



Understanding the Sorghum-growing Soils in a Semi-arid Ecosystem of Telangana, India and Assessing their Land Suitability for Sorghum Cultivation

K.S. Karthika¹, K.S. Anil Kumar¹, R. Srinivasan¹, M. Chandrakala¹, S. Parvathy¹, Jagdish Prasad²

10.18805/IJARE.A-6322

ABSTRACT

Background: Sorghum (Jowar), a nutritionally rich, great millet is frequently cultivated in semi-arid tracts of India but at places without considering the suitable soil-sites, which result in lower productivity. Thus, understanding of sorghum-growing pedo-environment *vis-à-vis* crop requirements is a pre-requisite for soil-site evaluation of crop and hence present case study was carried out in Mahabubnagar rural mandal of Mahabubnagar district, Telangana state.

Methods: The detailed soil survey (1:10000 scale) of Mahabubnagar Rural mandal (Mahabubnagar district), Telangana was carried out using Sentinel 2 satellite data and mapped with 66 mapping units. These mapping units along with relevant physical and chemical properties were evaluated for their suitability for sorghum farming.

Result: Our results indicated that major sorghum-growing soils of Mahabubnagar Rural mandal have been grouped as Typic Rhodustalfs, Aquic Haplustalfs, and Typic Haplusterts at the sub group level. Out of the 18-soil series, major sorghum-growing soils belong to Telugugudam, Kotakadira and Potanpalle series occupying 7.56% of the geographical area. The soil-site evaluation study indicated that the maximum area (33.99 per cent) was rated as marginally suitable with limitations of gravelliness, nutrient availability, rooting conditions, and texture while 1.51 per cent area was highly suitable for sorghum cultivation.

Key words: Characterization, Land evaluation, Land suitability, Semi-arid, Sorghum.

INTRODUCTION

Sorghum (Jowar) is an important food crop and it is consumed widely in the central and south-central parts of India. It is regarded as one of the best crops to grow in arid and semi-arid environments since it can withstand heat stress and drought to a very excellent degree. The major sorghum-growing regions fall under the semi-arid tropics with length of growing period of 90-150+ days (Mandal *et al.*, 2001). It is cultivated in an area of 1.20 lakh acres with a production of 0.138 million tonnes and a productivity of 1025 kg ha⁻¹ in Telangana. In Mahabubnagar district, *Kharif* sorghum is grown in an area of 56000 ha and *Rabi* sorghum (rainfed) in an area of 20000 ha.

Land has a potential and each land possesses such capabilities and it may differ in these, thus supporting different crops depending on the land capabilities (Dent and Deshpande, 1993). Every crop has different requisites for their optimum growth. Land evaluation has been defined by FAO (1976) as the process of assessment of land performance when used for specified purposes, involving the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation. The evaluation is a vital link in the chain leading to sustainable management of land resources (Sharma *et al.*, 1994). Thus, land evaluation involves assessing the suitability of a land mainly based

¹ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore-560 024, Karnataka, India.

²ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur-440 033, Maharashtra, India.

Corresponding Author: K.S. Karthika, ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore-560 024, Karnataka, India. Email: kksagri@yahoo.com.

How to cite this article: Karthika, K.S., Kumar, K.S.A., Srinivasan, R., Chandrakala, M., Parvathy, S. and Prasad, J. (2024). Understanding the Sorghum-growing Soils in a Semi-arid Ecosystem of Telangana, India and Assessing their Land Suitability for Sorghum Cultivation. Indian Journal of Agricultural Research. 58 (Special Issue): 1100-1108. doi: 10.18805/IJARE.A-6322.

Submitted: 13-10-2024 **Accepted:** 13-10-2024 **Online:** 12-11-2024

on crop productivity and is fundamental in identifying the potential of existing natural resources and their optimal utilization to sustain crop productivity. The climatic conditions, soil, levels of crop management reflect in the performance of any crop. Land suitability studies focus on understanding the climatic conditions and soil-site suitability in each soil unit to prescribe options of potential crops that can be raised in that given unit (Singha and Swain, 2016) and can maximize crop production per unit of land, labour and inputs (Naidu *et al.*, 2006). However, in many cases farmers grow different crops without giving much consideration to soil suitability.

This unwise utilization of land can be avoided to a greater extent with land evaluation (Abdel-Rahman *et al.*, 2016). The mismatch between what is present in the field to what the soil is suited for can be reduced by land suitability analysis (Hegde *et al.*, 2012). Land evaluation is essential for planners as well as policy makers for better land use planning (Young, 2000).

Sorghum is one of the dominant crops cultivated in the study area. There are certain soil factors that limit the suitability of sorghum, which can be understood only by evaluating the same. An understanding of potentials and constraints of the soils is essential to evaluate the suitability of the soils for sorghum to increase its productivity and hence the present study was carried out.

