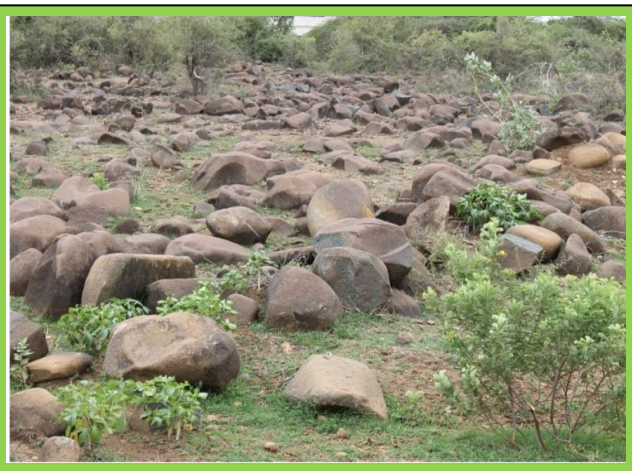
# Visual signs of Biophysical indicators for assessing the status of degradation in drylands of Pulivendula tehsil, Kadapa district, Andhra Pradesh




ICAR – NATIONAL BUREAU OF SOIL SURVEY AND LAND USE PLANNING
Regional Centre, Bangalore-560024

# Visual signs of Biophysical indicators for assessing the status of degradation in drylands of Pulivendula tehsil, Kadapa district, Andhra Pradesh

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**By**

**Dr. B.P.Bhaskar**
Principal scientist
ICAR-NBSS&LUP
Regional centre
Hebbal, Bangalore-560024



**ICAR-National Bureau of Soil Survey and Land Use planning**
**Regional Centre, Bangalore-560024**

# ABOUT NBSS & LUP

The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur, a premier institute of Indian Council of Agricultural Research (ICAR), was set up in the year 1976 with the objective of preparing soil resource maps at village, watershed, taluk, district and state level and to provide research inputs in soil resource mapping, soil correlation and classification, soil genesis, remote sensing applications, land evaluation, land use planning, land resource management and data base management using GIS for optimizing land use on different kinds of soils in the country. The Bureau has been engaged in carrying out agro-ecological and soil degradation mapping at the country, state and district levels for qualitative assessment and monitoring of soil health towards viable land use planning.

The research activities of the Bureau have resulted in identifying soil potentials and problems and the various applications of soil surveys with the ultimate objective of sustainable agricultural development. The Bureau has the mandate to correlate and classify soils of the country and maintain a National Register of all the established soil series. The Institute is also imparting in-service training to staff of soil survey agencies in the area of soil survey, land evaluation and land use planning. The Bureau in collaboration with Punjabrao Krishi Vidyapeeth, Akola is running a post graduate teaching and research programme in land resource management, under which M.Sc and Ph.D. degrees are awarded. The regional centre's of the Bureau are associating with SAU's in teaching, research and other academic activities.

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*For further information*

Director,

National Bureau of Soil Survey and Land Use Planning (NBSS & LUP)
Amravati Road, Nagpur- 440010
Maharastra, India

Phone : (0712) 2500386, 2500664, 2500545
Tele fax : (0712) 2500534 , Telex: 0715-7262 NBSL IN
Email : director@nbsslup.ernet.in

OR

Head, Regional Centre,
NBSS & LUP, UAS Campus,
Hebbal, Bangalore-560024,
Karnataka, India.
Phone : (080) 23412242, 23410993, 23415683
Tele fax : (080) 23510350 Email: nbsslup@vsnl.net

# FOREWORD

The appraisal of agricultural land resources and its assessment towards degradation in drought hit regions of Rayalseema plateau, Andhra Pradesh is often time consuming, expensive and reliant upon the traditional knowledge and judgment of the soil surveyors. In the present study , the project associates conceived the idea of capturing Visual signs of Biophysical indicators for assessing the status of degradation in dry lands of Pulivendula tehsil, Kadapa district, Andhra Pradesh and described the development of visual methods to assess land degradation land degradation of red and black soils in Pulivendula at 1:25000scale. We made use of soil morphology and integrated with physic-chemical data sets through integrating remotely sensed, and field data, within a geographic information system (GIS). The key to this approach was the linkage of soil and erosional processes estimated using USLE and CORINE models (identified at the point scale) to mapped soil units via top sequences, and the allocation of land degradation classes to each of the units. Later on three widely used soil quality ratings were made to each mapping unit and assessed their current state of soil quality. The authors described an integrated approach to the assess the suitability of soils to ground nut and banana (most promising and popularized in the region) under drip irrigation systems with comparable landscapes and vegetative covers, where similar soils, terrain conditions exist. In this monograph, the authors evaluated the descriptive indicators for monitoring and predicting soil changes over landscapes. The study shows that visual, morphological observations can be used as tools for farmers to recognize degraded soil changes through anthropogenic activities in dry lands such as water erosion, loss of organic matter, soil crusting and surface sealing and development of sodicity in stream floors. Morphological attributes can be estimated well enough by calibrating qualitative observations against measured values. Using Key soil indicators a farmer can systematically use delineate areas where certain types of land degradation and improve soil sampling strategy for analysis and for better management decisions at landscape level. Such an effort has shown very positive utility elsewhere. National Bureau of Soil Survey and Land Use Planning is a premier Research Institute under Indian Council of Agricultural Research which is mandated with generation of land resource data sets and also interpreted for various thematic based mapping responsibilities for land evaluation for crop production.

Regional Centre, NBSS & LUP, Bangalore has undertaken the exercise for the Pulivendula region (at 1:25,000 scale) of Kadapa district, Andhra Pradesh. An effort of soil survey team under this project is made to identify soil related constraints for Groundnut and banana and special management practices needed to improve and sustain the crop productivity. The report also contains easily understandable thematic maps and soil data with statistical analysis. I am confident that the developmental departments can make best use of this report for sustaining the dry land agricultural development in Pulivendula. I congratulate the research team for their sincere efforts in bringing out this useful document in time.

**S. K. Chaudhuri**
Deputy Director General (NRM)
ICAR, NEW DELHI

# PREFACE

The simple soil morphological indicators has been compiled and evaluated for dominantly dry land farming systems of Pulivendula tehsil in Kadapa district, Andhra Pradesh. The present report has been compiled as guide for monitoring both seasonal and long term changes in soil bodies over lithologically different landscapes of the region .The study area needs immediate attention to measure soil variations resulting from both immediate soil degradation events such as erosion and those that are more gradual but that are evident within a human lifespan (e.g. regional changes in rising water tables due to introduction of canal irrigation from mailavaram dam to give protective irrigation to citrus gardens and to expand area under banana cultivation with heavy subsidized drip system ). These soil morphological indicators are sensitive and subjected to change in relation to climate change. Currently, there is no simple generic field guide for dry land farmers to decide drainage requirement and crop specific nutrient management. The dry land farmers in each major uniform soil- landscape-hydro-geological regions of Cuddapah basin in Andhra Pradesh need a simple field guide to help them use morphological indicators in their property and catchment planning.

This exercise is very basic requirement for agric planning and developmental activities at regional scale. National Bureau of Soil Survey and Land Use Planning are mandated with this task of identifying simple and easy soil indicators for degradation under uniform landscapes. Regional Centre at Bangalore has carried out this case study on visual signs of dry land degradation in Pulivendula region of Kadapa district. Research team has initiated the project at a right time to develop field guide with proper interpretation of land resource data base for planning activities. The field work, laboratory analysis and final report are completed in time. I believe that this scientific document will provide all the information/database for systematic planning and execution of rural development programs of Pulivendula region and serves as a valuable tool for assessing morphological properties of soils in relation to physic-chemical properties under a defined agro ecological regions.

