International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 201-207

Received: 19-01-2020
Accepted: 21-02-2020

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Mapping land suitability for groundnut (*Arachis hypogaea* L.) in arid environment of Andhra Pradesh using geographic information system

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2c.8768

Abstract
In the present study, mapping land suitability for groundnut was carried out in arid environment of Andhra Pradesh using detailed soil survey (at 1:10,000 scale) information. Seven soil series were established based on different landforms and soil characteristics. Soil was evaluated based on soil physical and chemical properties. Soils were shallow to deep, slightly acidic to moderately alkaline (pH 6.3 to 8.6) in reaction and non-saline. The soils were loamy sand to clay and the mean clay content ranged from 19.56 to 38.56%. The mean organic carbon in soils ranged from 0.32 to 0.98% and cation exchange capacity from 6.90 to 24.82 cmol (p^+) kg^{-1} soil, respectively. The standard land evaluation criteria have been followed to assess the land suitability for groundnut. The suitability analysis indicates that about 51.3% of total geographical area (TGA) is moderately suitable (S2), 35.6% is marginally suitable (S3) and 6.9% of the area permanently not suitable (N2) to groundnut cultivation.

Keywords: Land resource, soil-site suitability, groundnut, limitation, soil sustainability

Introduction
Groundnut is one of the most important oilseed crops of India where it is grown in about 8.9 m ha area producing 8.5 mt. Although India ranks first in area and production of groundnut, its productivity (1060 kg/ha) is much less than U.S.A., China and many other countries. The main reason for this low yield in India, is that this energy rich crop is grown under energy starved conditions, mainly under rain-fed (85% un-irrigated), vagaries of weather conditions and in low fertility of light-textured soils. Also the groundnut, being drought tolerant in nature, suffers from the nutrient deficiencies resulting in low yield and this is probably the reason why agriculturists are not able to break the barrier of the stagnated yield of groundnut (Singh *et al.*, 1997) [18]. It is cultivated in all the three cropping seasons, *i.e.*, rainy (June- October), post-rainy (November-February), and summer (March- May) with nearly 80% of the annual area under the rainy season crop.

In Andhra Pradesh, groundnut is mainly cultivated in Rayalaseema *i.e.*, in Anantapur, Kadapa, Kurnool and Chittoor districts in an area of 13.1 lakh ha, with 8.4 lakh tonnes production and productivity of 646 kg ha^{-1}. In our country, more than 16% of the total groundnut production comes from Andhra Pradesh alone, where Anantapur district is potential for groundnut production (Anonymous, 2012) [1]. However this district comes under scarce rainfall zone or rain shadow regions of southern Andhra Pradesh. The area under groundnut cultivation in Anantapur district during *kharif* season is 8.0 lakh ha, production is 3.98 lakh tones and yield is 510 hg ha^{-1}. During *rabi* season, groundnut is cultivated under assured irrigation in an area of 19,515 ha, with production of 26,974 tonnes and mean yield is 1,384 kg ha^{-1} (DAC, 2014) [2].

Today the decline in groundnut area is mainly due to inadequate and uneven rainfall and changes of cropping pattern in recent years under irrigation situation (Madhusudhana, 2013) [10]. The management of land is still a major issue and one of the causes for low efficiency groundnut is rapid decline in soil fertility.

The crop can be grown successfully in places receiving rainfall between 500 mm and 1250 mm.

The rainfall should be well distributed during the flowering, pegging and pod formation stages of the crop. The groundnut crop, cannot withstand frost, long and severe drought or water stagnation. An optimum daily mean temperature of 30°C is ideal for the crop growth. Groundnut is grown on wide variety of soil types. Well drained, light textured, loose, friable sandy - loam or sandy clay loam soils well supplied with calcium and a moderate amount of organic matter are ideal for groundnut cultivation.