MATERIALS AND METHODS

Description of the study area

The study area, Mahabubnagar Rural mandal is situated in Mahabubnagar Taluk and district of Telangana state which falls in AER 7 (Hot semi-arid eco-region with red and black soils and AESR 7.2: North Telangana Plateau, hot, moist, semi-arid eco-sub region with deep loamy and clayey mixed red and black soils, medium to very high available water capacity and LGP 120-150 days). It 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, characterized by ustic soil moisture and isohyperthermic soil temperature regimes. The climate is semi-arid with an annual average rainfall of 613.3 mm. The total potential evapotranspiration

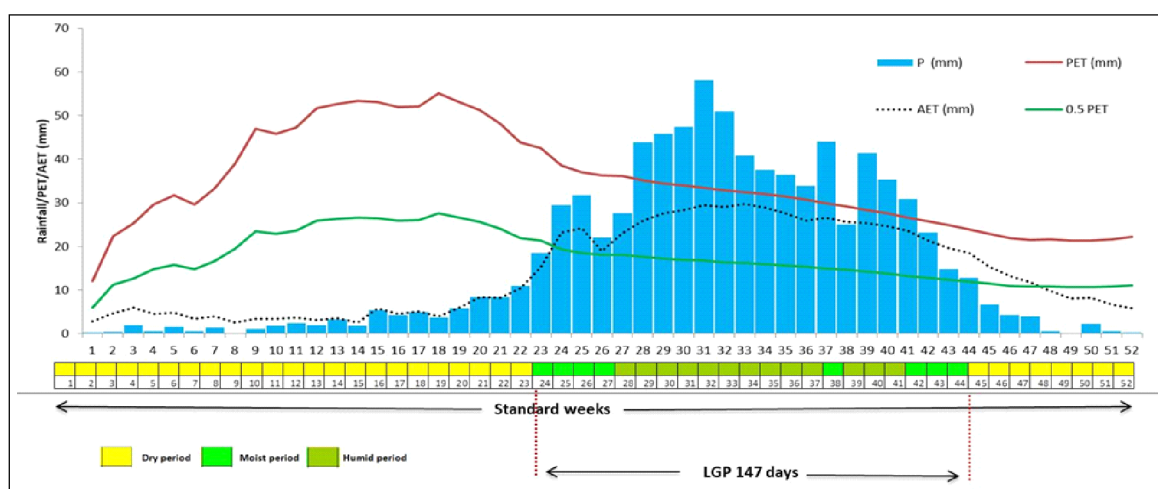


Fig 1: Water balance diagram of the study area indicating PET and RF.

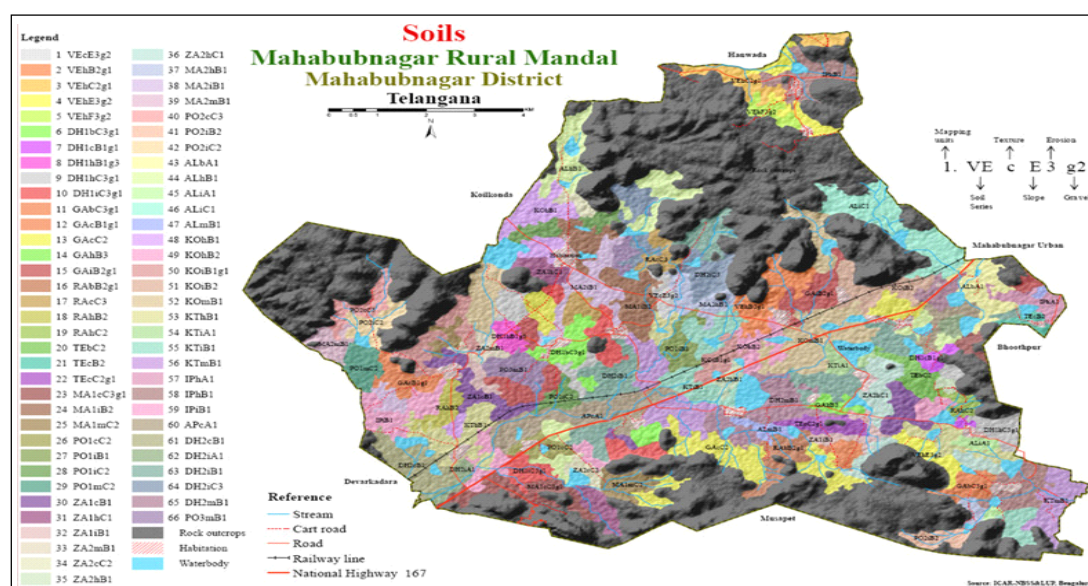


Fig 2: Soils of the area.

