Original Article

Indian Journal of Plant and Soil
Volume 6 Number 1, January - June 2019
DOI: http://dx.doi.org/10.21088/ijps.2348.9677.6119.1

Appraisal of Land Resources to Assess Climate Change Impacts for Rainfed Groundnut (*Arachis Hypogaea* L) Production Potential in Pulivendula Tehsil, YSR Kadapa District, Andhra Pradesh, India

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How to cite this article:

B.P. Bhaskar, Sunil Maske, S.C. Ramesh Kumar *et al.* Appraisal of Land Resources to Assess Climate Change Impacts for Rainfed Groundnut (*Arachis Hypogaea* L) Production Potential in Pulivendula Tehsil, YSR Kadapa District, Andhra Pradesh, India. Indian J Plant Soil. 2019;6(1):5-19.

Abstract

The land suitability evaluation was a spatial excercise to generate biophysical suitability for cropping systems on judging soil - climate - landscape systems and linked with to the individual polygons of (1 : 25 000 scale) soil map available for Pulivendula tehsil. Aridity is a recurring phenomena with serious economic loss in Pulivendula of Kadapa district, Andhra Pradesh where the rainfed groundnut yields are historically less than 400 kg/ha. The soil map with 43 soil series association showed that 38% of area is under hills and ridges with soil cover of inceptisols (46%), vertisols (13%), alfisols (5%) and entisols (4%) having slightly to moderately alkaline with low salt concentration (mean EC <0.5 dSm-1), high ESP (> 7.61% in case of soils on shale) and moderately deep (mean of 97.81cm) to very deep as compared to soils on quartzite (mean of 30.75 cm). These soils were evaluated as weakly susceptible to water erosion covering 29037 hectares (K < 0.20). The appraisal of suitable lands for groundnut showed that 42% of total cropped area is moderately suitable but extensively sprawled in Vempalli (6894 ha, 27.39% of cultivated area) and Vemula (3613ha, 17.29% of cultivated area). The agroeconomic analysis further showed that 13.94% of lands have benefit cost ratio less than I due to seasonal aridity and creating panic among groundnut growers. These findings illustrate a possible scenario for groundnut cultivation in the event of increasing aridity and impacting crop management practices in the region.

Keywords

Aridity index; Angot index; Benefit-cost ratio; Land evaluation; Soil mapping unit; Pulivendula.

Introduction

Groundnut is grown on 26.4 million ha worldwide with a total production of 37.1 million metric tonnes and an average productivity of 1.4 metric t/ha (GOI, 2008). Over 100 countries worldwide grow groundnut. Developing countries constitute 97% of the global area and 94% of the global production of this crop. The production of groundnut is concentrated in Asia and Africa (56% and 40% of the global area and 68% and 25% of the global production, respectively). In India, about 75% of the groundnut is grown as kharif (June - September) in low to moderate rainfall zone (parts of peninsular region and western and central regions) with a short period of distribution (90 - 120 days). De *et al.* (2005) have reported that in India the extreme weather events have increased considerably over the period of 100 years.

In India, groundnut yields were reported to be vulnerable from year to year because of large inter–annual variation in rainfall (Sindagi and Reddi,

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Received on 22.02.2019; **Accepted on** 20.06.2019

1972) and 89% of yield variation is due to rainfall variability in August to December growing period (Bharghava *et al*., 1974). It was reported further that 50 per cent of variance in ground yield is attributed to rainfall (Challinor *et al*., 2003) and required seasonal rainfall of 50cm to sustain groundnut (Gadgil, 2000). The pod yield of groundnut showed highly significant curvilinear relationship with moisture use (sum of rainfall and soil moisture). Moisture use of 350-380 mm was found to be optimum for getting maximum yield (AICRPAM, 2003, Pandey *et al*., 2016). Scanty rainfall in Rayalseema plateau in Andhra Pradesh lead to drought, which affected water levels and caused misery and distress not only to small and marginal farmers but also to the large farmers. It was reported that the drought during 1983-84, there was a drop of groundnut production from 12,20,000 tonnes of output to 3,51,200 tonnes with a steep fall in agricultural production, large scale unemployment of agricultural labourers, acute drinking water scarcity and fodder scarcity. Andhra Pradesh is historically affected by severe droughts and home for 30 million people of which 70 percent of people in the state's suffer drought-related crop production loss. Under the "agribusiness as usual" every second or third year (in other words, in 40 percent of all years), average annual loss of output owing to the drought-prone climate is 5 percent and vulnerable sector to rainfall variability account for 43 percent of the cultivators and 36 percent of the agricultural laborers with an average per capita income below the state average (90 percent). In *kharif* -2014, it was reported that groundnut incurred heavy damage in 6.06 lakh ha (Govt. of A.P,. 2014). In the present study, Pulivendula, a drought hit tehsil in Kadapa district under Southern agro climatic zone (AP-4) was selected to assess the impacts of climate change and properties of major soil types of the Agricultural Development Areas (ADAs) of groundnut production. Groundnut being a cash crop, can give relatively higher returns for a limited land area, and is well adapted to the hot semi-arid conditions. In addition to that, it affects not only the high returns yielded by the groundnut producers and marketers, but the water resources management and the overall economy of the region (Birthal *et al.,* 2014; TERI, 2014; Bapuji Rao *et al*., 2015). The "land suitability" is an estimate of the fitness of a soil and its landscape for production of a specific agricultural crop based on production limitations and crop productivity (FAO, 1976). The FAO method of soil - site suitability criteria was employed for groundnut in Pulivendula tehsil, Kadapa district (Rajendra Hegde et al., 2018), cotton based cropping systems in Yavatmal district (Bhaskar *et al*., 2011) and for sorghum and pigeon pea using GIS on 1:10000 scale in Mormanchi Micro watershed, Gulbarga District (Rajendra Hegde *et al*., 2017). Methods of land evaluation (including land suitability) have become more sophisticated over time (Sonneveld *et al*., 2010) with increased availability of large geographic and production datasets and geographic information systems. Land have become more quantitative and process oriented (Elsheikh *et al*., 2013). The land suitability rating system (LSRS of Canada, Agronomic Interpretations Working Group (1995) and Pettapiece *et al*., 2007), respectively draw information from two data sets and facilitates to integrate soil survey data bases that contain attributes about the mapped soils and their associated landforms, and from regional climate data sets from which a series of agroclimatic indices are calculated. In the present work, soil-climate - landscape systems was adopted to assess climate change impacts in relation to soil and landscape attributes for groundnut production in drought hit Pulivendula tehsil of Kadapa district, Andhra Pradesh. The information of crop fitness in accordance with soil series has practical significance to provide more productive, profitable and sustainable options for groundnut growers in the region. This article further examined how climate change and variability occur and how crop production has responded in using land resource data of Pulivendula on 1:25000 scale to assess long term groundnut development.

Materials and Methods

Location and agroclimate

Pulivendula (Fig. 1) lies between 14°16′ to 14°44′ N and 77°56′ to 78°31′E covering an areaof 1,46,235 hectares (ha). The agroclimate is characterized as semiarid with mean annual rainfall of 564 mm and 43 rainy days. The LGP varied from 90-105 days for Pulivendla and Vemula, 105-120 days for Lingala and Tondur and 120-135 days for Simhadripuram and Vempalli mandals. As per the land evaluation guidelines, this region is moderately to marginally suitable for peanut cultivation under hot arid ecosubregion (K6E2) with deep loamy and clayey mixed red and black soils, low to medium available water holding capacity (AWC) and length of growing period (LGP) 60-90 days (Mandal *et al*.,1999). Physiographically the area is characterized by rugged hills with valleys, pediments and the geology being granites, granite gneisses, cherty dolomites, quartzites and shales (Nagaraja Rao *et al.*, 1987). The study area is characteristically occupied by the Papaghni and Chitravati group of rocks of Cuddapah Super Group. Papaghni group includes a) Gulcheru formation comprising quartzite, arkose and conglomerate; b) Vempalli formation comprising dolomites, chert, mudstone, quartzite, basic flows and intrusive. The Chitravati group includes a) Pulivendla formation comprising quartzite with conglomerate and b) Tadipatri formation consisting of shales, dolomite and quartzite; c) Gandikota formation comprising quartzite and shale (Basu *et al.*, 2009). Using remote sensing data of IRS-P6-LISS-IV data on 1:25000 scale, 9 broad landforms such as elongated ridges / cuseta (750-360 m above mean sea level,), Dissected hills/summits, highly dissected plateau remnants, isolated hills / monadnocks / mounds / tors boulders/ domical rises/rock outcrops (54135 hectares of total area), interhill basins (6163 ha of total area), undulating upper sectors, gently sloping middle sectors (39092 ha of total area) and colluvial lower sectors (28542 ha of total area) were identified and reported (Naidu *et al.*, 2009).

