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Soil-site suitability evaluation for major crops grown in part of Palamaner division in Chittoor district, Andhra Pradesh, India

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Abstract
Six typical pedons in semi-arid region of Palamaner division in Chittoor district of Andhra Pradesh were studied for their morphological, physico-chemical and chemical characteristics to evaluate the suitability of soils for growing rice, groundnut, maize and finger millet. The soil belongs to Inceptisols, Entisols and Alfisols. All the pedons (P1 to P6) were not suitable (N) for rice, marginally suitable (S3) for groundnut and moderately suitable (S2) for maize and finger millet. The soil suitability criterion varies from crop to crop and soil to soil. The soils in the study area exhibited major limitations *viz.*, steep slope, wetness (excessive drainage), physical soil characteristics like texture, depth and soil fertility characteristics such as pH, organic carbon and $CaCO_3$. 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: Soil-site suitability evaluation, suitability class, limitation levels, potential land suitability

Introduction
Soil is a valuable resource and a critical component in many of the environmental and economic issues facing today's society. The inherent ability of soils to supply nutrients for crop growth and maintenance of soil physical conditions to optimize crop yields is the most important component of soil fertility that virtually determines the productivity of agricultural system. Judicious use of this vital natural resource influences the survival of life systems and there by socio-economic development of any country. Each plant species requires definite soil and site conditions for its optimum growth. Although some plants may be found to grow under different soils and extreme agro-ecological conditions, yet not all plants can grow on the same soil and under the same environment. Land suitability evaluation is the pre-requisite for sustainable agricultural production. It involves evaluation of the criteria ranging from soil, terrain to socio-economic, market and infrastructure (Prakash, 2003) [10]. The evaluation relates to the environmental and socio-economic conditions of the area as it includes a consideration of inputs and projected outputs of production process. According to the FAO general framework for land suitability evaluation (1976) [3]. Land suitability evaluation is the process of estimating the potential of land for land use planning (Sys *et al.* 1991) [17].
Since, the availability of both water and plant nutrients was largely controlled by the physico-chemical properties and microenvironment of soils, there a necessity of land suitability evaluation of soils to determine the needs of the crops. Studies and information on the soil-site suitability for crops in the state of Andhra Pradesh in general and in Chittoor 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, groundnut, maize and finger millet on the existing Entisols, Inceptisols and Alfisols in part of Chittoor district, Andhra Pradesh.

Material and Methods
Description of the study area
The study area lies in between 77° 54' and 79° 10' North lattitudes to 13° 41' and 12° 36' East longitudes at an elevation ranging from 720-760 m (msl). The study area was confined to semi-arid monsoon type of climate with distinct summer (April to June), rainy (July to November) and winter (December to March) seasons. The mean annual rainfall of the study area is 973 mm of which 95 per cent was received during May to December.

The mean annual temperature is 28.50 °C with a mean annual summer temperature of 32.19 °C and mean annual winter temperature of 24.08 °C. The maximum temperature for the last 30 years is 43.8 °C, recorded in the month of April whereas the minimum temperature is 14.5 °C, noticed in the month of January. The study area qualifies for ustic soil moisture regime and iso-hyperthermic soil temperature regime. The natural vegetation in study area comprises of *Delonix regia*, *Tamarindus indica*, *Tephrosia purpurea*, *Parthenium hysterophorus*, *Azadirachta indica*, *Cyperus rotundus*, *Cynodon dactylon*, *Prosopis juliflora*, *Pongamia pinnata*, *Tectona grandis*, *Acacia auriculiformis*.

Methodology

After traversing the area, based on the visual observations and based on the variations in soil site characteristics (Table 1), ten sites were selected for digging profiles by following the procedure outlined by soil survey division staff (2000). Soil correlation exercise yielded six typical pedons *i.e.*, two pedons in upper slope, mid slopes and foot slopes. The morphological properties of soil profiles were recorded as per Soil Survey Staff (1951) [14] and classified as per USDA soil taxonomy (Soil Survey Staff 2014) [13]. Horizon-wise soil samples were collected for laboratory analysis. Processed soil samples (< 2 mm) were analyzed for various physico-chemical properties such as pH (1:2.5 soil water suspension), organic carbon, texture, electrical conductivity, calcium carbonate, exchangeable bases and cation exchange capacity by adopting standard analytical procedures (Bower *et al*. 1952; Chopra and Kanwar, 1991; Jackson 1973; Piper, 1966) [1, 2, 4, 9].