**B.S. Diwedi**

(Director, ICAR-NBSS & LUP)

# RESEARCH PROJECT TEAM

| | | |
|---|---|---|
| Project Leader | : | B.P.Bhaskar |
| Project Associates | : | S. Srinivas<br>Rajendra Hegde<br>Sunil maske<br>K.Sujatha<br>S.C.Ramesh Kumar<br>V.Ramamurthy |
| Head, Regional Centre | : | Rajendra Hegde |
| Director | : | B.S.Diwedi |

## CONTRIBUTORS

| | | |
|---|---|---|
| B.Pbhaskar | : | Project Planning, Climatic Analysis, Co-ordination, report writing |
| Rajendra Hegde | : | Logistic support |
| S. Srinivas | : | GIS Interpretation |
| S.C.Ramesh Kumar | | Field photos, economic data |
| V.Ramamurthy | | Land evaluation |
| Bhoora Prasad,<br>K. Paramesha,<br>N. Somasekhar,<br>C. Bache Gowda,<br>Jaya Ramaiah and<br>B.M. Narayana Reddy | : | Field Survey and Mapping |
| K.Sujatha | | GIS Interpretation,Map generation and Report |
| Arti Koyal | : | Laboratory Analysis |
| N.Maddileti | : | Map Generation |

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**FIGURES**

## ABBREVIATIONS USED

ANOVA =Analysis of variance

ASER =actual soil erosion risk

BGI =Bagnouls and Gaussen

CEC = cation exchange capacity

Ci =Capability index

CORINE =Coordination of Information on the Environment

CV = Coefficient of Variation

ESP = exchangeable sodium per cent

EX.Mg= exchangeable Magnesium

Ex.Na= exchangeable Sodium

EXCa=exchangeable Calcium

EXK=exchangeable Potassium

FAO = Food and agricultural organization of United Nations

GDD =growing degree days

GIS =Geographical information system

GSDP =Gross State Domestic Product

Idmi =Aridity index (De Martonne)

IRS-P6 = Indian remote sensing satellite- ResourceSat-1

K= Angot pluvial index

LISS = Linear Imaging and Self-Scanning Sensor

MFI =Modified Fournier index

MPCE=monthly per capita expenditure

MSL = mean sea level

MSQR= Muencheberg soil quality rating

PCI - Precipitation concentration index

PSER =Potential soil erosion risk

RAI = Rainfall Anomaly Index

Sd= standard deviation

SH= stromatolites hemispheroids

SIC = soil inorganic carbon

SMU = soil mapping unit

SOC = soil organic carbon

**SQI = S**oil quality index

SQR= soil quality rating

Vs=visual scoring

VSA= visual soil assessment

Ẇ= profile weighted mean

# UNITS USED

**Units used**

cmol/kg=centi mole per kilogram

dSm-1 = deci siemens per meter

ha=hectare

g/kg=gram per kilogram

kg=kilogram

Mg/ha=Mega gram per hectare

mm=millimeter

m= meter

mg/kg =milligram per kilogram

mg=milligram

%=per cent

$^{0}$C=centigrade

## EXECUTIVE SUMMARY

It is interesting to discuss about degradation aspect of dry lands form the largest biome complex on Earth, covering about 41 per cent of the terrestrial surface where unpredictable and extreme events of precipitation events and temperature during summer. This section of Rayalseema region has unique agro ecosystem with striking ecological diversity and offering ecosystem goods and services for local agrarian communities. Dry lands in Andhra Pradesh are the cradle of humankind with high reciprocal adaptability to water scarcity and strengthened land–human connections since historical times. Over the last four to five decades, dry lands in Kadapa region have undergone loss of productivity and biodiversity, and increasing drought frequency, food insecurity, poverty, migration and social disintegration. With this background , the present study of "Visual signs of Biophysical indicators for assessing the status of degradation in dry lands of Pulivendula tehsil, Kadapa district, Andhra Pradesh" was carried out using the land resource data generated at 1:25000 scale of Pulivendula tehsil, Kadapa district, Andhra Pradesh. Pulivendula tehsil lies between 14°16′ and 14° 44′ N latitude and 77°56′ and 78° 31′ E longitude and covers 1, 27, 463 ha (hectares). The data on per capita available land shows that per capita land is below or equal to 1 ha in all mandals whereas per capita net sown area is 0.2ha in Vempalli to 0.7ha Pulivendula. The mean per capita net sown area is 0.4 ± 0.1 with coefficient of variation of 35.5 per cent. The per capita irrigated land is 0.1 ha except in Lingala where it is 0.2ha with coefficient of variation of 29 per cent (moderate variation). Demographic statistics shows that Pulivendula tehsil has 50563 farm house holds with 66 per cent of small and marginal farmers owning 87409ha.

The study area comes under Papagni sub basin and consists of rocks belong to Gulcheru formation of Papagni group and Pulvendla formation of Chitravati group of Cuddapah Supergroup. The geological formations give rise to 10 land forms such as elongated ridges all along the southern portion of Pulivendula (8442.90ha,6.62% of total area ) ; Dissected Hills/summits (aligned parallel to the elongated ridges but more highly dissected and denuded, indicating the sedimentary beds here are less resistance to weathering and erosion) -2.32 per cent of total area (32962.15ha); Highly dissected plateau remnants (16.18% of total area;20263.65ha); Isolated hills/mounds (6.87% of total area,8756.61ha); Inter-hill basins (5815.34ha;4.56% of total area); Undulating Upper sectors (10205.83ha;8.01%); Gently sloping middle sectors(35535.58ha, 27.88%); Colluvial lower-sectors (27457.79ha, 21.54%) and Narrow valley floors (3.48% of total area, 4440.84ha).

The Precipitation Concentration Index (PCI) calculated and classified as irregular (PCI =15.7) to moderate for 2012-2013 (PCI = 12.76). The monthly rainfall data shows that September and October receives more than 100mm rainfall with CV less than 55 per cent. The coefficient of variation is more than 100 per cent for January, February, March, April and December. The skewness coefficients are positive (skewed to the right) indicating that the low rainfall occurs regularly, while high value rainfall happens very often. The monthly rainfall is more skewed. The skewness coefficient for August, September and October is identical to or nearly identical to zero indicating the data follows a normal distribution. The mean air temperature is $26.23^0$C $\pm 0.38^0$C with CV of 1.43 per cent. The monthly mean air temperature more than $30^0$C is recorded for April and May but rest of the months, the mean air temperature is 22.01±0.61 $^0$C for December and $28.4^0$C ± $0.7^0$C for June. The air temperature shows negatively skewed for January, May, June, August and December and closed to zero indicating the normality of data. The cultivars planted between June 5 - 20 were exposed to high air temperature and were thus rapidly stressed. The stages of developing pegs and the timing of filling pods of peanut were exposed to low temperature. The two earliest plantings supply the longer growth for the peanut cultivars that is needed to reach the required 1450 and 1550 Growing Degree Days (GDD) for gynophore formation to maturity. The GDD for this region is 1476 full filling the requirement for gynophores formation to maturity.

Out of 102 years of data, this area experiences 17 extremely dry years, 20 each of very dry and dry years , 22 humid years and 11 extremely humid years. 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 15) and increased erosive potential of high-quantity or high-intensity rainfalls with a probability of occurrence > 50% occur (Dragot˘a, 2006). Over 109 years of monthly rainfall data was used to compute the angot index and worked out the wet-dry spells. It is estimated that 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 is 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.

The results of angot rainfall index, respectively in terms of the proportion predisposed to trigger slope linear processes and erosion is found that 64% of cases in June, there is no risk of pluvial erosion, in 50 % of cases in September / October (43%) favorable for triggering pluvial linear erosion. The very high rainfall events favoured high rates of erosivity in 11 years, out of it, the more pronounced erosivity with very high MFI values viz., 262.54 for the year 1960 and 200.43 for the year 1975. There are only three very low erosivity occurred in the year 1904 (MFI of 56.90), 1907 (MFI of

74.03) and in 1951 (MFI of 60.03). The region experiences 40 moderate (36.7%) and 38 high (34.86%) erosivity events with CV of around 8 per cent .