Climate data and analysis

The monthly rainfall, maximum, minimum and mean temperature and potential evapotranspiration data for the period of 1901 to 2002 for kadapa district was obtained from Indian Water Portal.org. of IMD data (Indian Meteorological Department) to workout climatic indices such as (1) aridity index of De Martonne (1925) and Angot index (Dragot˘a *et al.*, 2008).

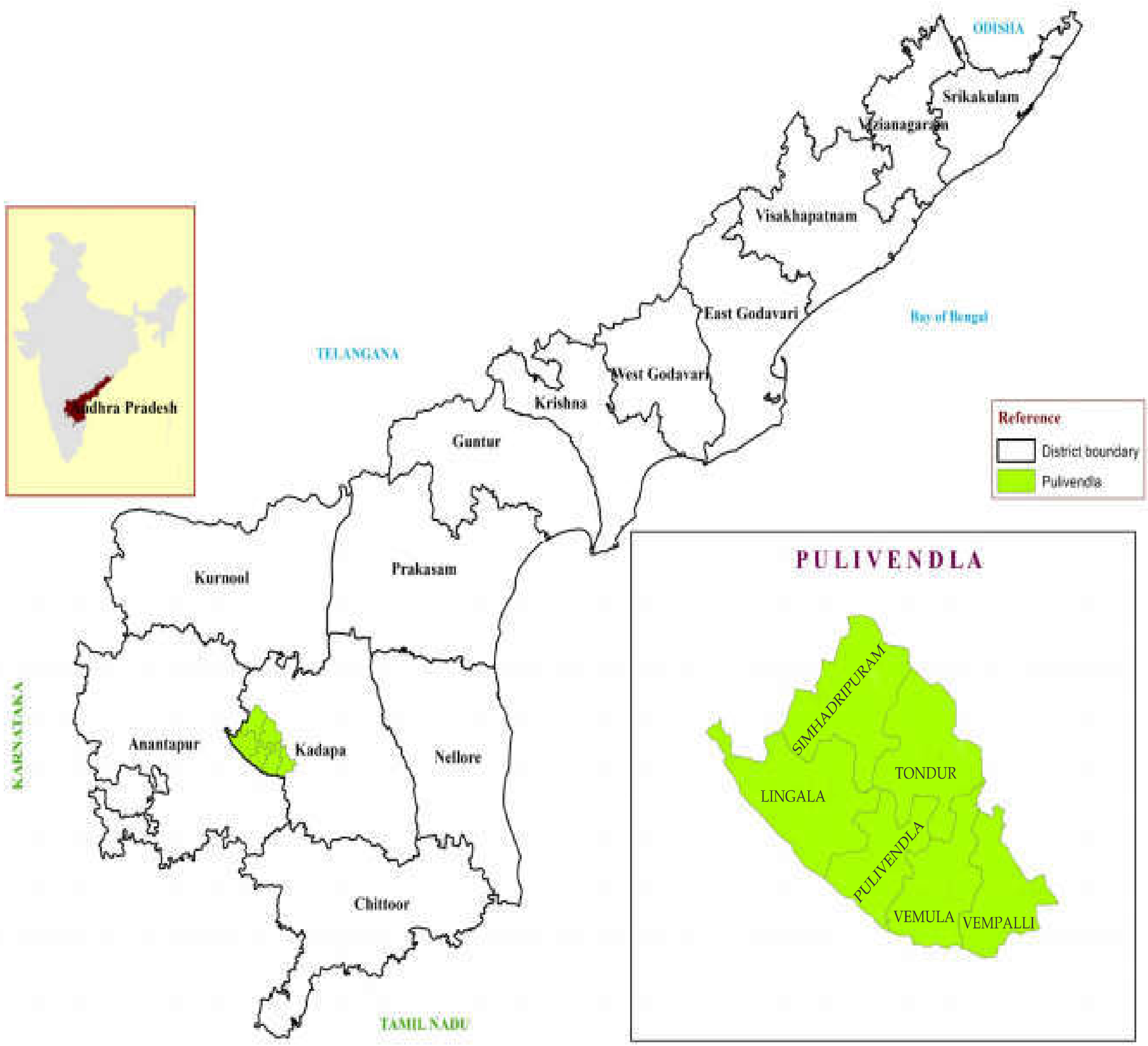

Fig. 1: Location map of Pulivendula tehsil with mandal boundaries, Kadapa district

- *The aridity index of De Martonne*

The aridity index of De Martonne (Im) is therefore defined as the ratio of the annual precipitation sum P in mm and the annual mean temperature in °C +10 as defined below:.

I_{dm} = Aridity Index (De Martonne) = Where AAR = Annual average rainfall in mm, AAT = Average daily temperature over the year °C.

The monthly value of the De Martonne Aridity Index is calculated by the following equation: Im = 12p′/t′ + 10 where p′ and t ′ are the monthly mean values of precipitation and air temperature for the driest month (considered January, February, March, April, May for kadapa district). When the value of I_{dm} is lower than 20, then the land in this month needs to be irrigated (Zambakas, 1992).

Aridity index	Climate type
0-10	Arid
10 to 20	semiarid
20-24	Mediterranean
24-28	Semi-humid
28-35	humid
35-55	Very humid
>55	Extremely humid

- *Angot pluvial index (K)*

Angot pluvial index was initially aimed at determining the characteristic types of monthly and annual variation of precipitation based on regional and local comparisons. It was computed according to the formula below (Dragota *et al*., 2008):

K (Angot pluvial index) = p/ P

where p = q/n, q is the monthly precipitation amounts; and, n is the number of days/months.

P = Q/365 where Q is the multiannual precipitation amounts. Therewith, the pluvial peaks for each relief unit were highlighted (Dragota *et al*. 2008).

Susceptibility classes of precipitation liable to triggering soil erosion based on Angot pluvial index.

Field survey and soil mapping

A field survey was conducted using false colour composites (FCC's) of P6-LISS-IV imagery to prepare a landform map on 1:25,000 scale. In the study area, about 330 profiles were studied in 66 transects (cut across as 3 to 4 landform units) along with 120 random checks for verification of occurrence of soils with respect to landform units.

The morphological properties of twenty five soil series were described as per Schoeneberger *et al.* (2012) and collected horizon wise soil samples for determination of physical (particle size distribution) and chemical (pH in 1:2.5 soil water), Organic carbon by wet digestion, Exchangeable bases by IN NH_4O Ac extractable and distillation of ammonium for CEC, avaliable N, P, K and DTPA extractable Fe, Mn, Cu, and Zn as per standard procedures described in Dewis and Freitas (1970). The soil map is generated for 43 mapping units as series and its association in GIS environment (ARC info. Version 10). Soil erodability and soil loss estimations were made as per USLE equation (Wischmeier and Smith, 1978) and categorized soil loss in to different soil erosion risk zones based on Uddin, *et al.* (2016) as : very low = soil loss of < 0.5t/ha/year, low = 0.5-1t/ha/year, low-medium = 1-2 t/ha/year; medium =2-5t/ha/year; high - medium = 5-10t/ha/year, high =10-20t/ha/year, very high = 20-50t/ha/year and extremely high = > 50t/ha/year.