(PET) of the area is about 1806.3 mm, which is much higher than the amount of rainfall received in the area (Fig 1). The average temperature of the area ranges between 16°C and 34°C with May being the hottest month and January, the coldest month. The growing period for the area is about 147 days, which starts from the beginning of June (23rd week) to the end of October (44th week). The study area geologically belongs to the granite-gneiss of Archaean origin dating back to the lower Precambrian age and it was divided into three broader landforms namely hill side slopes, uplands and the lowlands.

The major crops of the area are rice and sorghum followed by pigeon pea, cotton and castor. The major vegetable crops include tomato, chilli, brinjal and onion. The major horticultural crop is mango. Natural vegetations include Neem (*Azadirachta indica*), Pongame (*Pongamia pinnata*), *Cassia tora* and Jaali (*Prosopis juliflora*).

Field work and soil map preparation

Survey of India Topo-sheet (1:50,000 scale), Sentinel 2 satellite data in Google imagery were used for digitizing the habitation, roads and drainage lines. Detailed soil survey (1:10,000 scale) was carried out and a total of 114 pedons were morphologically studied. After thorough soil correlation, 18 soil series with 66 phases (mapping units) were mapped in Arc Geographic Information System (GIS) environment (Fig 2).

Laboratory analysis

The horizon-wise soil samples collected from representative pedon of a series were processed and analysed for different parameters. Particle-size distribution in the fine earth (<2 mm) was determined by International

pipette method (Piper 2002). Soil reaction (pH in water) and electrical conductivity (EC) were estimated by potentiometric and conductometric methods (Jackson 1973). The cation exchange capacity was estimated by 1 N Ammonium acetate displaceable method (Sarma *et al.* 1987) and exchangeable bases by atomic absorption spectrophotometry. The soils were classified according to the Keys to Soil Taxonomy (Soil Survey Staff, 2014).

Land suitability evaluation

Land suitability was evaluated using the suitability criteria (Naidu *et al.*, 2006) for sorghum (Table 4). Soil texture, erosion, reaction, salinity, sodicity, calcareousness, cation exchange capacity, slope, depth of soil *etc.* are considered as the different land quality parameters for land evaluation. Based on the number and intensity of limitation, classes were assigned as S1- highly suitable, S2: Moderately suitable, S3: Marginally suitable and N: Currently not suitable. There are no sub-classes within the suitability class S1. Classes S2 and S3 were divided into sub-classes based on the specific limitations in the area for the selected land use. The specific limitations affecting crop production in the area are indicated with the symbols *viz.*, erratic rainfall and its distribution and short growing period (c), soil texture (t), erosion hazards (e), nutrient availability (n), rooting conditions (r), drainage problem (w) and gravelliness (g). Limitations are indicated in lower case letters after the suitability class symbol. For example, marginally suitable land with flooding or drainage as a limitation is designated as S3w. Normally two and sometimes three limitations are included at sub-class level. Land suitability units are indicated by the Arabic numbers after the limitation symbol.

Table 1: Soil series identified in the area and their taxonomical classification.

Landforms	Series	Taxonomical classification
Hill side slopes	Venkatapur	Loamy-skeletal, mixed, superactive, isohyperthermic family of Typic Rhodustalfs
Uplands	Dharmapur 1	Clayey-skeletal, mixed, superactive, isohyperthermic family of Typic Rhodustalfs
	Gajulapet	Clayey-skeletal, mixed, active, isohyperthermic family of Typic Haplustalfs
	Ramchandrapur	Clayey, mixed, active, isohyperthermic family of Typic Haplustalfs
	Telugugudam	Loamy-skeletal, mixed, active, isohyperthermic family of Typic Rhodustalfs
	Manikonda 1	Fine-loamy, smectitic, superactive, isohyperthermic family of Typic Haplustepts
	Potanpalle 1	Clayey-skeletal, smectitic, superactive, isohyperthermic family of Typic Haplustepts
	Zamistapur 1	Clayey, mixed, active, isohyperthermic family of Typic Haplustalfs
	Zamistapur 2	Fine-loamy, smectitic, superactive, isohyperthermic family of Typic Haplustalfs
	Manikonda 2	Fine-loamy, smectitic, superactive, isohyperthermic family of Typic Haplustepts
	Potanpalle 2	Fine-loamy, smectitic, superactive, isohyperthermic family of Aquic Calcustepts
	Allipur	Fine-loamy, smectitic, superactive, isohyperthermic family of Aquic Natrustalfs
	Kodur	Fine, smectitic, superactive, isohyperthermic family of Vertic Haplustepts
Lowlands	Kotakadira	Fine, smectitic, superactive, isohyperthermic family of Aquic Haplustalfs
	Ippalapalle	Fine, smectitic, superactive, calcareous, isohyperthermic family of Aquic Natrustalfs
	Appayapalle	Loamy-smectitic, superactive, isohyperthermic Aquic Natrustalfs
	Dharmapur 2	Fine-loamy, smectitic, superactive, calcareous, isohyperthermic Aquic Natrustalfs
	Potanpalle 3	Fine, smectitic, superactive, isohyperthermic Typic Haplusterts