These six pedons were evaluated for commonly growing crops of the study area based on the guidelines of FAO (FAO, 1976) [3] as mentioned by Sys (1985) [16] and the crop requirements as suggested by Naidu *et al* (2006) [8] are followed. The landscape and soil requirements for these crops were matched with generated data at different limitation levels: no (0), slight (1), moderate (2), severe (3) and very severe (4). The number and degrees of limitations suggested the suitability class for pedons to particular crops and the potential land suitability sub- classes were determined after considering the improvement measures to correct these limitations (FAO, 1976; Sys *et al*., 1985) [3, 16].

Table 1: Landscape characteristics of Pedons

Pedons	Villages	Location	Elevation above sea level MSL (m)	Physiography	Slope (%)
P1 Typic Haplustepts	Kanalillu	N 13 ^{0} 10ˆ21.0" E 078^{0}36'21.3"	757	Upper slope	3-5%
P2 Typic Haplustalfs	Kummaragunta	N 13 ^{0} 10ˆ02.5" E 078^{0}35ˆ44.6"	754	Upper slope	3-5%
P3 Typic Ustorthent	Chellara Gunta	N 13^0 09ˆ 36.9" E 078^{0}36ˆ13.4"	749	Middle slope	1-3%
P4 Typic Haplustalf	Settipalli	N 13^0 08ˆ 14.6" E 078^{0}37ˆ04.0"	736	Middle slope	1-3%
P5 Typic Haplustalf	Gorreladoddi	N 13^O 12ˆ 17.4" E 078^{O}35ˆ59.5"	728	Lower slope	0-1%
P6 Typic Haplustalf	Chinnapuram	N 14^0 53ˆ 07.9" E 078^{0}26ˆ50.6"	725	Lower slope	0-1%

Table 2: Soil site characteristics (weighted means) selected for suitability evaluation for major crops

Soil site characteristics	P1	P2	P3	P4	P5	P6
Site characteristics						
Slope (%)	3-5%	3-5%	1-3%	1-3%	0-1%	0-1%
Erosion	Moderate	Moderate	Slight	Nill	Nil	Nil
Drinage / wetness	Moderately Drained	Well Drained	Well Drained	Well Drained	Well Drained	Well Drained
Soil characteristics						
Texture	scl	sl	sl	sl	sl	sl
Depth (cm)	110	90	95	120	110	135
$CaCO_3$	6.17	7.29	6.39	6.9	6.85	5.91
OC(%)	0.32	0.24	0.45	0.23	0.15	0.32
BS(%)	74.21	80.39	86.8	78.07	68.02	81.76
EC(dSm^{-1})	0.15	0.13	0.12	0.14	0.14	0.06
pH(1:2)	6.76	6.62	6.72	6.49	6.11	6.65
ESP	1.71	1.47	6.01	4.26	1.71	2.41

Table 3: Limitation levels of the land characteristics and land suitability classes

Pedon No.	Land form	Crop	Wetness (w) drainage	Physical soil characteristics (s)			$CaCO_3$ (%)	Soil fertility characteristics (f)			Alkalinity (n)	Actual land suitability sub-class	Potential land suitability sub-class
				Texture	Coarse fragments (Vol. %)	Soil depth (cm)		Sum of basis cations [cmol (p+) kg^{-1} soil]	pH 1:2.5	OC (%)	ESP		
1	Upper slope	Rice	2	3	0	0	2	0	0	3	0	Nwsf	S3s
		Groundnut	3	0	0	0	0	0	0	3	0	S3wf	S1
		Maize	1	0	0	0	0	0	0	1	0	S2wf	S1
		Finger millet	0	0	0	0	0	0	0	1	0	S2f	S1
2	Upper slope	Rice	4	3	0	0	2	0	0	3	0	Nwsf	S3s
		Groundnut	3	0	0	0	0	0	0	3	0	S3wf	S1
		Maize	0	1	0	0	0	0	0	2	0	S2sf	S2s
		Finger millet	0	1	0	0	0	0	0	2	0	S2f	S1
3	Middle slope	Rice	4	3	0	2	2	0	0	3	0	Nwsf	S3s
		Groundnut	2	0	0	1	0	0	0	3	0	S3wsf	S2s
		Maize	0	1	0	1	0	0	0	1	0	S2sf	S2s
		Finger millet	0	1	0	0	0	0	0	1	0	S2sf	S2s
4	Middle slope	Rice	4	3	0	0	2	0	0	3	0	Nwsf	S3s
		Groundnut	2	0	0	0	0	0	0	3	0	S3wf	S1
		Maize	0	1	0	0	0	0	0	2	0	S2sf	S2s
		Finger millet	0	1	0	0	0	0	0	2	0	S2sf	S2s
5	Lower slope	Rice	4	3	0	0	1	0	0	3	0	Nwsf	S3s
		Groundnut	0	0	0	0	0	0	0	3	0	S3f	S1
		Maize	0	1	0	0	0	0	0	2	0	S2sf	S2s
		Finger millet	0	1	0	0	0	0	0	2	0	S2sf	S2s
6	Lower slope	Rice	4	3	0	0	2	0	1	3	0	Nwsf	S3s
		Groundnut	0	0	0	0	0	0	1	3	0	S3f	S1
		Maize	0	1	0	0	0	0	0	1	0	S2sf	S2s
		Finger millet	0	1	0	0	0	0	0	1	0	S2sf	S2s

