7.40	0.70
Bwk2	43-72	53.92	16.44	29.64	8.18	21.09	100	0.83	9.16	0.71
Bwk3	72-96	57.98	15.37	26.65	8.25	19.43	100	2.12	6.52	0.73
Bwk4	96-125	56.82	16.64	26.54	8.47	17.43	100	4.48	4.24	0.66
Kodur series: Fine-loamy, smectitic, superactive, isohyperthermic family of *Vertic Haplustepts*										
Ap	0-13	58.68	15.65	25.67	7.71	17.43	100	0.61	2.44	0.68
Bw1	13-30	49.74	19.15	31.11	8.10	24.41	100	2.05	2.08	0.78
Bw2	30-56	53.89	17.45	28.66	8.29	22.46	100	3.18	1.84	0.78
Bw3	56-91	48.69	20.79	30.52	8.19	22.36	100	3.48	2.80	0.73
Bw4	91-122	38.17	23.13	38.70	8.11	26.20	100	2.91	3.04	0.68
Bw5	122-148	39.63	21.80	38.57	8.21	26.53	100	2.37	4.36	0.69

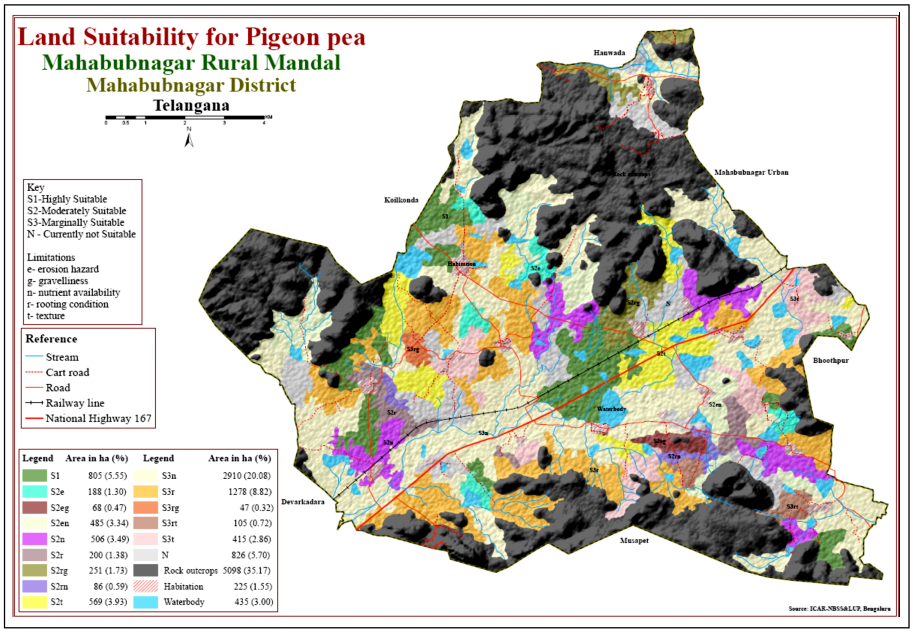


Fig 1: Land suitability for pigeon pea in Mahabubnagar Rural mandal.

Table 3: Mapping units of major pigeon pea growing soils in the study area and their suitability class.

Series name	Depth (cm)	Phases of series	Mapping units	Surface texture	Slope %	Gravel -liness	Drainage	Erosion	Area (ha)	Area (%)	Suitability class
Gajulapet	25-50	GAbC3g1	11	ls	3-5	gravelly	WD	severe	797	5.49	S3rt
		GAcB1g1	12	sl	1-3	gravelly	WD	slight			S3r
		GAcC2	13	sl	3-5		WD	moderate			S3r
		GAhB3	14	scl	1-3		WD	severe			S3r
		GAiB2g1	15	sc	1-3		WD	moderate			S3r
Manikonda1	50-75	MA1cC3g1	23	sl	3-5	gravelly	WD	severe	456	3.15	S3r
		MA1iB2	24	sc	1-3		WD	moderate			S3r
		MA1mC2	25	c	3-5		WD	moderate			S3r
Manikonda2	100-150	MA2hB1	37	scl	1-3		MWD	slight	346	2.39	S3n
		MA2iB1	38	sc	1-3		MWD	slight			S3n
		MA2mB1	39	c	1-3		MWD	slight			S3n
Potanpalle2	100-150	PO2cC3	40	sl	3-5		MWD	severe	198	1.37	S2en
		PO2iB2	41	sc	1-3		MWD	moderate			S3n
		PO2iC2	42	sc	3-5		MWD	moderate			S2en
Kodur	>150	KOhB1	48	scl	1-3	-	WD	slight	962	6.63	S1
		KObB2	49	ls	1-3		MWD	moderate			S1
		KOiB1	50	sc	1-3		WD	slight			S1
		KOiB2	51	sc	1-3		WD	moderate			S2n
		KOmB1	52	c	1-3		MWD	slight			S2t
Total									2759	19.03	

ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; WD: Well drained; MWD: moderately well drained, S1: Highly suitable; S2: Moderately suitable; S3: Marginally suitable; r: rooting conditions; t: texture; e: erosion; n: nutrient availability.

Table 4: Land suitability and the management strategies for pigeon pea in the study area.