RESULTS AND DISCUSSION

Description of soils

The soils of area were grouped in three soil orders namely Alfisols, Inceptisols and Vertisols. Venkatapur series (moderately deep), a Typic Rhodustalfs cover an area of 464 ha (3.20%) on the hill side slope. Major soils of uplands were grouped into Kodur series (deep), a Vertic Haplustepts which cover an area of 962 ha (6.63%) and Gajulapet series (shallow), a Typic Haplustalfs cover an area of 797 ha (5.49%). Major soils of lowlands (Dharmapur 2 series) is a very deep Aquic Natrustalfs. These three soils are dominant in Mahabubnagar Rural Mandal and cover an area of 1014 ha (7.00%). Kotakadira series (deep), an Aquic Haplustalfs (Table 1) cover an area of 805.0 ha (5.54%).

Sorghum is an important crop in 15 out of the 18 soil series along with the rice and pigeon pea. Sorghum was dominant land use in Telugugudam (TE) series of uplands and Kotakadira (KT) and Potanpalle 3 (PO3) series of lowlands. Telugugudam soils (TE) cover an area of 171 ha (1.18%), Kotakadira soils (KT), an area of 805 ha (5.54%) and Potanpalle 3 soils cover the least area of 121 ha (0.84% of TGA).

Telugugudam series (TE) are spread in Telugugudam, Zamistapur and Allipur villages on very gently (1-3%) to gently (3-5%) sloping uplands at an elevation of 450 to 462 m above mean sea level, subjected to moderate erosion. The thickness of solum ranges from 109 to 124 cm. The A horizon is 13 to 16 cm thick. Its colour is in 5YR and 7.5YR hues, value 3 to 4 and chroma 3 to 4. The texture is sandy loam to loamy sand. The thickness of B horizon ranges from 100 to 108 cm. Its colour is in 2.5YR to 5YR hue, value 3 and chroma 4 (Table 2). The texture is sandy clay. TE series has three phases namely TEBc2, TEcB2 and TEcC2g1.

Kotakadira series (KT) occur in Zamistapur, Kotakadira, Bakalonipalle, Kodur, Ramchandrapur and Gajulapet villages spread over an area of 805 ha on nearly level (0-1%) to very gently sloping lowlands at an elevation of 330 to 402 m above mean sea level, with 1-3 per cent slopes and subjected to slight to moderate erosion. These soils are moderately well drained with medium permeability. The thickness of solum ranges from 105 to 143 cm. The A horizon is 13 to 20 cm thick. Its colour is in 10 YR hue, value 3 to 4 and chroma 2. The texture is sandy clay to clay.

Table 2: Salient morphological and physical properties of sorghum-growing soils.

Depth (cm)	Horizon	Moist colour	Total			Coarse fragments/ Stones and boulders: (Volume%)	Fine earth texture (USDA)
			Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
16°23'39.083"N;77°56'24.453"E							
TE	Loamy-skeletal, mixed, active, isohyperthermic Typic Rhodustalfs						
0-13	Ap	7.5 YR 3/3	83.82	9.20	6.98	20	ls
13-39	Bt1	2.5 YR 3/4	51.61	7.70	40.69	50	sc
39-62	Bt2	2.5 YR 3/4	49.59	9.85	40.56	60	sc
62-83	BC1	2.5 YR 3/4	70.13	8.77	21.10	55	scl
83-113	BC2	2.5 YR 4/6	76.04	9.37	14.59	30	sl
113-166	Cr						
16°43'06.393"N; 77°53'08.32"E							
KT	Fine, smectitic, superactive, isohyperthermic Aquic Haplustalfs						
0-15	Ap	2.5Y 4/1	58.43	18.38	23.19		scl
15-34	BA	10YR 4/2	55.58	19.70	24.72		scl
34-59	Bt1	10YR 3/2	33.99	24.30	41.71		c
59-90	Bt2	10YR 4/3	46.40	18.11	35.49		sc
90-130+	Bt3	10YR 4/2	49.12	15.42	35.46		sc
	Cr						
16°41'20.223"N; 77°52'39.78"E							
PO3	Fine, smectitic, superactive, isohyperthermic Typic Haplusterts						
0-19	Ap	10 YR 3/1	25.82	20.94	53.24		c
19-42	Bss1	10 YR 3/1	26.12	19.45	54.43		c
42-67	Bss2	10 YR 3/1	26.76	20.91	52.33		c
67-109	Bss3	10 YR 3/1	21.74	21.39	56.87		c
109-146	Bss4	10 YR 3/1	15.32	25.55	59.13		c
149-154	Cr						

The thickness of B horizon ranges from 80 to 140 cm. Its colour is in 10YR hue, value 3 to 5 and chroma 2 to 6. The texture is sandy clay loam to clay. KT series has four phases (KThB1, KtiA1, KtiB1 and KtmB1).