Land evaluation

The soil map on 1:25000 scale was used for land evaluation exercise in GIS environment (Arc info. version 10). In the first step, only static land variables such as slope, soil, irrigation, drainage, and village borders were used to distinguish land units. In the next step, dynamic variables (rainfall and temperature), properties of the top soil horizon (0–20 cm), and land requirements for ground nut were used to determine suitability classes. Crop requirements were matched with land characteristics and applied to determine overall suitability for groundnut. The criteria used for groundnut suitability analysis was done as per the evaluation scheme of FAO (1983). The socio-economic survey of farm households in Pulivendula tehsil were conducted and collected information on cost of groundnut cultivation with respect to soil mapping units depicted on 1:25,000 scale. On each soil types, about 9 farm households (3 each of marginal, small and large farm households) were

Pluviometric attributes	Very dry	dry	normal	rainy	Very rainy
Pluvial erodibility classes	Very low	low	Moderate	severe	Very severe
Angot index values (K)	<0.99	1.0-1.49	1,50-1.99	2.00-2.49	>2.50

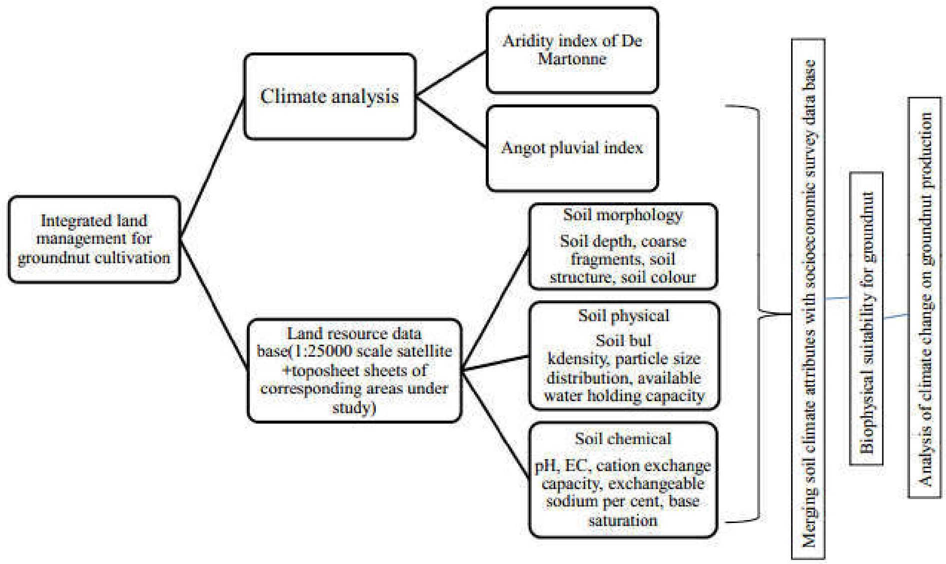

Fig. 2: Methodology for integrating soil-climatic attributes to derive land suitability for groundnut in Pulivendula tehsil, Andhra Pradesh

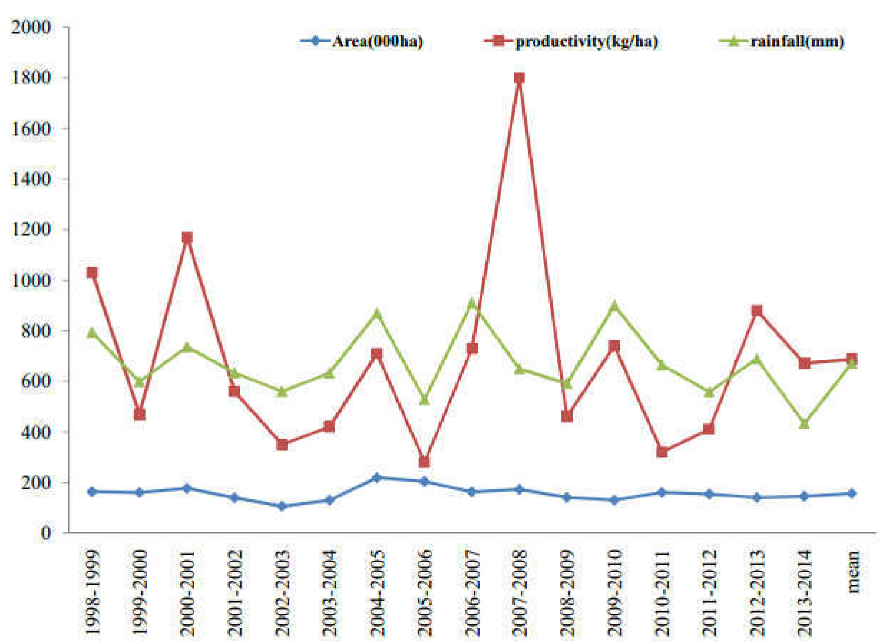

Fig. 3: Yearwise area and productivity of groundnut in kadapa district in relation to rainfall

selected and collected data for 20 soil types.The flow chart of methodology adopted in the present study was given in figure 2.

Results and Discussion

Area and productivity of Groundnut in relation to south west monsoon rainfall

The livelihood system of the rainfed farmers in Pulivendula tehsil is planned on the basis of arrival of south west monsoon (june to september) and depends on the farming operation and labour productivity hindered by the acute aridity during crop growing season (wide differences exist between the wet and dry seasons). Thus, the series of the seasons are remarkably important for production and allocations of land for groundnut production. The data pertaining to area and productivity of groundnut in relation to south west monsoon (1988-99 to 2011-12) for Kadapa district (Fig. 3) shows that the groundnut is grown in 1.51 ± 39.32 lakh hectares with coefficient of variation of 25.9 per cent and mean productivity of 623.57 ± 294.94

kg/ha. This area received mean rainfall of 402.4 ± 110.53 mm during south west monsoon (June to September) with coefficient of variation of 29.43%. During 2004 -2005 and 2005-2006, the area under groundnut is exceeded more than 2 lakhs with low productivity of 280 kg/ha. It is interesting to note that maximum yield of groundnut is 1080 kg/ha in the south west monsoon rainfall of 259 mm. It is true to say that sowing of groundnut between 26^{th} to 27^{th} standard week, reasonably a good crop can be produced under 269 to 298 mm of rainfall as stated by Guled *et al*. (2013). Earlier attempts were made to establish relation of rainfall with productivity of groundnut and fitted regression model as Yield =15.01+ 1.892 June + 2.301 July + 1.582 August + 0.648 September with R^2 (coefficient of determination) of 0.48 (Parmar, 2013). Here, the influence rainfall on area and productivity of groundnut in kadapa district is expressed in polynominal equation as given under:

Area (ha) = -0.010 (rainfall, mm)^2 + 0.573 (rainfall, mm) +82.98 (R^2 = 0.522*)

Productivity (kg/ha) = 8E-07 (rainfall, mm)^4 +0.001 (rainfall, mm) 3 - 0.795 (rainfall, mm)^2 + 198.6 (rainfall, mm) -1673--------(R^2=0.370)