The very high erosivity class has mean of 189.08±28.29 with CV of 14.96 per cent. The data clearly 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 ± 294.94kg/ha. This area received mean rainfall of 402.4 ± 110.53mm 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 lakhs with low productivity of 280kg/ha. It is interesting to note that maximum yield of groundnut is 1080kg/ha is recorded under the south west monsoon rainfall of 259mm. It is true to say that sowing of groundnut between $26^{th}$ to $27^{th}$ standard week, reasonably a good crop can be produced on as little as 269 to 298 mm of rainfall .

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Twenty five soil series were identified and designed 43 soil mapping units to generate soil map. The morphological properties of soil series are briefly discussed as : The soils with A/C horizons include two soil series viz., Kanampalli soils (P1) with dark reddish brown, moderately alkaline gravelly sandy clay loam A horizon overlying hard quartzite and Ganganapalle series (P2) with red, neutral, sandy clay A horizon in association with Parnapalle soils (P18) on alluvium with dark grayish brown, strongly alkaline, sandy loam A horizon and dark grayish brown to dark yellowish brown, strongly alkaline, sandy loam C horizon. The soils with A/Bw horizon sequences include five series with dark reddish brown, moderately alkaline and gravelly clay loam A horizons but dark red slightly alkaline B horizons in Lingala (P3) but more than 65% gravels in B horizons in Mupendranpalle (P5), Tallalapalle series (P6) and Santakovur series (P7). The Rachakuntapalle series (P4) have yellowish red, neutral, gravelly sandy clay loam a horizons and yellowish red, slightly alkaline, gravelly sandy clay B horizon with 60-85 per cent gravel. They have developed from quartzite and occur on strongly sloping lands with 10-15 per cent slope at an elevation of about 540 m above MSL.The soils with argillic red clay horizons include four series viz., Kottalu (P10), Murarichintala series (P11), Vemula soils (P12) and Velpula (P15). The soil series with cambic horizons (black soil) include Tatireddipalle series (P8), Cherlapalle series (P9), Sunkesula soils (P13), Gondipalle soils (P19), Goturu soils (P20), Pulivendla soils (P21), Pernapadu soils (P22) and Agadur (P23). These soils in general have dark brown, strongly alkaline, gravelly clay A and B horizons. They have developed from shales and occur on nearly level to very gently sloping colluvial lower sector with 0-3 per cent slope at an elevation of 220 m above MSL. The soils with slickensided horizons include four series viz., Simhadripuram series (P14), Agraharam soils (P16), Balapanur soils (P17) and Bhadrampalle soils (P25). These soils have very dark grayish brown, strongly alkaline clay a horizons and dark brown, strongly alkaline, clay B

horizons over hard shale rock. These soils have intersecting slicken sided horizons with wedge shape aggregates.

The Kanampalli (P1) and Ganganapalli (P5) have lithic contact within 50cm with particle size class as loamy skeletal for P1 and clayey for Ganganaepalli (P2). The Kottalu (P3) and Rachanukuntepalli (P4) have A and BW horizon sequence within 50cm of lithic contact. These soils display an increase of clay more than 1.2 times from A horizon to B horizon. The trends are similar in Rachanukuntapalli series (P4) with an illuvial coefficient of 1.31, clay of 32.2% in B horizon to 24.4% in A horizon. The particle size class is clayey skeletal for P3 and loamy skeletal for P4. Mupendrapalli (P5) and Tallalapalle (P6) have clayey skeletal paticle size with a clay increase less than 1.2 times. The Vemula soil (P12) has more than 40% clay with gradational increase and an illuvial coefficient of 1.09 o 1.17 in B horizons. Parnapalle (P18) shows irregualr sand to silt ratio with an abrupt increase from 6.88 (C2) to 17.89 (1Bw2). The Santhakovur (P7) series have clay increase in cambic B horizon (32.5 to 38.8%) with gradational decrease of silt to clay (0.58 to 0.49) and sand to silt ratio more than 2. The Tatireddipalli series (P8) and Cherlapalle series (P9) have very fine particle size with clay content exceeding more than 60%. The fine loamy Kottalu soil (P10) and Murarichintala (P11) shows clay enriched B horizons with an illuvial coefficient exceeding 2 in P10 and P11. Velpula (P15) shows irregular depth distribution of sand and silt with high inflictions of sand to silt ratio exceeding more than 3.0. Simhadripuram soil (P14) has more than 55 per cent of clay in a horizon but increased to 62% in B horizons. The profile distribution of sand (13.7 to 23.2%) and silt (19.5 to 24.5%) is irregular with values less than 1 in some B horizons. The silt to clay ratio is less or equal to 0.4. The agraharam soil (P16) has clay content more than 60% in control section (25 -100cm) with illuvial coefficient of 0.90 to 1.12. The depth trends are irregular for sand, silt and clay. The silt content in Pulivendula series (P21) is irregular but its content is less than 4%. Similar depth trends are noticed for clay with its content but vary from 39.1 in Bw4 to 63.6% in Bw2 horizon. Ninety samples of soil seperates are plotted and constructed ternary diagram more than 65 per cent are concentrated in clay textural class , 8 per cent in sandy clay loam and sandy clay textural class.

The total SOC stock above the mean value of 52.47±17.55 Mg/ha is recorded as: Pernapadu (80.56Mg/ha) < Sunkesula (77.27Mg/ha) < Agadur (73.21Mg/ha) < Simhadripuram (72.43Mg/ha). These soils are mostly occurring in interhill basins and colluvio-alluvial sectors of Pulivendula. The SIC stock is relatively more to that of SOC and recorded a maximum of 334.74 Mg/ha in Tondur series (Tdr) and almost nil in Rachkuntapalle series. The mean SIC stock is 134.52 ± 106.71 Mg/ha with CV of 79.32 per cent. The soils identified and mapped in the study area fall under four orders (Alfisols, Entisols, Inceptisols and Vertisols), five suborders (Ustalfs, Orthents, Aquepts, Ustepts and Usterts) seven greatgroups (Paleustalfs, Rhodustalfs, Haplustalfs, Ustorthents, Halaquepts, Haplustepts and Haplusterts), twelve subgroups, eighteen families and twenty five series. Alfisols cover about 6367

ha (4.8 %), Entisols about 5477 ha (4.1 %), Inceptisols 47342 ha (35.5 %) and Vertisols 31118 ha (23.3 %). Twenty five soil series were identified and prepared soil map of 43 mapping units. The soils on quartzitic hillsand ridges have eight mapping units mostly associated with rock outcrops, and covers 54812hectare (42.62% of total area) whereas soils on shale landforms cover 73797ha (57.4% of total area). 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. The high actual erosion risk levels are in 66.96 % of total area as against the PSER of 62.62% of area. The high level of potential erosion risk area decreases when it is evaluated as actual erosion risk assessment indicating the effect of vegetation cover on erosion risk.

Using the existing three methods of visual scoring of 10 biophysical parameters, the results showed that poor quality soils occupy 35.25% of total area (45338ha) wherein shallow soil series are mostly associated with rock outcrops as dominant feature. Both interhill basins and colluvio-alluvial sectors, the moderate quality of soils cover 25.25% of total area (32823ha) where as good quality soils accounts to 39.23% (50448ha). The results of Muencheberg soil quality rating showed that soils on hills and ridges are rated as very poor with more than 60 per cent of coarse fragments in A-C horizons and mainly associated with rock outcrops. This quality rating is for farm land hence these soils are not suitable for banana and also have very poor quality. The area under this unit covers 54812ha. 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. The results from suitability analysis of banana under drip irrigation show that 56091ha of land in interhill basins and colluvio-alluvial deposits are evaluated as suitable (S2 and S3) as against the current area of 22000ha. Further the study shows that 34502ha of suitable land for banana is evaluated as highly suitable for drip irrigation system with an extremely high erosion risk area of 16364 ha. In the study present study, the pedological links were made with environmental factors and erosional estimation to expand area under banana through drip irrigation as majority of farmers reluctant to grow groundnut due to high cost of cultivation and crop loss due to increasing the frequency of seasonal droughts in the region.