The lower yields of groundnut may be attributed to some of the essential soil variables *viz*., genesis, physiography, climate, vegetation, depth, colour and age etc. The understanding of soil characteristics will be helpful know the changes that may have taken place during the development and for proper planning management practices and efficient land use planning (Savalia and Gundalia, 2010) [16]. In the present study, attempt has been made to mapping land suitability for groundnut crop in arid environment of Anantapur district of Andhra Pradesh.

Materials and Methods

Study area

A case study was conducted during 2018-19 in 3 Panchayats (Ingaluru, Venkatapuram and Thummalakuntla Palle) from Obuladevaracheruvu Mandal, Kadiri, Anantapur district in the Rayalaseema region of Andhra Pradesh covering 4822 ha (Fig. 1). The study area is coming under Deccan plateau of Rayalaseema region and lies between 14°0' to 14^0 5' N latitude and 78°0' to 78° 3' E longitude, belongs to agro-ecological region (AER) of 3. The major landforms of the area are hills, ridges, uplands and low lands. Landscape and soils characteristics are given in Table. 1. Major sources of irrigation in the area are Somavati river part of Penna river system. Major land uses are rainfed and irrigated groundnut followed by pearl millet, sorghum and pulses.

Climatic condition

The climate of the study area is arid and categorized as chronic drought - prone with an average annual rainfall of 574 mm, of which about 320 mm is received during south-west monsoon period from June to September, north-east monsoon contributes about 190 mm during October to December and the remaining 70 mm is received during the rest of the year. Last 30 years rainfall distribution data are presented in figure. 2. The rainfall is erratic, uneven distribution and varies between seasons with droughts being common. The mean temperature is always above 23°C. April and May are the hottest months with mean temperatures between 32-35°C. Mean maximum temperature ranges from 30°C in December and 40°C in May. Mean minimum temperatures are lowest in December and January and ranges between 17-19°C. The length of growing period (LGP) is less than 90 days (Fig. 3).

Field Studies

The detailed soil survey was carried out in 3 Panchayats (Inagalur Venkatapuram and Thummalakuntla Palle) using village cadastral maps and IRS satellite (IRS LISS IV and Cartosat-1) imagery on 1:10,000 scale. The false colour composites of IRS imagery were interpreted for physiography and these physiographic delineations were used as base for mapping soils. The soils were studied in several transects and a soil map was prepared with phases of soil series as mapping units. Random checks were made all over the area outside of the transects to confirm and validate the soil map unit boundaries. The establishment soil series of shows the distribution, characteristics, classification, behavior and use potentials of the soils in the area. The latitude, longitude and elevation at each sampling site were recorded using a hand held global positioning system (GPS). Soil pits/profiles were excavated and describing morphological characteristics (Soil Survey Staff, 2003) [20]. One hundred and fifteen (176) soil profiles were studied and 7 major soil series were established and surface soils properties were mapped under GIS environment (Fig. 4).

Soil analysis

The soil samples were collected horizon-wise, air dried, processed, sieved using 2 mm sieve and used for determination of soil physical and chemical characteristics *viz*., Particle-size distribution by the international pipette method (Day, 1965) [3]. Soil pH and EC were determined using the procedures as described by Jackson (1973) [7] and Page *et al.* (1982) [13], respectively. Soil organic carbon was determined by the wet oxidation method (Walkley and Black, 1934) [24]. Cation exchange capacity (CEC) was determined using 1 *N* ammonium acetate at pH 7.0 (Page *et al.*, 1982) [13]. Soil moisture-retention characteristics were determined by soaking disturbed soil samples for 48 hrs to allow complete saturation. The saturated soil samples were put in the pressure plate extractor and pressure applied at 0.03, 0.05, 0.1, and 1.5 MPa suction until water ceased to drain out. The soil samples were weighed and oven dried at 105 °C for 24 hrs. Available water capacity (AWC) was calculated as the water retained between suction 0.03 and 1.5 Mpa (Klute, 1986) [8]. Base saturation, Exchangeable sodium percentage (ESP) $CaCO_3$% was determined by using standard methods given by Jackson, 1973[7]. The soils were characterized and classified as per the guidelines given in Keys to Soil Taxonomy (Soil Survey Staff, 2010) [19] given in Table.2.