Climatic characteristics

We initially defined "cultivable areas suitable for groundnut by month, setting criteria of minimum monthly rainfall of 100 mm for tillage/seedling establishment and minimum temperature of 21°C with 500 mm of rainfall during crop season and 25^0C to 30^0C optimal air temperature over the entire growing period (Cox, 1979). The criteria applied across the region for groundnut cultivation as (1) monthly temperature > $21^0 \approx 23^0$ C and with a Tfp (bud temperature) of 40^0C based on Prasad *et al.* (2003) and monthly rainfall > 40 mm and monthly aridity (De Martonne Aridity Index) < 20. The decadal mean and standard deviation for rainfall, mean temperature and De Martonne Aridity Index for the period of 1901 to 2002 is worked out (Table 1). The data shows that this area receives mean annual rainfall of 679.59 ± 237.52 mm, of which the *kharif* rainfall contributes 340.69 mm (50.28% of total rainfall) with a range of mean air temperature of 30.7^0C to 36.9^0C and an aridity index of 11.29 to 14.25 indicating semiarid conditions during groundnut growing season. The regional rainfall analysis shows that September is rainy with mean of 186.82 ± 81.56 mm and 43.61 per cent of coefficient of variation during 1981 to 1990. Next to September, October receives mean rainfall of 100.28 ± 60.01 mm (1941-1950) but 152.24 ± 88.70 mm (1971-1980) and August with irregular rainfall trends from 65.26 ± 30.25 mm (1921-1930) to 119.87 ± 40.78 mm (1991-2002). The De Martonne Aridity Index (Im) below 15 is reported for monthly decadal data sets from June to September to define climate as semiarid and Im lower than 20, then the land in this month needs to be irrigated (Zambakas, 1992). Similar kind observations were reported and warrants to identify alternate remunerative crops to rainfed groundnut in alfisols (Radha kumara *et al*., 2016) where rainfall is reasonably distributed throughout the growing season, crops produce about 5 to 10 kg/ha of pods per millimetre of rainfall. For dryland peanuts, in the region an average rainfall of at least 400 mm from June to September is needed to produce a reliable crop. The long term rainfall data shows a deficit of 60 mm but receives >135 mm rainfall during pod development phase (September).

Angot index

Angot's pluviometric index (k), is used to highlight the annual variation characteristics of atmospheric rainfall and in particular, to determine the types of their variation during the year. Thus, rainy intervals (k >1) and dry intervals (k) are being emphasized. According to the obtained values, ratings of rainy month for supraunitary values, and dry month, for subunitary values, were assigned. This also represents the ratio of the average between the daily volume of precipitation in a month and the amount that would be returned in case of a uniform distribution of the annual rainfall amount in all days of the year. The resulted index values were used to determine the rainy intervals by grouping them under the pluvial classes corresponding to the assigned rainfall attributes (Table 2). Therewith, the pluvial peaks for each relief unit were highlighted. In order to explain the cumulative effect of the erosivity triggered by precipitation, Angot pluvial index was computed using the climate data registered at Kadapa station over 109 years (1901 to 2010).

On an yearly basis, for the 5 mm and 10 mm thresholds, the March–October interval marks the season of the year most affected by such amounts, while the upper threshold (20 mm) is restricted to the August to October (Table 2) and increased erosive potential of high - quantity or high - intensity rainfalls with a probability > 50% (Dragota, 2006). Over 109 years of monthly rainfall data was used to compute the angot index and workedout the wet-dry spells. It is estimated that

Table 1: Mean and standard deviation (± SD) of monthly precipitation, average temperature and De Martonne Aridity Index

Climatic variables	January	February	March	April	May	June	July	August	September	October	November	December
1. Rainfall (mm)												
1901-1910	1.43± 1.21	2.28± 5.71	4.63± 8.73	18.62± 25.42	44.17± 39.90	43.06± 19.57	63.60± 29.08	103.59± 60.98	176.62± 82.24	104.18± 49.80	64.57± 72.64	20.44± 21.60
1911-1920	0.92± 0.98	1.37± 2.73	8.51± 15.70	10.71± 15.82	56.12± 23.58	36.12± 16.36	66.88± 43.34	79.21± 43.14	170.89± 48.33	116.33± 73.58	97.69± 59.57	12.69± 15.08
1921-1930	1.14± 0.69	3.57± 5.64	6.42± 9.43	27.61± 27.43	57.36± 72.57	45.70± 17.63	65.49± 33.28	65.26± 30.51	155.81± 68.94	119.47± 66.47	82.06± 63.17	14.56± 22.86
1931-1940	0.61± 0.80	5.61± 9.41	5.91± 6.17	29.45± 30.65	43.55± 30.14	48.67± 21.81	61.89± 19.63	81.84± 64.01	140.83± 74.68	109.43± 46.50	76.42± 45.02	11.76± 16.39
1941-1950	0.62± 0.84	2.96± 3.97	4.94± 11.19	17.58± 13.52	60.03± 43.76	46.98± 20.96	66.90± 35.95	96.25± 34.56	166.05± 48.67	100.78± 60.01	73.64± 56.05	18.91± 24.06
1951-1960	0.40± 0.58	0.96± 2.22	5.79± 7.48	30.28± 27.88	75.77± 58.74	51.66± 37.50	80.50± 31.87	82.85± 51.50	143.46± 108.38	133.10± 76.19	49.89± 53.15	18.27± 24.36
1961-1970	0.80± 1.57	1.96± 3.19	5.69± 9.93	26.13± 32.35	58.25± 42.45	55.85± 20.53	79.11± 30.22	107.83± 54.89	161.76± 72.80	118.32± 67.88	58.12± 53.72	25.04± 18.19
1971-1980	0.45± 0.83	3.70± 6.09	3.10± 5.45	20.87± 31.38	70.64± 53.73	46.61± 16.52	70.85± 30.52	86.92± 45.29	137.16± 71.43	152.24± 88.70	83.21± 46.30	14.07± 19.01
1981-1990	0.71± 1.32	4.45± 8.02	12.94± 9.91	21.11± 16.66	51.44± 46.92	46.82± 20.12	79.92± 36.64	85.25± 57.16	186.92± 81.56	116.09± 39.37	58.19± 23.56	18.82± 11.93
1991-2002	0.67± 1.05	2.12± 4.28	3.98± 5.60	23.69± 17.31	62.36± 25.33	63.78± 29.63	65.52± 21.81	119.87± 40.78	124.86± 40.48	165.75± 41.87	60.12± 36.70	16.58± 19.99
2. Monthly average temaparature (°C)												
1901-1910	28.72± 0.59	31.15± 0.56	34.33± 0.43	36.68± 0.70	36.69± 0.75	33.46± 0.57	31.45± 0.53	30.77± 0.39	30.69± 0.53	29.98± 0.28	27.87± 0.64	27.05± 0.63
1911-1920	28.35± 0.66	31.15± 0.87	34.34± 0.62	36.63± 0.45	36.65± 0.70	33.29± 0.86	31.62± 0.47	31.06± 0.42	31.05± 0.51	30.08± 0.42	28.27± 0.39	28.35± 0.57
1921-1930	28.83± 0.50	31.00± 0.61	34.49± 0.56	36.80± 0.78	37.05± 0.59	33.84± 0.35	31.61± 0.27	31.18± 0.32	30.90± 0.28	29.72± 0.47	27.70± 0.61	27.18± 0.50
1931-1940	28.38± 0.72	31.16± 0.60	34.24± 0.49	36.47± 0.36	36.81± 0.87	33.28± 0.73	31.18± 0.18	30.86± 0.33	30.87± 0.36	29.88± 0.35	27.73± 0.44	27.09± 0.40
1941-1950	28.67± 0.65	31.06± 0.53	34.41± 0.63	36.61± 0.41	36.86± 0.67	33.32± 0.57	31.31± 0.53	30.88± 0.35	30.44± 0.35	29.79± 0.53	27.91± 0.61	27.10± 0.54
1951-1960	28.78± 0.34	31.47± 0.65	34.88± 0.56	37.01± 0.42	37.05± 0.82	33.48± 0.79	31.07± 0.59	30.76± 0.64	30.79± 0.35	29.94± 0.50	27.90± 0.66	27.25± 0.49
1961-1970	28.66± 0.55	31.63± 0.64	35.21± 0.71	37.00± 0.77	37.09± 0.58	33.43± 0.47	31.38± 0.40	30.78± 0.54	30.65± 0.31	29.90± 0.47	28.09± 0.58	27.37± 0.67
1971-1980	28.62± 0.68	31.84± 0.58	34.98± 0.40	37.20± 0.48	36.79± 0.93	33.20± 0.69	31.44± 0.50	30.78± 0.68	31.08± 0.60	30.17± 0.60	28.37± 0.64	27.48± 0.82
1981-1990	29.18± 0.46	32.16± 0.72	35.48± 0.73	37.52± 0.47	37.38± 1.02	33.64± 0.60	31.66± 0.69	31.14± 0.49	31.33± 0.79	30.38± 0.42	28.59± 0.35	27.93± 0.46
1991-2002	29.45± 0.72	32.38± 0.57	35.89± 0.44	37.54± 0.58	37.58± 0.76	33.86± 0.89	31.98± 0.54	31.21± 0.21	31.63± 0.48	30.38± 0.35	28.98± 0.56	27.67± 0.49
3. De Martonne Aridity Index												
1901-1910	10.06± 0.04	10.07± 0.18	10.13± 0.25	10.52± 0.71	11.22± 1.11	11.29± 0.58	12.03± 0.93	13.37± 1.99	15.79± 2.75	13.49± 1.68	12.34± 2.66	10.75± 0.79
1911-1920	10.03± 0.03	10.05± 0.09	10.25± 0.46	10.29± 0.43	11.54± 0.66	11.09± 0.51	12.13± 1.39	12.56± 1.42	15.52± 1.62	13.88± 2.47	13.45± 2.09	10.46± 0.54
1921-1930	10.04± 0.02	10.11± 0.18	10.19± 0.27	10.75± 0.75	11.58± 2.01	11.35± 0.53	12.08± 1.07	12.10± 0.99	15.05± 2.25	14.03± 2.26	12.97± 2.28	10.54± 0.86
1931-1940	10.02± 0.03	10.18± 0.30	10.17± 0.18	10.81± 0.85	11.20± 0.85	11.47± 0.67	11.98± 0.63	12.66± 2.09	14.57± 2.47	13.66± 1.57	12.75± 1.61	10.44± 0.61
1941-1950	10.02± 0.03	10.09± 0.13	10.15± 0.34	10.48± 0.37	11.65± 1.25	11.41± 0.63	12.15± 1.17	13.13± 1.14	15.46± 1.62	13.40± 2.10	12.62± 1.95	10.68± 0.87
1951-1960	10.01± 0.02	10.03± 0.07	10.17± 0.22	10.82± 0.75	12.06± 1.61	11.55± 1.14	12.60± 1.06	12.71± 1.70	14.68± 3.55	14.47± 2.60	11.78± 1.92	10.67± 0.89
1961-1970	10.03± 0.05	10.06± 0.10	10.16± 0.29	10.72± 0.90	11.58± 1.17	11.67± 0.62	12.52± 0.97	13.52± 1.81	15.29± 2.43	13.98± 2.30	12.06± 1.87	10.91± 0.66
1971-1980	10.02± 0.03	10.12± 0.19	10.09± 0.16	10.57± 0.85	11.94± 1.49	11.40± 0.48	12.27± 1.00	12.85± 1.51	14.44± 2.35	15.08± 3.00	12.91± 1.60	10.51± 0.67
1981-1990	10.02± 0.05	10.14± 0.26	10.37± 0.29	10.56± 0.45	11.40± 1.34	11.39± 0.60	12.54± 1.21	12.76± 1.87	16.02± 2.75	13.82± 1.30	12.03± 0.83	10.67± 0.42
1991-2002	10.02± 0.04	10.07± 0.13	10.11± 0.16	10.64± 0.47	11.67± 0.69	11.90± 0.92	12.05± 0.68	13.84± 1.32	13.96± 1.32	15.46± 1.41	12.07± 1.24	10.60± 0.71