## ABSTRACT

The land suitability evaluation (LSRS) was as a spatial modeling tool that generates a class rating for parcels of land for groundnut based on a soil–climate–landscape potential and linked with to the individual polygons of a detailed (1: 25 000 scale) soil map available for Pulivendula tehsil with a large drop in land suitabililty for groundnut due to increased climatic and soil moisture deficits when applied LSRS module. Aridity is a recurring phenomena with serious economic loss in Pulivendula (133315 hectares, ha) of Kadapa district, Andhra Pradesh where the rainfed groundnut yields are historically less than 400kg/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 <0.5dSm$^{-1}$) and 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 30.75cm). These soils were evaluated as not susceptible (60764hectares, soil erodibility (K) of < 0.15 t ha h ha$^{-1}$ MJ$^{-1}$ mm$^{-1}$) to weakly susceptible to water erosion (29037hectares, K < 0.20). As per Corine model, the area under high potential soil erosion risk zones was reported as 62.62% whereas 33.85% of area under moderate erosion risks level. The estimated area under high actual erosion risk levels is 66.96 % of total area as against the PSER of 62.62% of area. The visual scoring method showed that poor quality soils occupy 35.25% of total area (45338ha) in hills and ridges but moderate quality of soils covering 25.25% of total area (32823ha) and where as good quality soils accounts to 39.23% as good quality in both interhill basins and colluvio-alluvial sectors. The Muencheberg quality rating of soils on hills/ridges were rated as poor but ten mapping units in interhill basins and four mapping units in colluvio-alluvial sectors as moderate. The measured soil properties were used to derive Soil quality rating and evaluated as moderate to high quality in terms of physic-chemical properties. The appraisal of suitable lands for groundnut showed that 42% of total cropped area is moderately suitable and extensively cultivated in Vempalli (6894 ha, 27.39% of cultivated area) and Vemula (3613ha, 17.29% of cultivated area). The agroeconomic analysis showed that 13.94 % of lands have benefit cost ratio less than I due to seasonal aridity and creating panic of groundnut growers in the region. The results from land evaluation for drip irrigation shows that among 13 units, nine SUS are evaluated as marginally suitable for banana (34502 ha) whereas 8 SMUs (13882ha) of moderately suitable. These findings illustrate a possible scenario for groundnut cultivation in the event of increasing aridity (mainly due to rising temperatures) and impacting timing of crop management practices in the region.



**Key words** : Aridity index, Angot index, Land evaluation, benefit-cost ratio, soil mapping unit

## 1. INTRTODUCTION

The phenomenon of Desertification affects directly or indirectly the agrarian communities (Thomas and Middleton, 1994) and treated as natural cause revealing the productive activities of a given community, their strengths and weaknesses of socio - political and economic systems to cope with the crisis (Apeldoorn, 1981). For example, the droughts in Kadapa district of Rayalseema is common with lot of forest loss, over cultivation and grazing, sodification of canal irrigated tracts and over mining activities are recognized as chief drivers of desertification and land degradation (Bhaskar, et al., 2019). Furthermore, this district is known as drought prone area in Andhra Pradesh where the impact of land degradation and desertification has led to a Malthusian crisis and failed to yield results to agrodevelopmental interventions. It is further argued that the crisis of land degradation in the Kadapa region is being contained in small and marginal farming communities. Batterbury and Warren (2001) stated that some factors are undermined themes in debate on desertification/degradation such as periodic changes in crop sown area, anthropogenic activities as in case of study area (mining of shale/dolomite/quartzite) verus climatic factors (frequency and duration of droughts - very crucial for this region), delicacy (mainly for seasonal crops like groundnut/cotton in uplands) versus flexibility of agro ecosystems (degraded forestry/water intensive crops such citrus/banana under irrigation systems). Malthusian crisis in dry land agricultural systems is the main factor in decline of soil fertility and degree of soil erosion status especially of hilly terrains of Pulivendula. Then the question arises how to distinguish desertification with land degradation. Technically speaking, land degradation is defined as reduction or loss of biological productivity in arid, semiarid and dry sub humid areas of whereas Desertification is land degradation in arid, semiarid and dry sub humid areas resulting from various factors including climate change and anthropogenic activities (UNCED, 1992). This definition is regarded as simplified version of desertification related to biological or economic productivity of rainfed croplands, forests and woodlands resulting from land uses or combination of processes arising from human activities such as: (i) soil erosion caused by wind and / or water; (ii) deterioration of the physical, chemical, and biological or economic properties of the soil; and (iii) long-term loss of natural vegetation (UN, 1994).

Further extending the definition of land degradation that describes the quality of land that changes from productive state to a unproductive state (reduction or loss in the quality of land) with focus mainly on economic loss but not agro ecological deterioration (Kassas, 1995). He further stated that there is a strong connection between land degradation and land use systems but with varied manifestation of symptoms of desertification. For example, in irrigated farmlands, the soil degradation is often connected to ground water table because of imbalance between 'excessive irrigation and inefficient drainage' (Kassas, 1995). Referring to degradation in rain-fed farmlands, the degradation is usually assessed with degree and extent of soil erosion, loss of organic matter and depletion of nutrients, compaction and crust formation, and excessive evasion of weeds. In spite of lot of debate on how to distinguish between desertification and land degradation, several researches advocate the use of term land degradation as against desertification since land degradation does not have emotional implications (Le Houérou, 1996). The second distinction of desertification is better understood as "the continuous degradation of dry land ecosystems by human activities and climatic variations". The climatically sensitive dry lands of Kadapa district (drought prone area), it is recognized as serious environmental problem affecting 488584 land holdings with a net irrigated area of 144298 hectares. In several reports, it is mentioned that the socio-economic life of farmers in times of drought lead to the migration of people to urban areas and to economic and social strives. It leads to the destruction and loss of biodiversity and impacts on water resources (World Bank, 2006). Drought is a recurrent and normal feature of a climate in Kadapa basin, although its exact meaning is area and context-specific. The agro meteorological droughts are considered as natural hazard (UNCCD, 1994; Kassas, 1995) which causes temporal changes in crop area and productivity. There are three ideas and theories summed up based on the concepts of ecology and system's theory. These concepts influenced greatly on scholars of present era to debate on human – environmental interactions that shaped the desertification concept (Leach and Mearns, 1996).

1. The concept of "climax vegetation community" (Clements, 1916) states that each climatic zone supports its own type of vegetation in the absence of disturbance. The equilibrium between climatic factors and vegetation within a natural environment is disturbed by human interaction.

2. The second idea clearly states that reduced vegetation cover is closely linked with decreased rainfall (Stebbing, 1937). This concept has a direct link with deforestation and climate change. There are divergent outlooks about the processes of increased dryness as a result of natural processes, while others saw it as the result of human mismanagement (Grove, 1994);

3. The third theory is Malthusian crisis in which he explained demographic pressure beyond the environment's carrying capacity on food supply. He argued that there are limits to growth; the world is finite and can only support a finite population (Hardin, 1968; Meadows, *et al*., 1972).