Land evaluation

Land suitability evaluation for groundnut was carried out based on the procedures given by FAO (1983) [5], Sys *et al.* (1991) [23] and NBSS&LUP (1994) [12]. Slight modification is taken care based on interaction with farmers and performance of the groundnut crop in field. Soil suitability criteria were matched with soil-site characteristics of different soil types to arrive at suitability classes. Suitability classes were determined with regards to the number and intensity of limitations. Based on the ratings, the groundnut growing sites were grouped as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and temporarily not suitable (N1) and permanently not suitable (N2), which are mapped under ArcGIS software (Fig. 5).

Results and Discussion

Soil properties

Physical properties: The data pertaining to particle size analysis revealed that the mean clay content varied from 19.5 to 38.5 % (Table 3). Increase in clay content with depth is in series of 1 to 5, might be due to downward translocation of finer particles from the surface layers. The decrease in clay content with depth in other series might be influences of in-situ weathering. Silt and sand contents in general, exhibited an irregular trend with depth, which might be due to variation in weathering of parent material or in-situ formation (Geetha and Naidu, 2013) [6]. The soils textural variation ranged from loamy sand to clay. The wide textural variation might be due to variation in parent material, topography and age of the soils (Kumar and Naidu, 2012) [9]. Mean coarse fragments of

different soil series varied from 10 to 46%. Higher coarse fragments found in VGP and MTP soil series. Water holding capacity of different series mean varied from 6.42 to 17.0%. Low water holding capacity found in red gravelly soils (MLP), whereas high WHC found in clay rich soils (ODC). These variations were due to the difference in depth, clay, silt and organic carbon content (Nataraj *et al.,* 2016) [11].

Physico-chemical characteristics: The soils are slightly acidic (6.31) to moderately alkaline (8.61) in nature (Table 3). This wide variation was attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium (Devi and Anil Kumar 2010) [4]. The mean EC ranged from 0.03 to 0.04 dS m-1 in upland red soils, whereas low land series (IGR and ODC) are varied from 0.27 to 1.9 dS m^{-1} (mean of 0.4 to 1.07 dS m^{-1}). Low land soil series are have more soluble salts than upland, it may be leaching of salts from upland and transported by water and deposited in to lowland (Ram *et al.,* 2010) [15]. The mean organic carbon (OC) content varied from 0.32 to 0.98% in different series, high OC found in SVP. Higher organic matter in hills surface soils was due to addition of organic matter through leaf fall, stubbles, and roots restricting to the surface soils (Srinivasan *et al.,* 2011) [21]. The low organic carbon content was found in MLP, IGR and ODC series, might be attributed to frequent allvium depositional activities and poor soil fertility management (Srinivasarao, 2011) [22]. The mean CEC and base saturation (BS) ranged from 6.90 to 24.8 cmol (P^{+}) kg^{-1} and 81 to 100% respectively. Low values from MTP upland red soils and highest from low land ODC soils series. The low CEC and BS may be due to good drainage conditions, which favour to removal of bases by percolation of water from upper to lower slopes. The high CEC values are directly related to clay type and organic carbon content of the soils. The free $CaCO_3$ ranged from 1.3 to 5.26% being mean was high in IGR and ODC series, might be due to semi-arid climate. In ODC soils, the $CaCO_3$ increased with depth which might be due to leaching of calcium and its subsequent precipitation in lower horizons due to high pH level (Sharma *et al.,* 1996) [17]. The mean ESP ranged from 0.39 to 5.7%. The comparatively higher ESP values than upland red soils, which due to leaching of sodium ions from upland and deposited in lower layer of the profiles. The above findings are in line with Savalia and Gundalia (2010) [16] in Uben Irrigation command area of Saurashtra region in Gujarat.