Soils of Potanpalle 3 series (PO3) cover an area of 121 ha in Potanpalle and Manikonda villages on very gently sloping lowlands at an elevation of 400 to 404 m above mean sea level on very gently sloping lowlands with 1-3 per cent slopes and subjected to slight erosion. These soils are moderately well drained with slow permeability. The thickness of solum ranges from 154 to 155 cm. The A horizon is 18 to 19 cm thick. Its colour is in 10 YR hue, value 3 and chroma 1 to 2. The texture is clay. The thickness of B horizon ranges from 135 to 137 cm. Its colour is in 10 YR hue, value 3 to 5 and chroma 1 to 4. The texture is clay to sandy clay. This series has only one phase (PO3mB1).

The soils of TE series was dark brown (7.5 YR 3.3) in the surface and the redness increased with depth (2.5 YR 3/4 to 4/6). The KT soils were dark gray (2.5 Y 4/1) in the surface and the sub -surface was dark grayish brown. PO3 soils were very dark gray (10 YR 3/1). The dominant colour was dark gray and the soil colour depends on the mineral composition and changes in soil coating (Schaetzl and Anderson, 2005). An increase in clay content was observed with depth from 6.98 in Ap to 40.56 in Bt2 in TE and from 23.19 in Ap to 35.46 in Bt3 in KT soils indicating the process of clay illuviation (Sarkar *et al.*, 2002). Only TE soils were gravelly and coarse fragments increased with the depth.

The surface texture was loamy sand in TE, sandy clay loam in KT and clay in PO3 soils.

The soil pH increased with depth from 6.18 (slightly acidic) at the surface to 6.60 (neutral) in the BC2 horizon (Table 3). The KT and PO3 soils had higher pH (slightly alkaline). The cation exchange capacity (CEC) was higher than 40 cmol (+) per kg of soil in PO3 series, whereas it was relatively low in other two soils (<15 cmol (+) per kg of soil). The low CEC values in TE and KT soils indicate the dominance of low activity clays. In general, CEC followed a similar trend that of clay content in soils. Exchangeable bases were higher in PO3 and exchangeable Na was slightly higher than exchangeable K. Exchangeable Sodium Percentage (ESP) was recorded in all the soils; however, it was <8% which does not pose any problem in sorghum farming. It was slightly higher (>5) only in the sub-soils of KT. Base saturation by ammonium acetate was very high (100%) in the KT series compared to the other two soils which could be due to higher Ca⁺ occupying exchange sites on the colloidal complex (Sireesha and Naidu, 2013).

The soils of Telugugudam and Kotakadira series were keyed as order Alfisols, whereas Potanpalle 3 series was classified as Vertisols. The soils of Telugugudam series had clay content of 26% and a gravel content of >35% in the control section making it to classify under loamy-skeletal particle-size class. The CEC: clay ratio (0.49) in the soil control section justified its placement under the active CEC class. The soils were keyed out as suborder

Table 3: Chemical properties of sorghum-growing soils identified in Mahabubnagar Rural mandal.

	pH(1:2.5)	CEC	Exch. Ca	Exch. Mg	Exch. K	Exch. Na		BS (%)		ESP	
Depth(cm)	← c mol (+) kg ⁻¹ →						Sum	Sum of	NH ₄ OAc	%	CEC/Clay
	cations										
TE											
0-13	6.18	4.00	1.97	0.60	0.27	0.05	2.89	72		1.31	0.57
13-39	6.20	16.21	7.81	2.92	0.27	0.09	11.09	68		0.54	0.40
39-62	6.51	14.99	7.38	3.16	0.26	0.13	10.93	73		0.88	0.37
62-83	6.55	10.58	5.42	1.85	0.15	0.14	7.56	71		1.31	0.50
83-113	6.60	10.26	6.05	1.86	0.12	0.13	8.16	80		1.27	0.70
KT											
0-15	8.14	16.98	14.72	14.12	0.47	0.09	29.40	100	173.1*	0.51	0.73
15-34	8.32	17.65	12.80	12.59	0.36	0.48	26.23	100	148.6*	2.70	0.71
34-59	8.48	23.53	10.10	10.99	0.34	1.24	22.66	100	96.3	5.26	0.56
59-90	8.62	19.44	9.90	9.36	0.23	1.00	20.50	100	105.4*	5.17	0.55
90-130	8.20	17.06	7.72	8.04	0.23	0.81	16.80	100	98.5	4.75	0.48
PO3											
0-19	7.77	58.16	41.57	6.86	0.65	0.65	49.73	85		1.11	1.09
19-42	8.14	57.94	37.17	5.31	0.31	0.79	43.58	75		1.36	1.06
42-67	8.18	56.50	35.72	6.94	0.33	0.68	43.67	77		1.20	1.08
67-109	8.07	57.46	43.08	11.66	0.34	0.51	55.59	97		0.88	1.01
109-146	7.96	59.94	40.12	14.68	0.49	0.43	55.72	93		0.71	1.01