Considering the above three points of view, the appraisal of land resources in general reflects physical and natural relationship of man and environment but in literally, it means "creation of land according to an idea". In the planning exercise, the environment is viewed as an entity that requires synoptic approach with integrated solutions. Thereby, the landscape is treated as ensemble of more or less cultivated areas fulfilling many ecological services. In this context, the land resource inventories at landscape level are useful to draw interrelated environmental problems prevailed at regional level. Base for comprehensive understanding the issues of sectors and domains at appropriate scale. It also addresses externalities affecting the farming activities at regional level and also contributes towards building socio - ecological systems. The evaluation and planning of land resources are prerequisite to standardize agricultural landscape with four functions as listed below:

- sustainable agricultural production : It is characterized by ecological suitability, more variation of crops and crop rotations, minimal use of fertilizer and no chemical treatment of weeds
- preservation and development of land scape elements of nature–forestry, water bodies, streams and river beds, hills and hillocks, pastures and grazing lands and wild life habitat .
- Boosting of the regional self-sufficiency in field of agriculture and allied sectors. Along with planning principles of spatial management and integration of various farming activities;

  market orientation and regulation to protect and enhance the landscape; and local governance of water bodies and bioresources.

- Finally the implementation of concrete practices of sustainable land management by considering biological farming practices and natural incentives in safe guarding and conserving bioresources of local importance.

The dry land agriculture in Andhra Pradesh is historically affected by severe drought and home for 30 million people of whom 70 percent of people in the states suffer drought-related crop production loss. Under the "business 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 an unaccounted loss of biodiversity. A large proportion of land holdings are involved in agriculture (the economic sector most vulnerable to rainfall variability occurring in these districts) and account for 43 percent of the cultivators and 36 percent of the agricultural laborers. The average per capita income is 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 types of soil types of the Agricultural Development Areas (ADAs) on groundnut production. Groundnut being a cash crop, can give relatively high 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 wielded 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 Microwatershed, Gulbarga District (Rajendra Hegde, *et al*., 2017). Methods of land evaluation (including land suitability) have become more sophisticated over time (Sonneveld, *et al.*, 2010) and with increased availability of large geographic and production datasets, evaluations 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 agro climatic indices are calculated.

The land degradation and land management interventions in dry lands is new emerging challenge to small and marginal farmers on the hill slopes, in terms of meeting livelihood and economic needs. Many local farmers aware of the negative effects of erosion, mining and other forms of land degradation such as salinisation / alkalization, but not in position to pay attention on these problems due to labour shortage and high cost inputs. Therefore, strengthening their effort through technical support in building their skill and knowledge about soil erosion and innovative erosion control practices, along with genuine participatory approaches, is essential and must be increased. In the hilly regions of Pulivendula tehsil of Kadapa district, Andhra Pradesh where small-scale groundnut/banana based farming systems based farming systems prevail, and also high demographic pressure on land use has resulted in severe land degradation. Soil erosion and mining activities in shale/lime stone areas of Vemula, Balapanur, and Tandur in conjunction with minimal adoption of improved soil conservation measures (stone/gravel bunding). During field traverse, it was observed that poor land and water conservation practices, lack of effective planning and implementation of conservation programmes are also responsible for accelerating degradation of agricultural lands and siltation of lakes and reservoirs in the region. The top loss is not easily perceived over landscape until it reaches the stage of gully formation. The empirical assessment of erosion using baseline data on present land resource/land use throws some light on what is going on and how much and where to prioritize conservation programmes but little consideration to sharing and enhancing farmers' local knowledge about soil erosion. Any successful implementation of conservation programmes at regional level, the experts must involve farmers and share their knowledge about land degradation to chalk out implementation strategies. To do this exercise, the understanding of land and water degradation processes starts with an assessment of individual farm management practices and ends with landscape level management systems. In semiarid environments, therefore, there is a need to encourage top sequence land management options and systems and to ensure high-priority sites for holistic land and water resources management. The effective implementation of soil water conservation practices at landscape level requires simple and locally understandable field erosion assessments. The mutual sharing of farmers' knowledge of on-site erosion indicators and experience of soil conservation adoption at level is possible through frequent field visits and discussions of farmer-expert. The

landscapes of Pulivendula of Kadada basin reveals the rich stories of past with complex geological evolution and also reflections of regional economy, agro ecology and cultural values of farming communities. The terrain include the rugged and spectacular ferruginous quartzite hill ranges; the basaltic caps of western plains; and the majestic gorges of Gondikota formations of Chitravathi and Penneru river basins with scattered *Prosopis* throughout the grazing lands.

This monograph on appraisal of land resources of Pulivendula tehsil, Kadapa district, Andhra Pradesh focuses primarily on climate analysis and its influence on agriculture, status of land resources in terms of erosion status and assessed pedo constraints for crop production and delineation of suitable crop zones for optimizing land use with local understanding and thinking of the livelihood strategies for rural households. With this background, the present study was made with the objectives as given under

- mapping and assessment of soil degradation in dry lands of Pulivendula tehsil, Kadapa district
- An evaluation of visual assessment tool to assess degradation and desertification in Pulivendula tehsil, Kadapa district

## 2.0. Materials and methods

### 2.1. Location and agro climate

Pulivendula (Fig.1) lies between14°16'to 14°44' N and 77°56' to 78°31'E covering 127463.0hectares (ha). The agro climate is characterized as semiarid with mean annual rainfall of Pulivendula is 564mm and 43 rainy days. The LGP varied from 90-105 days for Pulivendula 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 has 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 Chitravathi group includes (a) Pulivendula formation comprising quartzite with conglomerate, (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 (750-360m above mean sea level,), Dissected hills/summits, highly dissected plateau remnants, isolated hills/monadnocks/mounds/tors/boulders/ domical rises/rock outcrops (54135hectares of total area), interhill basins (6163ha of total area), undulating upper sectors, gently sloping middle sectors (39092ha of total area) and colluvial lower sectors (28542ha of total area) were identified and r eported (Naidu, *et al*., 2009).

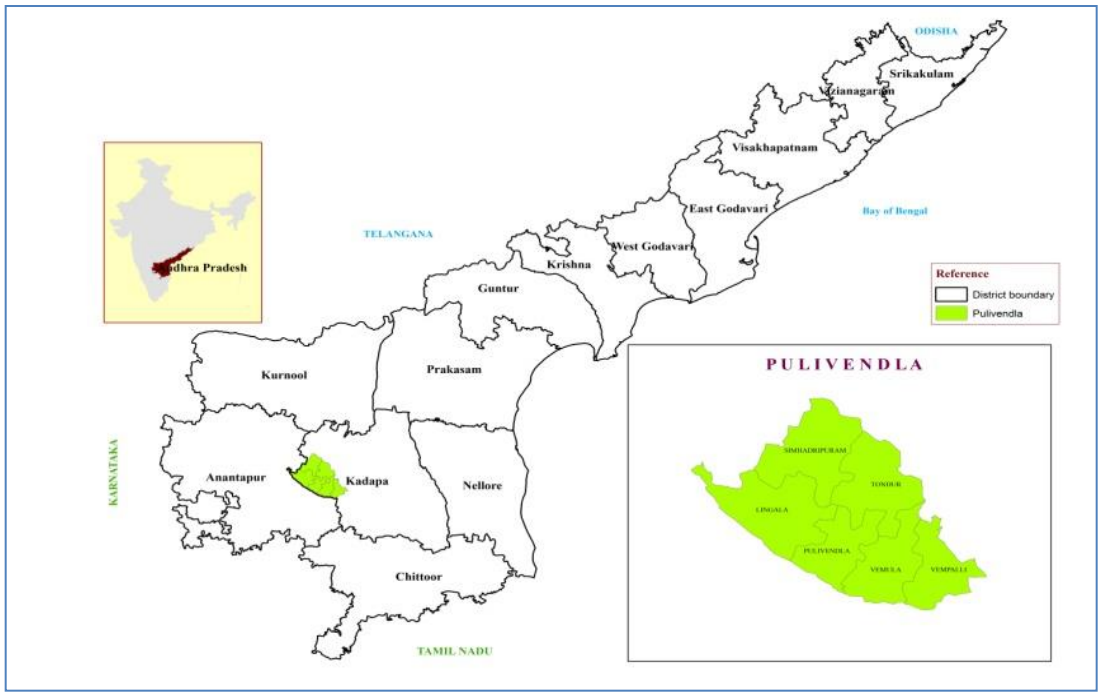



**Fig.1.** Location map of Pulivendula tehsil with mandal boundaries, Kadapa district

### 2.2. Climatic 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 (1926) and Angot index (Dragoťa, *et al.*, 2008).