Soil-Site suitability evaluation for Groundnut

The analysis for groundnut suitability indicates that the soil developed in different slope position (0-15%) with slight to severe erosion. Soils are moderately shallow to very deep depth with moderately to well drained. Among the soil series none of them qualified to highly suitable (S1) class with no limitation for groundnut cultivation. Whereas, moderately suitable (S2) class is occupied 2470 ha (51.3%) with slight limitation of excess gravelliness, low soil depth, poor soil fertility and heavy texture. Slight soil limitations are corrected through proper soil and water conservation measures and addition of soil nutrients. Marginally suitable (S3) soils are present in 1716 ha (35.6%) with major limitation of heavy soil texture, rooting condition, gravelliness and undulating topography and 333 ha (6.9%) area are permanently not suitable (N2) to groundnut cultivation. Similar results were also reported by Rajendra Hegde *et al.* (2018) [14].

Table 1: Landscape characteristics of study area

S. No	Landform	Series	Slope%	erosion	Drainage	Area (ha)	%TGA
1	Hiils/Dyke	Settivaripalle (SVP)	5-15	Severe	Somewhat excessive	214	4.4
2	Uplands	Mittapalle (MTP)	3-5	Moderate	Well	747	15.5
3		Venukanagayyapalle (VGP)	1-3	Moderate	well	1058	21.9
4		Mallapalle (MLP)	1-3	Moderate	well	505	10.5
5		Gajukuntapalle (GKP)	1-3	Moderate	well	653	13.5
6	Low land	Inagalur (IGR)	0-1	Slight	Moderately well	899	18.6
7		Obaladevaracheravu (ODC)	0-1	Slight	Moderately well	110	2.3