Limitations: 0- No; 1-Slight; 2-Moderate; 3-Severe, 4-Very severe
Suitability classes: f-Soil fertility limitations; s-Physical soil limitations; w-Wetness limitations; n-Salinity (and / or alkalinity) limitations.

Result and Discussion

Weighted means of soil characteristics are given in table 2. Kind and degree of limitations of the soils for rice, groundnut, maize and finger millet crops are presented in table 3. The soils with no or only four slight limitations were grouped under suitability class (S1) (very suitable); the soils with more than four slight limitations, and/or with more than three moderate limitations under moderately suitability class (S2); the soil with more than three moderate limitations, and/or one or more severe limitations (s) under marginally suitable (S3) class; the soils with very severe limitations which can be corrected under N (currently not suitable); the soils with very severe limitations which cannot be corrected grouped under unsuitable class (Sys *et al.*, 1991) [17].

This method also identifies the dominant limitations that restrict the crop growth in 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 were decided by the most limiting soil characteristics. The studied soils vary in their suitability for different crops according to the criteria for the determination of the land suitability classes (Table 3). Pedons 1 and 2 are classified under Typic Haplustepts and it is not suitable (N) for rice, marginally suitable (S3) for groundnut and moderately suitable (S2) for maize and finger millet. The major limitations are excessive drainage, texture, $CaCO_3$ and organic carbon. Typic Haplustepts were not suitable for rice in soils of Prakasam district in Andhra Pradesh (Kumar and Naidu, 2012) [5].

Pedon 3 is grouped under Typic Ustorthents and the soils are not suitable (N) for rice, marginally suitable (S3) for groundnut and moderately suitable (S2) for maize and finger millet. Lithic Ustorthents in Srikalahasti division of Chittoor district, Andhra Pradesh were marginally suitable for groundnut (Nagarjuna and Naidu, 2021) [7] ang the suitability of soils for groundnut and rice was also reported by Supriya *et al.*, 2019. The major limitations of these soils are excessive drainage, soil depth, texture, $CaCO_3$ and organic carbon. Pedons 4, 5 and 6 are placed under Typic Haplutalfs and they are not suitable (N) for rice, marginally suitable (S3) for groundnut and moderately suitable (S2) for maize and finger millet. The major limitations for growing of these crops are texture, $CaCO_3$ and organic carbon. Typic Haplusteps were marginally suitable for (S3) for growing paddy crop in Yerpedu mandal of Chittoor district, Andhra Pradesh (Leelavathy *et al*., 2010) [6].

Management practices

All the soils are not suitable for paddy because of excessive drainage due to the texture of the soils and it can be improved by mixing with tank silt year after year. The soils that are located in upper slopes have erosion as a major constrain and it can be managed by taking up contour farming or contour bunding to restrict the erosion hazards. Soil depth is also problem in pedon 3 and it can be improved by deepening the soil by ridging and deep ploughing. Organic carbon status in all the soils is major fertility constrain and it is improved by improved by the application of farm yard manure, adoption of green manuring and inclusion of legumes in rotation, organic manures or application of neutral fertilizers.

Conclusions

In conclusion, the soil site suitability evaluation of study area revealed that all the pedons were not suitable for rice, marginally suitable for groundnut and moderately suitable for maize and finger millet. All the pedons have the major limitation of organic carbon so, soil and water management practices like crop rotation, application of FYM, including

legumes in cropping sequence, green manuring, integrated use of chemical and organic manures to achieve sustainable yield besides maintaining the soil quality.

Competing interests

Authors have declared that no competing interests exist.

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