### 2.2.1. 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) = $\frac{AAR}{AAT+10}$ 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 |

### 2.2.2. 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 (Dragot˘a 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 (Dragot˘a et al. 2008).

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

| **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 |

### 2.3. Field survey and soil mapping

**2.3.1. Post field activities** :The activities performed during this phase includes :review of literature, collateral data on agriculture (Agriculture information theory) and other related data base such as geology, geomorphic history, ground water data / information, history of droughts and socioeconomic analysis of farmers.

- Topographic maps at 1:50000scale, map sheet no- from survey of India top sheets
- Satellite imagery of false colour composites (FCC's) of P6-LISSIV imagery on 1:25,000 scale.-NRSC centre, Hyderabad
- Geological map of ground water board, Kadapa district(Geological Society of India )
- Climatic data from Kadapa district and also IMD data from 1901 to 2002
- Guide lines for profile description as per Schoeneberger et al.2012
- Soil classification as per Soil Survey Staff (2014)
- Munsell colour charts (Munsell colour Co.1992)
- Review of literature and other related information from different source about the study area

Visual interpretation of false colour composites (FCC's) of P6-LISSIV imagery on 1:25000scale was made in conjunction with top sheets (1:50000scale) along with geological maps and field photos taken during field traverse at representative sites of Pulivendula tehsil during field traverse (May 2019 to July 2019). The key attributes used

in preparing landform map were: geology, altitude, drainage pattern and condition, vegetation cover/land use and degree of dissection. Here some modifications proposed as mining is major activity and are using JCB for land leveling/stone removal for banana cultivation all along river banks. Some of the anthropogenic modifications made on critical banana growing zones are also included in interhill basins and colluvio-alluvial sectors. The land units were described along with legend and compiled map. This map was used as base for soil survey and mapping.

### 2.3.2. Field activities

A field survey was conducted using false colour composites (FCC's) of P6-LISSIV imagery to prepare a landform map on 1:25,000 scales. 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 $NH_4OAc$ extractable and distillation of ammonium for CEC 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).

### Generation of the soil map

Finally, soil series is the most detailed level, and they are soils that are grouped together because of their similar pedogenesis, soil chemistry and physical properties. Each series consists of soil layers that are similar in colour, texture, structure, pH, consistence, mineral and chemical composition, and arrangement in the profile. The soil series were used to delineate the soil map units (SMU), following the criteria of VAN WAMBEKE and FORBES (1986). Two kinds of map units are appropriate for site-specific soil survey mapping – consociations (Map units will contain 75 percent or more of pedons that fit within the range of the taxon that provides the name for the map unit, or are in a similar taxa. No one similar soil is greater than the named reference taxa. The total amount of dissimilar inclusions will not exceed 25 percent. No single dissimilar soil will make more than 10 percent of the map unit. Limiting inclusions do not exceed

15 percent of the map unit. (More intensive separation of dissimilar inclusions within a map unit can be made at the discretion of the soil scientist). and complexes(Map units consist of areas of two or more kinds of soils that are in a regularly repeating pattern so intricate that the two components cannot be delineated separately at the scale of mapping. The major components that provide the name for the map unit are sufficiently different in morphology or behavior that the unit cannot be named as a consociation. No single dissimilar soil will make up more than 10 percent of the map unit. Limiting inclusions do not exceed 15 percent of the map unit. The total amount of dissimilar inclusion will not exceed 25 percent. At the discretion of the Soil Scientist, areas of dissimilar inclusions, too small to be delineated, will be shown with special features or symbols).The soil survey party plotted the map unit boundaries onto orthophotographs. These boundaries were determined by means of soil observations, looking for differences in slope gradient, landform, colour, stoniness… The identification of soil map units utilizes taxonomic class names at the series level, and accompanying phase terms. The primary identification of the map unit is described in terms of ranges of soil properties within the limits of defines NRCS/NCSS Official Series Description and ranges of inclusions. Some map units may require naming at a categorical level above the series.
When all SMU were delineated, they were listed and codified and the soil map legend could be designed. The resulting soil map was digitised and introduced within a Geographic Information System (GIS). The selected GIS software was ArcGIS (ESRI®). Consociations, or complexes composed of major components that fall within the range and characteristics of existing official series, will use the series name to identify the map unit

**Evaluation of soil mapping units**

The soil map units were defined in thissurveys as complex or consociations generally consisted of soil series. In order to generate a thematic map or conduct any sort of land evaluation, it was necessary that each soil map unit delineation has a single rating index. Therefore, criteria to process a map unit with multiple components were required.

The weighted average method allocates ratings to map units as follows:

Step 1: A map unit is selected, and the component soils are listed with the numeric value of the property under consideration and the proportion they make up of the map unit.

Step 2: For each component, the product of the numeric value of the property under consideration and the percentage of that component are found.

Step 3: The products calculated in step 2 are summed and then divided by 100 to give a weighted average.

Step 4: The weighted average is related to a prede fi ned set of ranges (e.g. EC 0–1.99 is rated as 1 and EC 2–3.99 is rated as 2) and the appropriate rating allocated to the map unit. Steps 1–4 are repeated for all other map units. (EAD 2009) .

Soil erodibility 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 <0.5 t/ha/ year, low = 0.5-1 t/ha/year, low-medium = 1-2t/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.

### 2.3.3. Assessment of soil erosion risk using CORINE model

The scheme of CORINE model (1992) was given along with their corresponding indices and then grouping to derive potential and actual erosion risk zones of study area (Fig.2).

#### 2.3.3.1. Soil erodibility

In Corine model, soil erodibility was calculated considering the 3 scale ratings of each soil property such as texture, depth class and stoniness. The soil texture was classified into three classes including (1) slightly erodible (clay, sandy clay and silty clay), (2) moderately erodible (sandy clay loam, silty clay loam, clay loam and loamy sand), and (3) highly erodible (loam, silt loam and sandy loam). Similarly, three depth classes were categorized: (1) slightly erodible (>75 cm), (2) moderately erodible (25-75 cm), and (3) highly erodible (< 25 cm) and finally stoniness into two classes as: (1) fully protected (>10%) and (2) not fully protected soils (<10%). Finally, the soil erodibility index was calculated (eq. 1) and reclassified into three classes (1) low, (2) moderate, and (3) high erosion.

Soil erodibility index = textural class x depth class x stoniness class ---- (eq.1)

**2.3.3.2. Erosivity**

Erosivity, was defined as detachment and transportation of soil due to raindrop impact and runoff, primarily depends on the intensity and the amount of rainfall (Lal, 1994). The erosivity factor (R) was the product of kinetic energy (E) of a rain storm. The monthly rainfall and mean air temperature data of 55 years collected from KSNDMC (Karnataka State Natural Disaster Management Centre) was used to calculate erosivity factor. The R factor was simply the multiplication of MFI (modified Fournier index, Arnoldus, 1980) and BGI (Bagnouls and Gaussen, 1952) using equation 2 as given below:

R = MFI class X BGI class (Eq. 2)

The long term monthly rainfall data used in MFI calculations was classified into five categories as: very low (< 60), low (60 - 90), moderate (90 - 120), high (120 - 160) and very high (>160).

$$\text{Modified Fournier index (MFI)} = \sum_{i=1}^{12} \frac{P_i^2}{P_a} \quad \text{(Eq. 3)}$$

Where Pi is total precipitation in a month $P_a$ is mean annual precipitation

$$\text{Bagnouls-Gaussen index (BGI)} = \sum_{i=1}^{12} (2T_i - P_i)k_i \quad \text{(Eq. 4)}$$

Where, $T_i$ is temperature in a month

$P_i$ is total precipitation in a month

$k_i$ is proportion of the month during which $(2T_i - P_i) > 0$ The BGI index was

Calculated from mean annual precipitation and temperature data and classified into four classes viz., humid (0), moist (0-50), dry (50-130) and very dry (>130)

**2.3.3.3. Potential soil erosion risk (PSER)**

The two indices were integrated to derive soil erosivity map and grouped into three classes such as Low (<4), Moderate (4-80 and High (>8). The slope map was generated using IRS - LISS-IV data merged cartostat data at the scale 1:10000 and classified the slopes into very gentle to flat (<5%), gentle (5-15%), steep (5-15%) and very steep (>30%). Then the potential soil erosion risk (PSER) map was determined as

PSER class = Soil erodibility class X erosivity class X slope class (Eq. 5)

and generated map under GIS. The potential erosion risk zones were delineated and grouped as none (0), low (0 - 5), moderate (5 - 11) and high (>11).