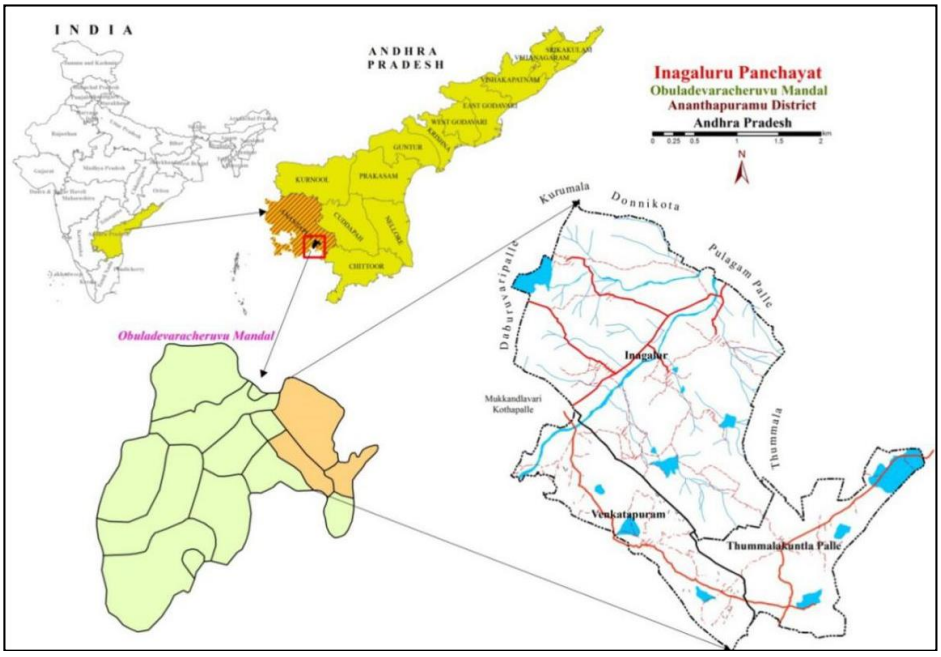


Fig 1: Location map of study area

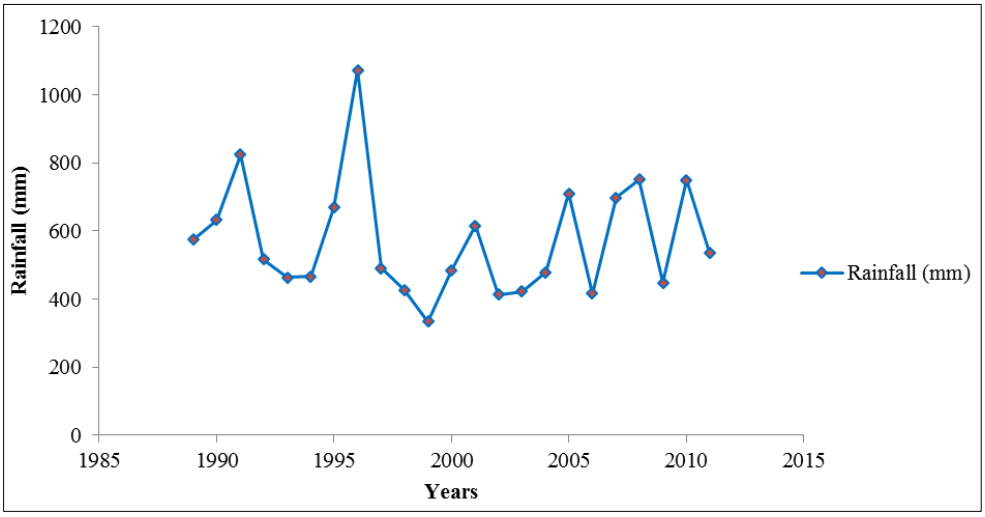
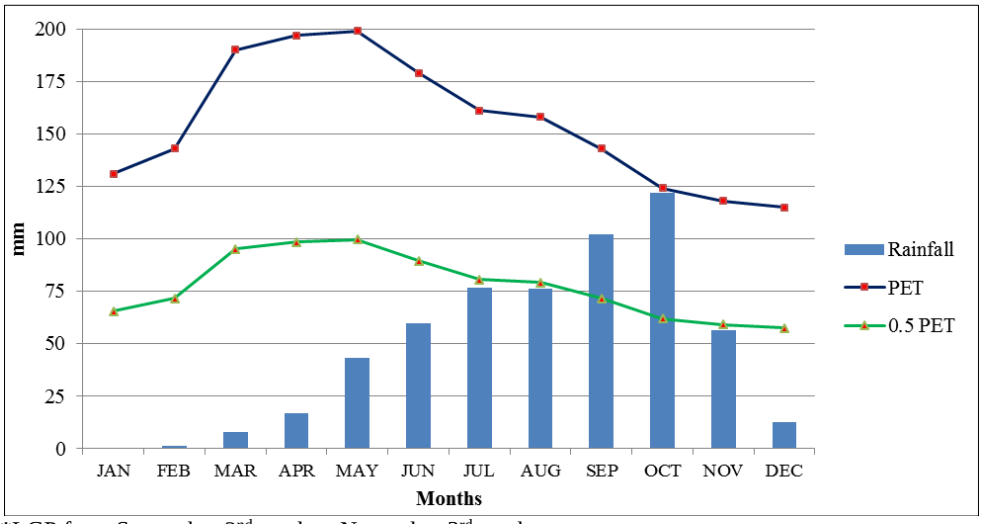


Fig 2: Average yearly rainfall distribution in ODC Mandal, Anantapur district, Andhra Pradesh



***LGP from September 2nd week to November 3rd week

Fig 3: Average monthly rainfall and Length of growing period of ODC Mandal, Anantapur district, Andhra Pradesh