Table 2: Decadal variation in angot pluviometric analysis in Kadapa distric

Year	January	February	March	April	May	June	July	August	September	October	November	December
1901-1910	0.03	0.05	0.09	0.42	0.83	0.82	1.19	1.79	3.25	1.99	1.12	0.38
1911-1920	0.02	0.03	0.15	0.21	1.06	0.67	1.16	1.39	3.14	2.08	1.81	0.26
1921-1930	0.02	0.03	0.15	0.21	1.06	0.67	1.16	1.39	3.14	2.08	1.81	0.26
1931-1940	0.01	0.13	0.10	0.57	0.84	0.97	1.21	1.55	2.71	2.09	1.57	0.23
1941-1950	0.01	0.06	0.08	0.33	1.04	0.89	1.20	1.78	3.12	1.78	1.33	0.35
1951-1960	0.01	0.02	0.12	0.54	1.39	0.98	1.46	1.48	2.46	2.33	0.82	0.33
1961-1970	0.01	0.03	0.10	0.49	0.94	0.98	1.36	1.84	2.83	1.96	0.98	0.43
1971-1980	0.01	0.07	0.05	0.39	1.21	0.83	1.21	1.56	2.39	2.54	1.47	0.23
1981-1990	0.01	0.10	0.23	0.36	0.84	0.87	1.40	1.38	3.25	2.07	1.11	0.34
1991-2000	0.01	0.10	0.23	0.36	0.84	0.87	1.40	1.38	3.25	2.07	1.11	0.34
2001-2010	0.01	0.09	0.25	0.24	1.07	1.11	1.25	1.64	2.40	2.09	1.55	0.27

January, February and March are totally very dry whereas 98 very dry spells in April, 67 in May and 64 in June with equally dry spells of 37 in June/July. The normal rainfall in July/August are 25 times but of 17 wet seasons in August and 20 in September. More than 50% of probability in case of September and 43% in October. Similar results are noticed for the angot rainfall index, respectively in terms of the proportion predisposed to trigger slope linear processes and erosion. It is found that 64% of cases in June there is no risk of pluvial erosion, whereas 50% of cases in September/October (43%) favorable for triggering pluvial linear erosion.

Soil characteristics

The pH of the soils in groundnut producing areas is 7.68 ± 0.68 with coefficient of variation of 7.99 per cent in soils on quartzite (P1 to P5) and 8.01 ± 0.2 with coefficient of variation of 2.47 per cent in other soils over shale. These soils are slightly to moderately alkaline with a pH up to 8.0 which helps in nitrogen fixation (Vara Prasad *et al.* 2009). These soils contained extremely low organic carbon of 2.6 gkg^{-1} in Pulivendula soil (P21) but is more than 10 gkg^{-1} in P8, P13 and P19 in soils developed over shale with mean of 7.26 ± 3.13 gkg^{-1} (Table 3). The organic carbon in soils over quartzite have a mean of 13.58 ± 4.24 gkg^{-1} to categorize as medium to high status (Pam Hazelton and Brain Murphy, 2016) that promotes good structural condition and stability. Only 20 per cent of soils have organic carbon above 10 gkg^{-1} and can be used for sustainable groundnut production. The remaining soils with low to extremely low organic carbon status have limited for enhancing groundnut productivity and need off organic carbon build up. The Cation Exchange Capacity (CEC) of soils is 7.2 cmol (+) kg-1 in P11 to 54.5 cmol (+) kg^{-1} in P8. The soils on Quartzite have mean CEC of 23.93 ± 7.64 cmol (+) kg^{-1} as against the soils on shales having mean CEC of 30.52 ± 13.12 cmol (+) kg^{-1}. These soils are grouped in accordance with CEC into 4 classes such as low (6-12 cmol/kg), moderate (12-25 cmol/kg), high (25-40 cmol/kg) and very high (>40 cmol/kg). It was found that 72 per cent of soils have high (48%) to very high CEC (24%) and remaining 28% soils have low (12%) to moderate CEC (16%). It is pertinent to say that low CEC can be attributed to the high sand and low organic matter content of soils. The calcium carbonate ($CaCO_3$) content is 10 g/kg in P1 to 160 g kg^{-1} in P12 to classify as Calcic Haplustalfs. The soils on shale have comparatively more $CaCO_3$ with mean of 87.62 ± 46.57 g/kg as against the soils on quartzite with mean of 20 ± 10 gkg^{-1}. It is observed during soil surveys in the area that higher $CaCO_3$ contents in the soils of interhill basin and colluvial alluvial complex is due to restricted drainage as evidence of appearance of calcic horizons in P12. This observation is in agreement with reports of Bhaskar *et al.* (2015) in Seoni district, Madhya Pradesh. In general, these soils have per cent base saturation more than 100 and have ESP (Exchangeable sodium per cent) less than 15% except in P9, P20 and P21. The soils on shale have mean ESP of 7.61 ± 15.03 but its value is less than 1 in soils of quartzite. The estimated *K* values for soils vary from 0.15 ± 0.03 t ha h ha^{-1} MJ^{-1} mm^{-1} (14 soil series not susceptible to water erosion: K < 0.20, 0.25 ± 0.023t ha h ha^{-1} MJ^{-1} mm^{-1} for 10 soil series with weakly susceptible to water erosion: K = 0.20–0.30 and 0.33t ha h ha^{-1} MJ^{-1} mm^{-1} for 1 series (santakovur, SVK) with medium susceptible to water erosion (K = 0.30–0.40). The coefficient of variation is 9.39 to 19.15% (Table 3).