### 2.3.3.4. Actual soil erosion risk (ASER)

The land use/cover estimations from satellite data as well as the present land cover at the time of field survey and land records. The vegetation cover was classified as fully protected (>50%) and not fully protected (< 50%). Finally actual soil erosion risk map (ASER) was generated with the combination of potential soil erosion risk and vegetation cover at the study site and classified into four classes as none low, moderate and high.

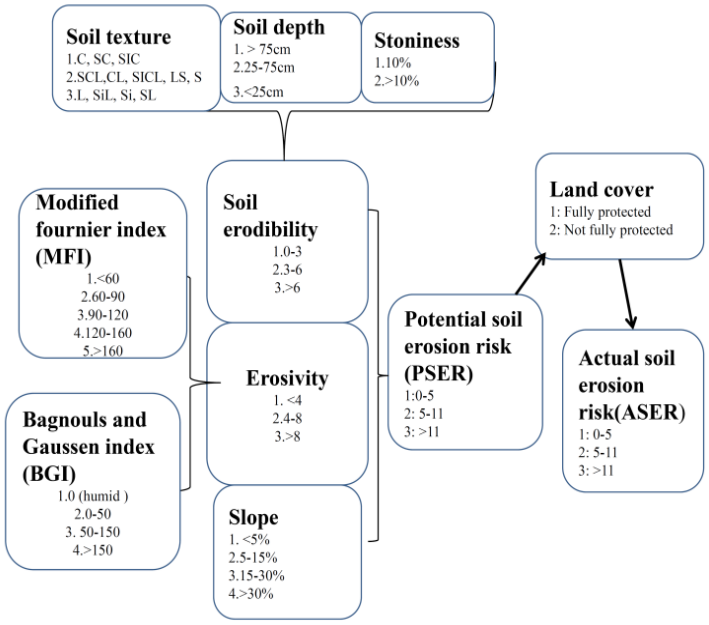



**Fig.2**. Schematic diagram of Corinne model

### 2.4.4. Visual signs of degradation

Arched and Cone (1992) recommend that qualitative soil morphological information should form an essential part of programs monitoring soil degradation or health. They pointed out that morphological observations are important for both farmers and scientists to recognize degraded soil quality caused by:

- water erosion, as indicated by rills, gullies, stones on the surface, exposed roots and uneven topsoil
- wind erosion, as indicated by ripple marks and sand against plant stems
- poor drainage and compact-hardpan structural deterioration, as indicated by standing water and patchy plant growth
- Salinization, as indicated by salt crust and ingress of salt-tolerant plants
- loss of organic matter, reduced aggregation, low hydraulic conductivity, soil crusting and surface sealing

#### 2.4.4.1. Visual soil assessment method (VSA)

Three widely used and simple methods were used in evaluating soil quality of Pulivendula tehsil for agridevlopment. The procedures adopted were given and discussed as below:

**Method 1** : Visual soil assessment is very important and end product of many physical, chemical and biological processes interacted with each other over a period of time in an agro ecological regions. The visual characteristics are always subjected to remarkable changes in land use or land management. These visual indicators are closely measured in quantitative means both by farmers and also by experts at field scale. The VSA method employed in this study has been developed to help farmers to easily, quickly, reliably and cheaply recognize at field scale for monitoring pedological changes and design sustainable land management practices.VSA is based on key soil ‘condition ‘and scoring assigned to each soil properties on a card and does not require knowledge of land use history of a location. The plant indicators are not considered in this study due to seasonal changes in crops in this part of Cuddapah basin. The practical meaning of VSA for applications in agriculture can be explained well with the examples as given under:

- The semiarid regions with frequent drought history and crop failures, the crop yields in a season may be good to think that the agriculture is fine in the

region. With the application of VSA, the soils quality is rated as moderate. A series of cultivation experience, farmers know that the input cost on fertilizers, pesticides and weed control increasing with a marginal productivity of major crops in the region. This VSA can help farmers to make choices to take care off reduction of input cost in farm management and also helps in expanding cropping systems in the region.

- The simple and easily recognizable soil properties in judging the status of soil quality at field scale to design appropriate irrigation designs and also agronomical conservation programmes in low productivity crop regions.

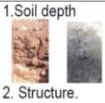
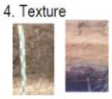
**2.4.4.2. Visual Scoring (VS)**

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil condition as per the field guide manual (FAO, 2008). It is a photo elicitation process (a method of interview in visual sociology and marketing research that uses visual images to *elicit* comments) and scoring of soil condition of selected properties under study. It is flexible scoring of assessing soil conditions by assigning value in between 0.5 and 1.5. The criteria of the scoring along with set of photographs are given in Table 1. Because of some soil factors or indicators are relatively more important for soil condition than others; VSA provides a weighting factor of 1, 2 or 3. For example, soil structure is a more important indicator (a factor of 3) than clod development (a factor of 1). The score you give each indicator is multiplied by the weighting factor to give a VS ranking. The total of the VS rankings gives the overall ranking score for the sample you are assessing.

The visual observations of soil characteristics with regard to depth changes in consistency, colour, structure, soil texture and abundance of roots in different restrictive layers have long been used as an integral part of soil survey procedures (McDonald, *et al.*, 1990; Soil Survey Staff 1994; Soil Survey Division Staff, 1993, Bhaskar, *et al.*, 2014) but recently reviewed to interpret soil processes and therefore soil quality (Mac Ewan and Fitzpatrick, 1996). This methodology was applied in Garakahalli micro watershed of Ramnagara district Karnataka and reported visual scoring of 10 biophysical indicators used by farmers are well in agreement with scientific methods (Ramesh kumar, *et al.*, 2017).These authors stated, all efforts were made in highlighting the difficulties in classification of soils and ignored the practical importance of soil morphological features

as indicators of soil quality. They proposed use of four key properties viz., consistence, soil texture effective rooting depth and soil colour and discussed in length of each property in visual assessments of soil quality.