The higher base saturation indicates the availability of cations especially Ca and Mg released from soil but not from the exchangeable sites and/or presence of zeolite

Ustalfs due to the ustic soil moisture regime and the hue of 2.5 YR and moist value of 3 resulted in classifying the soils under Rhodustalfs great group. At the family level, the TE series is classified as a member of Loamy-skeletal, mixed, active, isohyperthermic Typic Rhodustalfs. Kotakadira series having <60% clay in the control section has been put under fine particle-size group and the CEC:clay ratio was greater than 0.60 indicating superactive CEC class. The presence of redox depletions, with chroma 2 or less and aquic conditions resulted in Aquic Haplustalfs, thus keying out Kotakadira series to Fine, smectitic, superactive, isohyperthermic family of Aquic Haplustalfs. The soils of PO3 series had less than 60% clay in the control section soil resulting in fine textural

class and the CEC:clay ratio greater than 0.60 indicating superactive CEC class. The soils were classified under the suborder Usterts due to the ustic soil moisture regime and at the family level, Potanpalle 3 series is a member of Fine-smectitic, superactive, isohyperthermic Typic Haplusterts.

Land suitability evaluation

Land suitability was carried out as per the suitability criteria (Table 4) outlined by Naidu *et al.*, (2006) for sorghum farming. 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 and hence the prevailing climate in the region is highly suitable for sorghum cultivation.

Table 4: Soil-site suitability criteria (crop requirements) for sorghum.

Soil site characteristics		Rating				
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Non-suitable (N)
Climatic regime	Mean temperature in growing season	°C	26-30	31-34 24-25	35-40 20-23	<40 >20
	Mean max. temp. in growing season	°C	31-33	33-35	>35	-
	Mean min. temp. in growing season	°C	22-18	18-15	<15	-
	Mean RH in growing season	%	50-70	50-40	<40	-
	Total rainfall	mm	>650	650-550	450-550	<450
	Rainfall in growing season	mm	500-700	400-500	300-400	<300
	Land characteristics					
Land quality	Land characteristics					
Moisture availability	Length of growing Period	Days	>120	120-90	<90	-
	AWC	mm/m	>150	100-150	50-100	<50
Oxygen availability to roots	Soil drainage	Class	Well to moderate drained	Imperfect excessive	Poor and	Very poor
	Water logging in growing season	Days	2-3	3-4	4-5	>5
Nutrient availability	Texture	Class	c, cl, silcl, sc	l, sil, sic, skeletal	sl, ls	s, fragmental
	pH	1:2.5	6.0-7.9	5.5-6.0 7.9-8.4	<5.5 8.4-9.0	>9.0
	CEC	%	30-20	20-10	<10	
	BS	%	80-50	50-35	<35	
	CaCO ₃ in root zone	%	5-10	10-25	>25	
	OC	%	0.50-0.75	0.50-0.20	<0.20	-
	Effective soil depth	cm	100-75	50-75	30-50	<30
Rooting conditions	Stoniness	%	5-15	15-30	30-60	>60
	Coarse fragments	Vol %	5-15	15-40	40-75	>75
Soil toxicity	Salinity (EC saturation extract)	dSm ⁻¹	2-4	4-8	8-10	>10
	Sodicity (ESP)	%	5-8	8-10	10-15	>15
Erosion	Slope	%	<3	3-10	10-15	>15

Note:s-sand; ls-loamy sand; sl-sandy loam; cl-clay loam, silcl-silty clay loam; sil- silt loam; l-loam, sic-silty clay; sc-sandy clay;c-clay.