Soil mapping

Twenty five soil series were identified and prepared soil map of 43 mapping units. Broadly, the soils on quartzitic hills and ridges have eight mapping units mostly associated with rock outcrops, very shallow, some what excessively drained, moderately alkaline, sandy loam to clay loam textured soils and covers 54812 hectare

Table 3: Physical and chemical characteristics of soil series in Pulivendula tehsil

Soil series	Particle size distribution (%)			Textural class	pH	EC (dSm-1)	Organic carbon	$CaCO_3$	CEC cmol/kg	PBS	ESP	Depth (cm)	Erodability index (K)
	Sand	silt	clay				g/kg						
1. Kanampalli (Kpl)	72.1	4.3	23.6	scl	8.3	0.14	16.3	10	12.9	71	0.16	21	0.16
2. Ganganapalle (Ggp)	32.1	20.5	47.4	c	7.1	0.23	17.7	30	30.5	100	0.39	15	0.19
3. Lingala (Lgl)	44.4	23.8	31.8	gcl	8.1	0.22	11.9	20	26.6	100	0.15	47	0.28
4. Rachakuntapalle (Rkp)	57.3	18.3	24.4	gscl	7.2	0.16	8.4	-	25.7	46	0.16	40	0.27
5. Mupendranapalle (Mpl)	29.5	29.0	41.5	c	8.4	0.38	10.7	40	29.1	100	0.76	40	0.23
6. Tallapalle (TlP)	40.9	19.6	39.5	cl	7.9	0.19	9.7	70	28.3	100	1.13	40	0.25
7. Santhakovur (Skv)	48.8	18.7	32.5	gcl	7.9	0.29	9.2	150	21.7	100	2.76	62	0.33
8. Tatireddipalle (Trp)	14.9	27.8	57.3	c	7.7	0.22	11.2	40	54.5	100	0.26	55	0.16
9. Cherlapalle (Cpl)	32.5	21.2	46.3	c	8.1	0.34	6.2	110	33.2	100	23.64	105	0.17
10. Kottalu (Ktl)	74.9	10.3	14.8	sl	7.9	0.16	3.6	20	7.6	100	1.97	142	0.21
11. Murarichintala(Mct)	71.1	14.2	14.7	sl	8.0	0.25	4.7	10	7.2	100	0.14	155	0.27
12. Vemula (Vml)	32.8	24.9	42.3	c	8.0	0.20	7.0	160	30.1	100	1.79	72	0.22
13. Sunkesula (Skl)	50.1	15.4	34.5	scl	8.0	0.30	11.1	40	28.0	100	1.61	70	0.18
14. Simhadripuram (Spm)	23.2	21.5	55.3	c	8.0	0.25	8.4	140	42.7	100	6.46	92	0.15
15. Velpula (Vpl)	60.7	13.5	25.8	scl	7.9	0.14	3.3	50	13.0	100	2.31	138	0.25
16. Agraharam (Ahm)	23.6	18.2	58.2	c	8.3	0.21	9.3	110	44.2	100	2.22	120	0.10
17. Balapanur (Bpr)	23.0	24.0	53.0	c	8.0	0.41	5.7	100	37.4	100	11.04	14	0.16
18. Parnapalle (Prp)	78.4	8.9	12.7	sl	7.8	0.31	5.0	20	10.3	100	4.95	150	0.26
19. Gondipalle (Gpl)	29.5	19.4	51.1	gc	7.9	0.21	14.7	150	35.8	100	0.87	44	0.16
20. Goturu (Gtr)	42.0	13.9	40.0	c	8.2	0.47	8.4	90	36.9	100	15.77	70	0.19
21. Pulivendula (Pvd)	38.6	1.2	60.2	c	8.5	1.47	2.6	110	24.2	100	67.89	135	0.10
22. Pernapadu (Ppd)	33.4	19.3	47.3	c	8.0	0.19	6.3	130	45.0	100	0.33	103	0.24
23. Agadur (Agd)	32.6	19.8	47.6	c	7.8	0.19	5.4	100	42.6	100	0.45	145	0.13
24. Tondur (Tdr)	29.8	22.3	47.9	c	8.1	0.25	5.8	100	41.9	100	4.6	152	0.14
25. Bhadrampalle (Bpl)	45.0	5.9	49.1	sc	7.9	0.33	4.1	100	27.3	100	8.78	150	0.14

Table 4: Area and extent of soil-land form associations

Land form	Soil mapping unit	area		Soil loss (t/ha/year) / soil erosion risk
		ha (hectares)	Percent (%)	
Hills and ridges	1. Rockoutcrops (R)- Kanampalli (Kpl)	7953	6.18	25.11/high
	2. Rockoutcrops®- Ganganapalle (Ggp)	7464	5.80	57.94/high
	3. Rockoutcrops®- Rachanakuntapalle (Rkp)	24939	19.39	9.91/high-medium
	4. Rockoutcrops®- Lingala (Lgl)	6410	4.98	102.80/extremely high
	5. Rachanakuntapalle (Rkp)– rockoutcrops®	1333	1.04	8.93/high medium
	6. Ganganapalle (Ggp)- Rockoutcrops®	677	0.53	57.94/ extremely high
	7. Rockoutcrops®- Mupendranpalle (Mpl)	3572	2.78	8.6/high medium
	8. Mupendranpalle (Mpl)- Rockoutcrops®	2464	1.92	8.56/ high medium
Interhill basin	9. Tallalapalle (Tlp)	1829	1.42	8.97/ high medium
	10. Murarichintla (Mct)	1934	1.50	8.90/ high medium
	11. Tatireddipalle (Trp)	788	0.61	1.33/low medium
	12. Kottalu (Ktl)	372	0.29	3.46/medium
	13. Santhakovur (Skv)	548	0.43	11.84/high
	14. Murarichintala (Mct)- Tallapalle (TlP)	508	0.39	8.92/high medium
	15. Cherlapalle (Cpl)	184	0.14	5.27/high medium
	16. Balapanur (Bpr)	6559	5.10	24.23/very high
	17. Simhadripuram (Spm)	7583	5.90	1.82/low-medium
	18. Simhadripuram(Spm)- Agraharam (Ahm)	9125	7.10	2.68/medium
	19. Balapanur (Bpr)- Sunkesula (Skl)	4294	3.34	3.65/medium
	20. Vemula (Vml)	1667	1.30	7.65/high medium
	21. Velpula (Vpl)	1326	1.03	4.12/medium
	22. Parnapalle (Prp)	446	0.35	1.36/low-medium
	23. Agraharam (Ahm)	2690	2.09	3.59/medium
	24. Sunkesula (Skl)	2778	2.16	2.97/medium
	25. Agraharam (Ahm)- Sunkesula (Skl)	802	0.62	3.61/medium
	26. Agraharam (Ahm)- Simhadripuram (Spm)	369	0.29	2.78/medium
	27. Sunkesula (Skl)- Simhadripuram (Spm)	741	0.58	2.65/medium
	28. Velpula (Vpl)- Vemula (Vml)	712	0.55	5.36/high medium