Table 2: Characteristics and Classification of Soils in the study area

S. No	Series	Soil characteristics	Total profiles studied	*USDA -classification
1	Settivaripalle (SVP)	Settivaripalle soils are shallow (25-50 cm), well drained, have dark reddish brown, gravelly clay soils occurring on moderately sloping (5-10%) ridges.	5	Clayey -Skeletal, mixed, isohyperthermic (Paralithic) Haplargids
2	Mittapalle (MTP)	Mittapalle soils are moderately shallow (50-75 cm), well drained, have dark red to dark reddish brown, gravelly loamy soils occurring on very gently to gently sloping uplands under cultivation.	32	Loamy-skeletal, mixed, isohyperthermic Typic Paleargids
3	Venukanagayyapalle (VGP)	Venukanagayyapalle soils are deep (100-150 cm), well drained, have dark red to dark reddish brown, gravelly loamy soils occurring on very gently sloping to gently sloping uplands under cultivation	46	Fine-loamy, mixed, isohyperthermic Typic Paleargids
4	Mallapalle (MLP)	Mallapalle soils are shallow (25-50 cm), well drained, have dark reddish brown, gravelly clayey soils occurring on very gently sloping uplands under cultivation.	21	Clayey -Skeletal, mixed, isohyperthermic (Paralithic) Haplargids
5	Gajukuntapalle (GKP)	Gajukuntapalle soils are moderately deep (75-100 cm), well drained, have dark reddish brown, gravelly loamy soils occurring on very gently to gently sloping uplands under cultivation.	22	Loamy-skeletal, mixed, isohyperthermic Typic Paleargids
6	Inagalur (IGR)	Inagalur soils are deep (100-150 cm), moderately well drained, have dark brown to dark yellowish brown, clayey soils occurring on nearly level to very gently sloping lowlands under cultivation	29	Fine, mixed, isohyperthermic Typic Haplocambids
7	Obaladevaracheravu (ODC)	Obaladevaracheravu soils are very deep (>150 cm), moderately well drained, have very grey to very dark greyish brown, clayey soils occurring on nearly level to very gently sloping lowlands under cultivation	15	Fine, mixed, isohyperthermic Vertic Haplocambids