Out of 66 mapping units, only 4 units were found to be highly suitable for cultivation of sorghum (Table 5, Fig 3) constituting a small area (1.91%). These 4 units were 42 (PO2iC2), 45 (ALiA1), ALiA1 (47) and PO3mB1 (66). Nearly 23.22 per cent of the total area was moderately suitable with limitations of erosion hazards, gravelliness, nutrient availability and texture. The phases namely RAhB2 (18), ZA2hB1 (35), MA2hB1 (37), PO2iB2 (41), KOhB1 (48), KobB2 (49), KOiB1g1(50), KOiB2 (51), KOmB1 (52), KThB1 (53), KTiB1(55), KTmB1 (56), IPhA1 (57), IPhB1 (58), were the moderately suitable lands with limitations of nutrient availability and these occupy 15.68% of the area. The maximum area of 33.99 per cent was marginally suitable area with limitations of gravelliness, nutrient availability, rooting conditions and texture and out of this nearly 14.7%

had limitation of nutrient availability. These phases (mapping units) are VEhE3g2 (4), DH1hC3g1 (9), DH1iC3g1 (10), MA1iB2 (24), MA1mC2 (25), ZA1hC1 (31), ZA1iB1 (32), MA2mB1 (39), ALhB1 (44), IPiB1 (59), DH2iA1 (62), DH2iB1 (63) and DH2mB1 (65). Nearly 1.16 per cent of total area was found unsuitable for the cultivation of sorghum.

It was found that PO3 soils (PO3mB1) were highly suitable (S1). The three phases of TE series, viz. TEbC2 (20), TEcB2 (21), TEcC2g1(22) were rated as S3 with limitations of texture (t) and nutrient availability (n) denoted as S3tn. The soil phases of Telugugudam were found to be marginally suitable with limitations of texture and nutrient conditions. TEbC2 was loamy sand in texture, which limited its suitability to class S3 along with the lower organic carbon

Table 5: Land suitability for sorghum in Mahabubnagar Rural Mandal.

Mapping unit no.	Suitability classes	Description	Area (ha)	Area (%)
42, 45, 47, 66	S1	Highly suitable lands	277	1.91
19, 36, 38, 46, 64	S2en	Moderately suitable lands with limitations of erosion hazards and nutrient availability	797	5.50
2, 3	S2gn	Mod		
erately suitable lands	251	1.73		
18, 35, 37, 41, 48, 49, 50, 51, 52, 53, 55, 56, 57, 58	S2n	Moderately suitable lands with limitation of nutrient availability	2274	15.68
33, 60, 61	S2tn	Moderately suitable lands with limitations of texture and nutrient availability	45	0.31
4	S3gn	Marginally suitable lands with limitations of gravelliness and nutrient availability	131	0.90
9,10, 24, 25, 31, 32, 39, 44, 59, 62, 63, 65	S3n	Marginally suitable lands with limitation of nutrient availability	2131	14.7
14, 15, 27, 28, 29	S3r	Marginally suitable lands with limitation of rooting conditions	528	3.64
26	S3rt	Marginally suitable lands with limitations of rooting conditions and texture	46	0.31
11, 12, 13, 16, 17, 34, 40, 43	S3t	Marginally suitable lands with limitation of texture	985	6.8
6, 7, 20, 21, 22, 23, 30	S3tn	Marginally suitable lands with limitations of texture and nutrient availability	1107	7.64
1, 5, 8, 54	N	Currently not suitable	169	1.16
		Total	8739	60.28
Rock outcrops			5098	35.17
Habitation			225	1.55
Water body			435	3.00
		Total geographical area	14497	100.00