Colluvial-alluvial pediplains	29. Bhadrampalle(Bpl)- Agadur (Agd)	788	0.61	19.34/high
	30. Tondut (Tdr)- Pernapadu (Ppd)	1351	1.05	85.36/extremely high
	31. Tondur (Tdr)	3568	2.77	102.80/extremely high
	32. Agadur (Agd)	633	0.49	1.86/low - medium
	33. Pernapadu (Ppd)- Gondipalle (Gpl)	853	0.66	5.68/high - medium
	34. Tondur (Tdr)- Agadur (Agd)	709	0.55	90.56/extremely high
	35. Pulivendula(Pvd)- Pernapadu(Ppd)	101	0.08	15.32/high
	36. Goturu (Gtr)- Gondipalle (Gpl)	1501	1.17	2.75/low-medium
	37. Pernapadu (Ppd)	3689	2.87	17.31/high
	38. Pernapadu (Ppd)- Tondur (Tdr)	4358	3.39	85.36/extremely high
	39. Gondipalle (Gpl)	1683	1.31	3.10/medium
	40. Goturu (Gtr)	1707	1.33	1.33/low-medium
	41. Agadur (Agd)- Pernapadu (Ppd)	3613	2.81	15.36/high
	42. Bhadrampalle (Bpl)	448	0.35	24.23/very high
	43. Pulivendula (Pvd)	3540	2.75	17.31/high
	Total	128609	100	

(42.62% of total area, Table 4). The majority of area belongs to shale landforms covering 73797ha (57.4% of total area) as given below:- The soil mapping units under interhill basin include seven mapping units with six soil consociations and one soil association (4.79% of total area). These soils are shallow and well drained with strongly alkaline gravelly clay loam to gravely clay sub-soil layers. The gently sloping lands cover 39092 ha (30.4% of area) with 12 soil mapping units. The Vemula soils (20 - 1,667 ha, 1.2%) are moderately shallow, well drained, calcareous red soils with strongly alkaline clay surface soils and strongly alkaline gravelly clay subsoil with argillic horizon. The associated mapping units are Velpula soils (21 - 1,326 ha, 1.0%), Parnapalle in Lingala mandal (22 - 446ha, 0.3%), Velpula - Vemula association in Tondur mandal (28 - 712 ha, 0.5%). This mapping unit is associated with very deep, moderately well drained, calcareous, strongly to moderately alkaline black soils with shrink-swell potentials. Soils of colluvic and alluvial plains cover 28542 ha (22.19% of total land area) with association of Tondur - Pernapadu series (30), Pernapadu - Gondipalle association (33), Goturu - Gondipalle association (36), and Agadur - Pernapadu association (41). The soil erosion risk zones based on soil loss of each mapping unit are computed and categorized into six classes in the study area (Table 4). Based on area estimations, the soil erosion risk zones are arranged in ascending order as : high - medum (39142 ha, 31.16%) > high (276696 ha, 22.05%) > medium (23378 ha, 18.6%) > extremely high (16364 ha, 13.03%) > low - medium (12025 ha, 9.57%) > very high (7007 ha, 5.58%).

Soil – site suitability analysis

The suitability evaluation for groundnut shows that only 23 soil mapping units are moderately suitable with the limitations of rooting depth (r), topography (t) and salt content (z). The moderately suitable soil mapping units cover 56224 ha (43% of total area) with 13 soil consociations (31501 ha, 24.49% of total area) and 10 soil associations (24723 ha, 19.22% of total area). Even though, the suitability findings show 43% of total area having good potential for groundnut and extensively cultivated in Vempalli (6894 ha, 27.39% of cultivated area) and Vemula (3613 ha, 17.29% of cultivated area, Table 4). There is a lot of scope to expand area under groundnut as the arability and irrigability analysis shows 42 per cent (56092 ha) of arable land with 23 per cent of irrigable area. The suitability map clearly shows that north eastern parts of Pulivendula have moderately suitable sites in Simhadripuram, Tondur, Lingala mandals and Vemula / Vempalli mandals in south eastern parts.

Agro Economic analysis

In socio-economic survey, it is observed that there is a wide variation in seed rate ranging from 100 to 188 kg/ha among the farmers as against the recommended seed rate of 125 kg/ha with a mean cost of share of 19.56 ± 6.25%. The per cent contribution of human labour accounts to 36.0 ± 10.3 per cent of the total cost of production but reported more than 60% contribution in Balapanur (16) and a minimum of 22.4% in Pulivendula unit (43). In general N and P levels are used more than the recommended and farmers are not applying K, except few cases of excess application (5 to 90 $kgha^{-1}$). The cost of cultivation of groundnut is varied from a minimum of Rs 14025 (Pulivendula, 43) to Rs 31298 (Agadur - 32, Fig. 4) with a mean of Rs 21984 ± 4503 and per cent coefficient of variation of 20.5.

Only Pulivendula (43) has recorded gross returns of Rs 43750 with benefit cost ratio more than 2 but in others, this ratio is less 1 except in six mapping units (39, 4, 40, 42, 5 and 9) where this ratio is in between 1 and 2.

Soil-climate-landscape potential for groundnut production

In evaluating the performance of groundnut production in geologically diversified soil landscape systems of Pulivendula tehsil, where there is a scope for groundnut cultivation to expand in 42 per cent (56092 ha) of arable land with limitations of rooting depth (r), topography (t) and salt content (z). One of the major ways to increase the water use of the crop itself is by increasing the depth of rooting. In dryland environments of Pulivendula tehsil, crops do not use all the water available in the soil profile because of restrictions to root growth. These restrictions may be physical, chemical, or biological. Agronomic practices that reduce the physical impedance to root growth can benefit yields of groundnut in water - limited environments. The 'good growth plan for enhancing groundnut productivity in Pulivendula with the current management strategies entail growing groundnut drought tolerant varieties under three dominant landscape positions such as hills and ridges (54812 ha, 42.62% of total area), interhill basins (45255 ha, 35.19%of total area) and colluvio - alluvial landforms (28542 ha, 22.19% of total area). The area and productivity of groundnut over 14 years (1998 - 1999 to 2011-2012) shows that mean allocation of land for the groundnut is 1.51 ± 39.32 lakh hectares with coefficient of variation of 25.9 per cent and mean productivity of 623.57 ± 294.94 kg/ha. This area received mean rainfall of 402.4 ± 110.53 mm during southwest monsoon (June to September) with coefficient of variation of 29.43%. During 2004 - 2005 and 2005 - 2006, the area under groundnut is exceeded more than 2 lakh hectares with low productivity of 280 kg/ha. It is interesting to note that maximum yield of groundnut is 1080 kg/ha under the south west monsoon rainfall of 259 mm (Fig. 2). The criteria applied across the three soil-landscape field systems in the region were (1) monthly temperature > $21^0 \approx 23^0$C and with a Tfp (bud temperature) of 40^0C based on Prasad et al. (2003) and monthly rainfall > 40 mm and monthly aridity (De Martonne Aridity Index) < 20. The decadal mean and standard deviation for rainfall, mean temperature and De Martonne Aridity Index (Table 2) shows that this area receives mean annual rainfall of 679.59 ± 237.52 mm, of which the kharif rainfall contributes 340.69 mm (50.28% of total rainfall) with a range mean air temperature of 30.7^0C to 36.9^0C and an aridity index of 11.29 to 14.25 indicating semiarid conditions during groundnut growing season. The long term rainfall data shows a deficit of 60 mm but receives >135 mm rainfall during pod development phase (September). It is interesting to point out that mean annual rainfall of 250 mm at the time of sowing with a deviation of -100 to +100 mm, it will improve water use as well as higher yields in heavy clay soils (O' Leary and Connor, 1997). It was found that 72 per cent of soils have high