*USDA- United States Department of Agriculture

Table 3: Physical and Physico-Chemical characteristics of the soils

Depth (cm)	Horizon	Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)	Texture	Coarse fragments (%)	WHC%	pH (1:2.5)	EC (dS m^{-1})	OC %	CEC (cmol (P^+) kg^{-1})	BS %	$CaCO_3$ %	ESP %
S1-Settivaripalle (SVP) series														
0-13	Ap	50.2	17.2	32.4	scl	35	9.08	6.11	0.07	1.84	10.7	93	-	0.79
13-31	Bt1	57.8	5.97	36.1	sc	42	6.63	6.53	0.03	0.49	14.4	91	-	0.54
31-47	Bt2	46.8	7.40	45.7	sc	38	5.69	6.29	0.03	0.61	15.0	88	-	0.48
Mean		51.6	10.19	38.06		38	7.13	6.31	0.04	0.98	13.3	90		0.60
S2-Mittapalle (MTP) series														
0-13	Ap	86.7	8.62	4.67	ls	25	7.36	6.73	0.06	0.67	2.90	81	-	1.20
13-31	Bt1	68.1	9.17	22.6	scl	50	10.0	6.61	0.03	0.69	8.70	85	-	1.45
31-62	Bt2	58.9	9.53	31.4	scl	60	9.89	6.38	0.03	0.53	9.10	78	-	0.88
Mean		71.2	9.11	19.5		45	9.11	6.57	0.04	0.63	6.90	81		1.18
S3-Venukanagayyapalle (VGP) series														
0-20	Ap	85.4	6.99	7.54	ls	23	7.95	6.30	0.04	0.60	5.00	82	-	0.36
20-35	Bt1	60.1	9.33	30.4	scl	52	9.85	6.27	0.02	0.68	9.50	77	-	0.25
35-50	Bt2	56.9	11.9	31.0	scl	50	10.6	6.32	0.02	0.53	11.5	86	-	0.40
50-84	Bt3	63.6	11.2	25.0	scl	50	9.28	6.60	0.02	0.30	11.9	86	-	0.46
84-115	Bt4	60.5	11.4	28.0	scl	60	8.91	6.79	0.02	0.38	12.3	92	-	0.46
Mean		65.3	10.1	24.3		47	9.23	6.46	0.02	0.50	9.64	84		0.39
S4-Mallapalle (MLP) series														
0-13	Ap	86.3	7.20	6.43	ls	20	4.75	6.21	0.05	0.28	4.70	71	-	0.69
13-36	Bt1	56.6	4.96	38.4	sc	50	8.09	6.58	0.03	0.36	17.9	95	-	0.45
Mean		71.4	6.08	22.4		35	6.42	6.40	0.04	0.32	11.3	83		0.57
S5- Gajukuntapalle (GKP) series														
0-19	Ap	86.3	7.81	5.80	ls	10	8.32	6.75	0.05	0.62	3.30	87	-	0.40
19-42	Bt1	58.5	7.48	33.9	scl	40	11.1	6.52	0.04	0.88	11.2	82	-	0.43
42-66	Bt2	58.3	9.85	31.8	scl	35	12.5	6.53	0.02	0.67	12.8	82	-	0.44
66-95	Bt3	67.7	7.96	24.2	scl	35	10.7	6.74	0.01	0.67	10.0	84	-	0.41
Mean		67.7	8.27	23.9		30	10.6	6.63	0.03	0.71	9.32	83		0.42
S6- Inagalur (IGR) series														
0-16	Ap	53.5	11.4	35.0	sc	10	8.72	8.13	0.67	1.39	19.7	100	5.26	6.53
16-33	Bw1	49.4	20.2	30.3	scl	10	6.29	8.45	0.31	0.60	16.8	100	3.67	5.12
33-49	Bw2	37.0	27.9	35.0	cl	-	8.38	8.52	0.27	0.45	21.0	100	3.06	5.45
49-77	Bw3	26.4	30.4	43.0	c	-	7.89	8.53	0.29	0.26	24.8	100	3.30	5.49
77-104	Bw4	14.5	35.2	50.1	c	-	9.95	8.37	0.30	0.36	27.7	100	2.94	5.34
104-128	Bw5	52.9	18.1	28.9	scl	-	7.24	8.35	0.27	0.22	17.4	100	1.30	6.07
Mean		39.0	23.9	37.1		10.0	8.10	8.40	0.40	0.50	21.2	100	3.30	5.70
S7- Obaladevaracheravu (ODC) series														
0-15	Ap	36.5	26.0	37.4	cl	-	10.5	7.92	0.28	1.01	23.9	100	1.83	2.34
15-50	Bw1	41.5	23.2	35.2	cl	-	11.3	8.72	0.36	0.41	22.2	100	1.96	2.56
50-77	Bw2	38.6	22.0	39.3	cl	-	22.6	8.99	1.04	0.33	25.7	100	2.94	4.26
77-114	Bw3	33.4	23.9	42.6	c	-	21.6	8.78	1.90	0.22	27.8	100	4.41	9.44
114-145	Bw4	36.1	25.4	38.3	cl	-	19.4	8.65	1.80	0.18	24.5	100	5.26	9.47
Mean		37.2	24.1	38.5			17.0	8.61	1.07	0.43	24.82	100	3.28	5.61