Mapping unit no.	Suitability classes	Description	Area (ha)	Area (%)	Limitations	Management strategies
18,21,35,48, 49,50,55	S1	Highly suitable lands.	805	5.55	No limitations	Soil test based integrated nutrient management and choice of high yielding varieties.
17,19,34	S2e	Moderately suitable lands with slight limitation of erosion hazards.	188	1.30	Slope Gravelliness	Water conservation measures to control soil erosion related constraints.
22	S2eg	Moderately suitable lands with slight limitations of erosion hazards and gravelliness	68	0.47	Nutrient availability (soil pH)	Opening up of dead furrows perpendicular to the slope for *in situ* water conservation.
36,40,42,64	S2en	Moderately suitable lands with slight limitations of erosion hazards and nutrient availability.	485	3.34	Rooting conditions (Effective rooting depth)	Choosing shallow rooting varieties pattern with more feeder roots to survive in shallow soils or growing alternative crops such as minor millets or green gram.
37,45,51,53	S2n	Moderately suitable lands with slight limitation of nutrient availability.	506	3.49	Texture	Application of gypsum to ameliorate the high pH of soils for better nutrient availability.
30	S2r	Moderately suitable lands with slight limitations of rooting conditions.	200	1.38		
2, 3	S2rg	Moderately suitable lands with slight limitations of rooting conditions and gravelliness.	251	1.73		

Table 4: Continue...

Table 4: Continue...

32	S2rn	Moderately suitable lands with slight limitations of rooting conditions and nutrient availability.	86	0.59		
47,66	S2t	Moderately suitable lands with slight limitation of texture.	569	3.93		
31, 33, 38, 39, 41, 44, 46, 52, 56, 57, 58, 59, 60, 61, 62, 63, 65	S3n	Marginally suitable lands with slight limitation of nutrient availability.	2910	20.08	Nutrient availability (soil pH)	Application of gypsum to ameliorate the high pH of soils for better nutrient availability.
7, 9, 10, 12, 13, 23, 24, 25	S3r	Marginally suitable lands with slight limitation of rooting conditions.	1278	8.82	Rooting conditions	Growing alternative crops such as minor millets or green gram.
8	S3rg	Marginally suitable lands with slight limitations of rooting conditions and gravelliness.	47	0.32	Gravelliness Texture	
11	S3rt	Marginally suitable lands with slight limitations of rooting conditions and texture.	105	0.72		
6,16,20,43	S3t	Marginally suitable lands with slight limitation of texture.	415	2.86		
1, 4, 5, 14, 15, 26, 27, 28, 29, 54	N (S2*)	Currently not suitable.	826	5.70		The major limitations here are the slope and shallow depth of soils. *This can be overcome by proper management strategies such as soil and water conservation measures and choice of dwarf pigeon pea varieties having shallow rooting characteristics and this class could be converted to moderately suitable lands.
Total			8739	60.28		
Rock outcrops			5098	35.17		
Habitation			225	1.55		
Water body			435	3.00		
Total geographical area			14497	100.00		

carried out. The very deep soils of Kodur had five phases of which KOhB1, KObB2, KOiB1 were found to be highly suitable towards growing pigeon pea.

Only a very small area of 5.55 per cent was highly suitable for the crop in the entire study area. These soils were deep to very deep, with sandy clay loam or sandy loam horizons and well drained providing better infiltration, ensuring better availability of water and nutrients to crop. It was found that 16.24 and 32.79 per cent of total geographical area was moderately and marginally suitable respectively with limitations of erosion hazards, gravelliness, nutrient availability, rooting conditions and texture and 5.70 per cent of total area was found currently not suitable. Productivity of the crop is affected by soil slope, gravelliness and effective rooting depth (Shivaramu, 2012). The limitations of rooting conditions mainly are due to shallow soils, which could be managed either by choosing shallow rooted dwarf pigeon pea varieties with better anchorage and more feeder roots, or by choosing alternative crops such as minor millets or crops such as green gram (Ramamurthy *et al.*, 2019). Limitations due to slope and erosion can be managed by adopting proper soil and water conservation measures

in situ. This could include opening up dead furrows perpendicular to the slope or contour trench cum bunding. By adopting proper management strategies productivity of pigeon pea could be improved for sustained use.

CONCLUSION

Major pigeon pea growing soils of Mahabubnagar Rural mandal of semiarid Deccan plateau belonged to the orders *Alfisols* and *Inceptisols*. These five major pigeon pea growing soils were evaluated for the suitability towards growing pigeon pea and only Kodur soil series had phases that were highly suitable for growing of crop. Other soils were mostly marginally suitable for cultivation of crop.It was found that rooting conditions, nutrient availability and slope were the major limitations towards the cultivation and productivity of pigeon pea in the study area. In the entire study area, only 5.55 per cent of land was highly suitable to the crop, which was not cultivated with pigeon pea except for the three phases of Kodur series. This area could be utilized for the cultivation of pigeon pea and along with it marginal and moderately suitable areas can be improved by proper management techniques, by soil amelioration to improve nutrient availability by optimizing soil pH and by adoption of proper soil and water conservation measures. This would ensure a better sustained use of land and improve the productivity of the crop.

Conflict of interest

The authors hereby declare that there are no conflicts of interest on the manuscript submitted to the Journal -Legume Research.

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