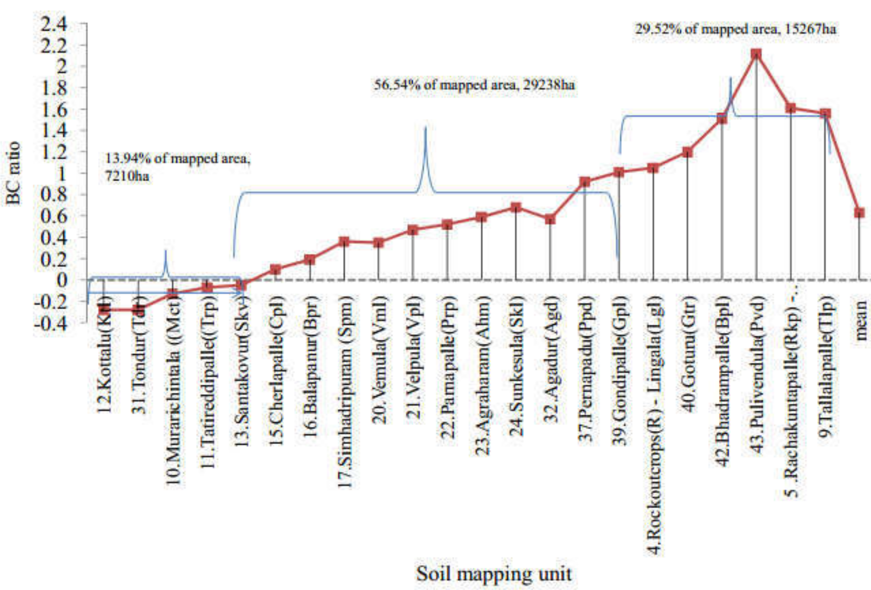

Fig. 4: Soil mapping unit wise agro economic analysis for groundnut

(48%) to very high CEC (24%) and remaining 28% soils have low (12%) to moderate CEC (16%). It is pertinent to say that low CEC can be attributed to the high sand and low organic matter content of soils. The soils on shale have comparatively more $CaCO_3$ with mean of 87.62 ± 46.57 g/kg as against the soils on quartzite with mean of 20 ± 10 gkg^{-1}. It is observed during soil surveys in the area that higher $CaCO_3$ contents in the soils of interhill basin and colluvial alluvial complex is due to restricted drainage as evidence of appearance of calcic horizons in P12.This observation is in agreement with reports of Bhaskar *et al.* (2015) in Seoni district, Madhya Pradesh (Table 4). It was further reported that 97% of soils have low available nitrogen, 47% under low available phosphorus and 74% as high status of available potassium (Naidu *et al.*, 2009). Among DTPA extractable micronutrients, DTPA extractable Fe is deficient in 57% of soils followed by 51% for DTPA extractable Zn. The deep black soils with sodic enriched clay is well distributed in north central parts of Pulivendula in 23533 ha (18.29% of total area) with benfit cost ratio of 1:1.6 (Fig. 4). Two key assumptions were implicitly made in this evaluation of linking pedological systems with climatic variability in the region. The first assumption is that evenly distributed seasonal rains (close to or above the long-term average), have resulted good yields but poorly - distributed rainfall such as mid-season droughts, prolonged dry spells during critical stages often resulting poor productivity. These assumptions are from the outcomes of socio economic surveys and also from district level crop statistics. The second assumption is consecutive crop loss and prolonged poor yields of groundnut (below state average) in drought hit Pulivendula region (as evident from crop yiled statistics and discussions with local farmers during surveys), there is a need for appraisal of land resources for groundnut suitability both in terms of physical and economic terms. The analytical results showed that there is a wide variation in seed rate ranging from 100 to 188 kg/ha that contributes 19.56 % and 36 per cent contribution of human labour of the total cost of production but reported more than 60 % in Balapanur mapping unit (16) and a minimum of 22.4% in Pulivendula unit (43). The soil mapping units under interhill basin include seven mapping units with six soil consociations and one soil association (4.79% of total area). These soils are shallow and well drained with strongly alkaline gravelly clay loam to gravely clay subsoil layers. The gently sloping lands cover 39092 ha (30.4%of area) with 12 soil mapping units where soils on colluvio - alluvial landforms with calcareous, strongly to moderately alkaline black soils (Tondur, Goturu, Pernapadu and Gondipalle series association). The estimated *K* values for soils of Pulivendula tehsil vary from 0.15 ± 0.03 t ha h ha−1 MJ^{-1} mm^{-1} (14 soil series not susceptible to water erosion: K < 0.20, 0.25 ± 0.023t ha h ha^{-1} MJ^{-1} mm^{-1} for 10 soil series with weakly susceptible to water erosion: K = 0.20–0.30 and 0.33 t ha h ha^{-1} MJ^{-1} mm^{-1} for 1 series (santakovur, SVK) with medium susceptible to water erosion (K = 0.30– 0.40). It is estimated that January, February and March are totally very dry whereas 98% of probable very dry spells in April, 67 in May and 64 in June with equally dry spells of 37 in June/July. The normal rainfall in July/August are 25 times but of 17 wet seasons in August and 20 in September. More than 50% of probability in case of September and 43% in October is reported. Similar results are noticed for the Angot rainfall index, respectively in terms of the proportion predisposed to trigger slope linear processes and erosion. It is found that for 64% of cases in June there is no risk of pluvial erosion, in 50% of cases in September/October (43%) for triggering pluvial linear erosion (Table 3). The critical seasonal erosion is in the month of September/October favouring high - medium soil erosion risk in an area of 39142ha (31.16%) but extremely high erosion in Quartzite hills of Pulivendula in an area of 16364 ha (13.03% of total area.

Conclusions

The climatic analysis in relation to pedological systems of hot arid ecosubregion (K6E2) of Pulivendula tehsil of Kadapa district is critically examined for rainfed groundnut production at an appropriate scale for regional sustainable development planning. It is identified that seasonal rainfall (southwest monsoon- June to September) is the main deciding factor in variability of area and productivity of groundnut over a period of 14 years. The analysis of mean monthly rainfall and average temperature over 109 years shows that this area receives mean annual rainfall of 679.59 ± 237.52 mm, of which the *kharif* rainfall contributes 340.69 mm but deficit of 60 mm to that critical rainfall of 400 mm (50.28% of total rainfall) with a range mean air temperature of 30.7^{0}C to 36.9^{0}C (favourable for crop growth) and an aridity index of 11.29 to 14.25 indicating semiarid conditions. The 'good growth plan for groundnut demands drought tolerant varieties suitable for three dominant landscape positions such as hills and ridges (54812 ha, 42.62% of total area), interhill basins (45255 ha, 35.19% of total area) and colluvio - alluvial landforms (28542 ha, 22.19% of total area and supporting red-black soils having limitations of low available nitrogen, 47% under low available phosphorus and 74% as high status of available potassium but also deficit in iron and zinc. The deep black soils with sodic enriched clay is well distributed in north central parts of Pulivendula in 23533 ha (18.29% of total area) with benefit cost ratio of 1:1.6.These soils are weakly to moderately succeptible to water erosion but have high erosion risk in an area of 16364 ha (13.03% of total area) in hilly region of Pulivendula. The study clearly shows that groundnut production to intensify in the region needs critical pedological links to the socio-economic conditions in water limited environments and on promotion of effective moisture conservation programmes for the future.

Acknowledgements

Thanks to Government of Andhra Pradesh for funding this project for assessing land resources for groundnut suitability and its economic evaluation. Authors wish to express thanks to Dr. L.G.K. Naidu, former Head, Regional Centre, NBSS & LUP and Dr. S.K. Singh, Director, ICAR-NBSS & LUP, Nagpur for his constant encouragement and cooperation in preparation of this manuscript. Thanks to Dr. Arti koyal, Dr. K.V. Niranjana and Dr. B. Dhanorkar for their useful discussions in land evaluation based on soil resource data base. Thanks to Chief planning officer, Kadapa for providing land use details of this tehsil during field investigation.

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