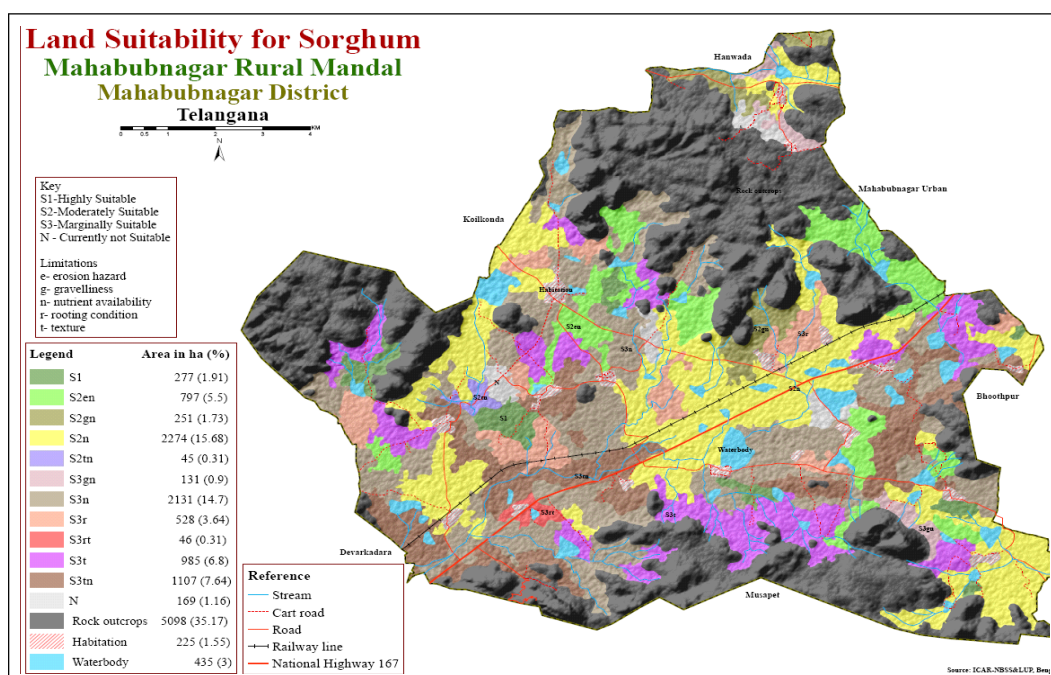


Fig 3: Land suitability for sorghum in Mahabubnagar Rural mandal

content of 0.19 % and low CEC of 4 cmol (+) per kg of soil. Lower organic carbon in the soil was one of the limiting factors in its suitability for cultivation of sorghum in an agricultural farm in Tanzania (Kaaya *et al.*, 1994) and in western Ethiopia (Yitbarek *et al.*, 2013). The other two phases had the limitations of sandy loam texture making them S3 suitability class. Sandy loam and loamy sand soil texture, a CEC lesser than 10 cmol (+) per kg of soil, organic carbon <0.20 per cent are classified under marginally suitable class (Naidu *et al.*, 2006). Soil texture and organic carbon (OC) were considered in the assessment of land suitability (Singha and Swain 2020).

Kotakadira series with three phases having CEC in the range of 10-20 cmol (+) per kg of soil have been grouped under the class S2n (moderately suitable) with limitations of nutrient availability. The phase KTIA1 (54) was currently not suitable due to a higher pH of >9. This could be brought under the marginally suitable class by adopting proper soil management to manage the alkalinity and thereby to improve nutrient availability. Application of gypsum may be carried out to ameliorate alkaline condition in the soil (Karthika *et al.*, 2022).

Potanpalle 3 soils had only one phase (PO3mB1) and this was highly suitable with no limitations for the cultivation of sorghum. The characteristics of these soils such as the clay texture, non-gravelly, moderately well-drained, non-calcareous, deep (100-150 cm), occurring on very gently sloping (1-3%) landscape, resulted in their high suitability. Their higher nutrient status and water retention support the good crop.

Most of the marginally suitable area for sorghum cultivation had limitations of gravelliness and erosion

hazards. Gravelliness limits the water retention and nutrient holding capacity. Productivity of the crop is affected by soil slope, gravelliness and effective rooting depth (Shivaramu 2012). The soil loss and soil erosion need to be managed to avoid further increase in gravel content by adopting proper soil and water conservation measures such as terracing, contour bunding across the slope depending upon slope gradient of hill side slopes (3 to 5%) and uplands (1 to 3% and 3 to 5%) as opined by Karthika *et al.*, (2021). The limitations of nutrient conditions were mainly due to poor organic carbon content and alkaline soil reaction. Organic material application can improve the soil organic matter content and thereby water and nutrient retention. The basic soil reaction can be managed by the application of gypsum (Karthika *et al.* 2021). By adopting proper management strategies productivity of sorghum could be improved for sustained use.

CONCLUSION

Major sorghum-growing soils of Mahabubnagar Rural mandal of semi-arid Deccan plateau belong to Alfisols and Vertisols order. Out of three major sorghum-growing soils, only phases of PO3 series were highly suitable for growing of the crop and other soils were marginally suitable. It was found that texture, soil reaction and nutrient conditions were the major limitations towards the cultivation and productivity of sorghum. Only 1.91 per cent of TGA of land was highly suitable to the crop. Proper management techniques, such as addition of organic matter, soil amelioration to improve nutrient availability by optimizing soil pH would ensure a better sustained use of land and improve the productivity of the crop.

ACKNOWLEDGEMENT

The authors hereby acknowledge the support provided by the entire staff of ICAR-NBSS and LUP, Regional Centre, Bangalore during the project period.

Authorship contribution statement

K.S. Karthika: Over all involvement in the research as PI. Field work, Soil analysis, Interpretation of data, Manuscript preparation and editing. K.S. Anil Kumar: Over all involvement and guidance in the research as Co-PI. Field work, Soil data interpretation, Manuscript editing and correction. R. Srinivasan: Co-PI in the research. Field work, Interpretation of soil data, Soil series finalisation M. Chandrakala: Co-PI in the research, Interpretation of soil data, Land suitability evaluation. S. Parvathy: Soil laboratory analysis and manuscript preparation. Jagdish Prasad: Manuscript editing and correction and overall guidance

Declaration of interest

The authors hereby declare no conflicts of interest.

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