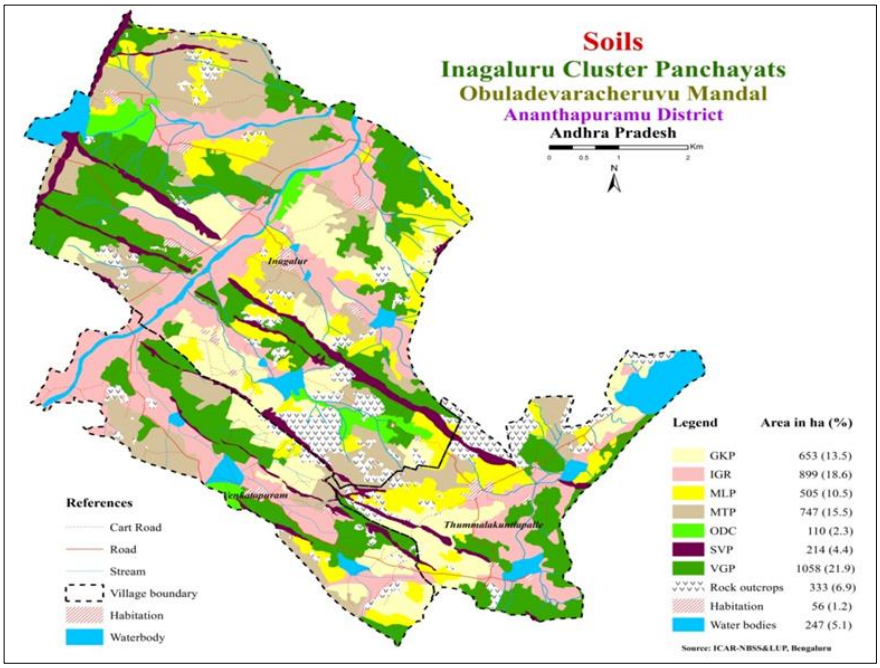


Fig 4: Soil map of the area

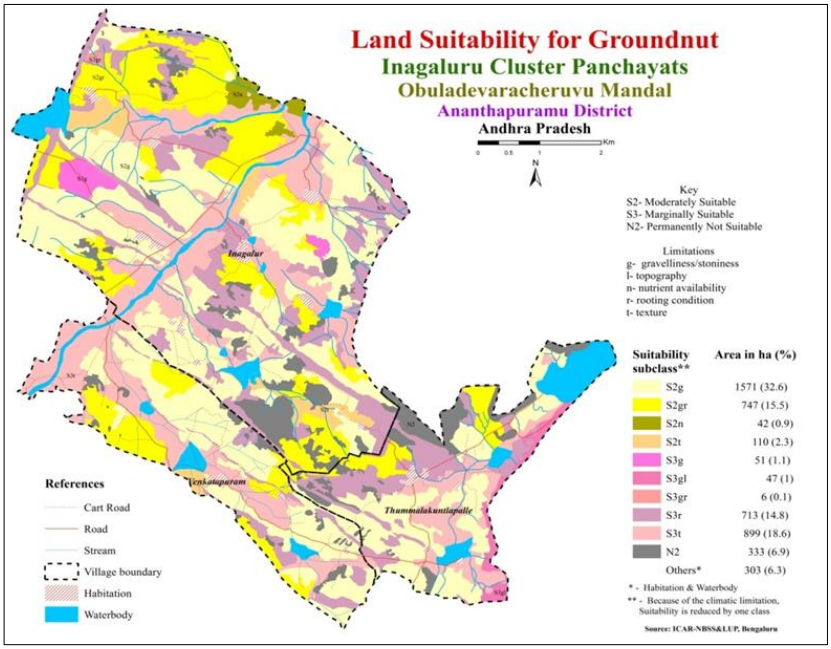


Fig 5: Land suitability evaluation for Groundnut

Conclusion

Based on the results of the study area, it is concluded that the soils in cluster of three Panchayats were moderately shallow to deep in depth, slightly acidic to moderately alkaline in reaction, non-saline and low to high in organic carbon and CEC and the exchangeable complex was dominated by Ca^{2+} followed by Mg^{2+}, Na^{+} and K^{+}. Result of suitability evaluation indicated that about 51.3% of TGA in the area is moderately suitable (S2), 35.6% is marginally suitable (S3) and 6.9% of TGA is permanently not suitable (N2) for groundnut cultivation. The major limitation of the area is high gravelliness, low soil depth, poor soil fertility, undulated topography and heavy soil texture. Assessment of site specific soil constraints to groundnut cultivation could able to implement better technologies and soil and water conservation measures for enhancing groundnut productivity by farming community.

Acknowledgements

The present study is a part of the research project of "Andhra Pradesh Drought Mitigation Project" (APDMP) funded by the International Fund for Agricultural Development (IFAD). The authors thank to Government of Andhra Pradesh for their financial support.

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