**Table 1.** Visual scoring of soil properties under study

| Soil property | Class/ range / Rating of soil constraints | | | |
|---|---|---|---|---|
| | Severe | Moderate | Slight | None |
| 1.Soil depth  | Very shallow(<25 cm) -0 | Shallow(25-50 cm)-1 | Moderately deep (50-100 cm)-2 | Deep(>100 cm)-3 |
| 2. Structure.  | None (Soil is single grain or massive)-0 | Weak(Poorly formed aggregates)-1 | Moderate(Well formed aggregates)-2 | Strong(Very well formed aggregates)-3 |
| 3.Tillage and pan compaction  | None (No tillage pan, friable consistence* (moist) and abundant pores/voids throughout)- 3 | Slight (Slightly developed tillage pan, friable to firm consistence (moist) and many fine pores throughout but with few large pores)- 2 | Moderate (Moderately developed tillage pan, firm consistence (moist) and moderate amount of pores but very few large pores)- 1 | Severe (Strongly developed tillage pan, with massive structure, very firm to extremely firm consistence (moist) and very few or no pores)- 0 |
| 4. Texture  | Sand, loamy sand (Low water and nutrient holding capacity*, good workability, high to very high infiltration rate)- 0 | Sandy loam, silt loam, heavy clay (Low to medium water and nutrient holding capacity; good workability) -1 | Medium clay, sandy clay loam, silty clay, sandy clay, silty clay loam (Medium to high available water holding capacity; high nutrient holding capacity;)- 2 | Loam, clay loam (Very high water holding capacity, high nutrient holding capacity, medium workability, moderate infiltration rate)- 3 |
| 5.Coarse fragments  | None to common (0 – 15% )- 3 | Common to many (15 – 40%)- 2 | Many to abundant (40 – 80%) 1 | Dominant (> 80%)- 0 |
| 6. Rooting condition  | Good condition (Unrestricted root development, many (<2 mm, 50/dm$^2$ ; > 2 mm, > 5/dm$^2$ ) - 3 | Moderate condition (Horizontal and vertical root development somewhat limited; more roots between | Poor condition Horizontal and vertical root development clearly limited; most roots concentrated in cracks between | Very poor condition Severe restriction of horizontal and vertical root development; presence of L-shaped roots, |

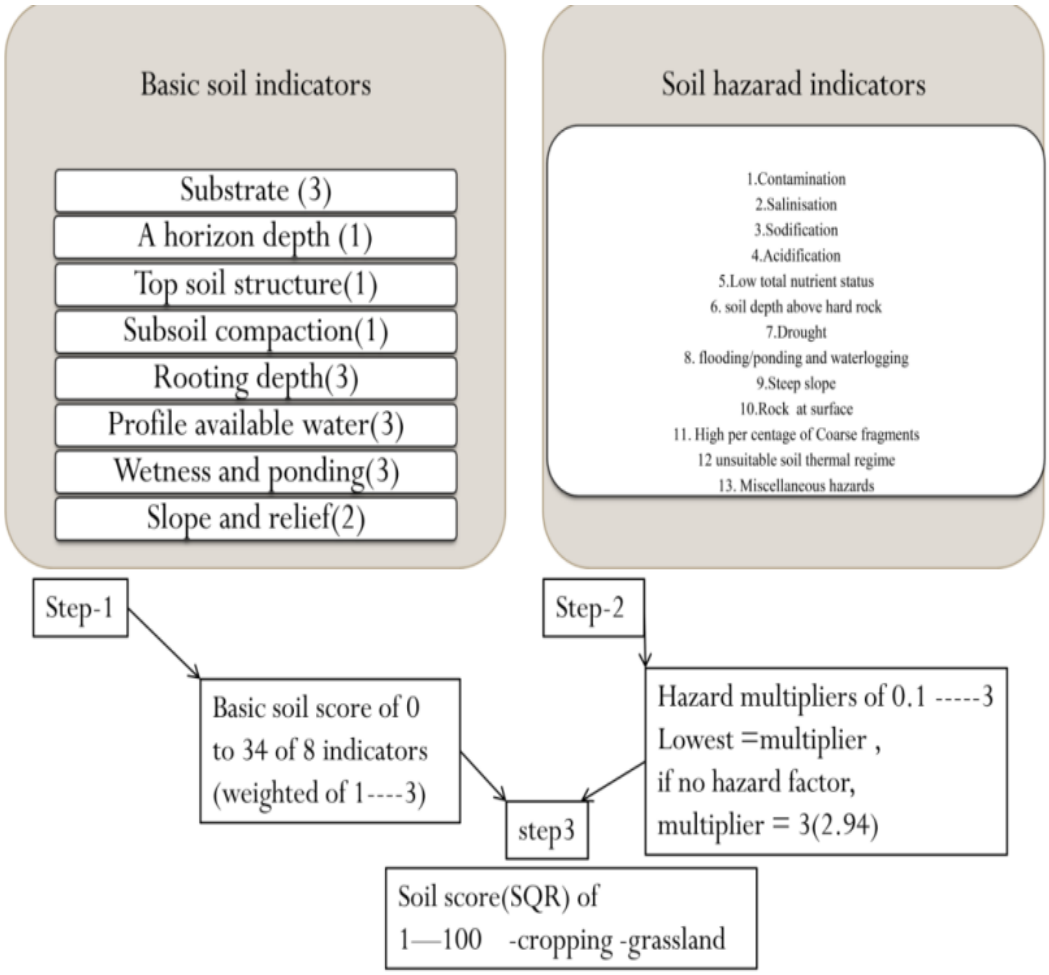
| Soil property | Class/ range / Rating of soil constraints | | | |
|---|---|---|---|---|
| | Severe | Moderate | Slight | None |
| | | coarse structural elements than inside; common roots (2 mm, > 5 - 20/dm$^2$ )- 2 | structural units, almost no roots inside units; few roots (2 mm, > 2 - 5/dm$^2$ )- 1 | over thickening of roots or roots squashed between coarse structural units or concentrated above dense layer, no roots inside units; none to very few roots (2 mm, 0 - 2/dm$^2$) - 0 |
| 7.organic matter/ colour  | Very low (White; value 8)- 1. | Low (Grey; value 5-7)-2 | Medium (Dark grey to black grey; value 3-4.5)- 2 | High (Black; value 2-2.5)- 3 |
| 8.Biological activity | None (No biological features, no earthworms)- 0 | Low (Few biological features or soil biota; 1- 4 earthworms counted in spadeful)-1 | Medium (Common biological features or biota; 4 – 8 earthworms counted in spadeful)-2 | High (Many biological features or biota; > 8 earthworms counted in spadeful)-3 |
| 9.surface crust / sealing a. Physical  | None (No crust present)- 3 | Slight (Thin to medium crust (1 – 5 mm) on up to 20% of the surface)- 2 | Moderate (Thin to medium crust (1 – 5 mm) present on 20 - 50% of the surface, thick crust (> 5 mm) present in few patches) -1 | Severe (Thin, medium and thick crust present on more than 50% of the surface with common patches of thick crust)-3 |
| 10.salinity/ sodicity  | None (No signs of sodicity, also not in nearby areas, see below; depth of groundwater > 2 m)- 3 | Slight Sodicity: (in shallow pit soil structure is weak; in close-by areas some puddles of surface water are coloured black by dispersed organic colloids (slick spots); upon drying, black crusts are formed)-2 | Moderate Sodicity: (water logging is a common surface feature; some puddles of surface water are colored black by dispersed organic colloids (slick spots); upon drying, black crusts are formed; hard setting surface, but when worked soil becomes easily dusty when dry. -1 | Severe Sodicity: (in shallow pit the top of the B-horizon is visible in the form of well defined vertical columns or prisms, having a rounded top with lighter colour and smooth, shiny and well defined sides.)- 0 |

**Method 2: The Muencheberg soil quality rating** (SQR, Muller, *et al*., 2007) was used and scored each soil series within a 100 point scale (Appendix.1). This score was a measure of the long-term soil quality and will provide a rough estimate of the local crop yield potential. In this method, estimated Indicators were based upon profile features of main soil series with due consideration of topography and hydrological position of the pedon. The basic soil scoring procedure was compatible with the VSA method (Shepherd, 2000) for the evaluation of the dynamic soil quality and gives hints at management deficits. This method has two steps such as basic soil indicators which were scored by using scoring tables. Single scores are on a quasi -ball scale ranking from best conditions (2) to worst (0) with possible increments of 0.5, or 0.25 in very sensitive cases (Fig.3).

Basic soil indicators were estimated in the field with supportive measurements of soil properties.

In SQR, hazard indicators considered as multipliers for the basic soil score, ranging from about 0.01 (hazard properties do not allow farming) and 3 (no hazard properties). The lowest multiplier will be the valid one. The occurrence of more than one suboptimum hazard indicators be considered in such a way that the multiplier was set to a lower value within the range of scoring. Under low ratings (< 1.5) of the slope gradient with sub-optimum (ratings < 2) of any other hazard indicator, the valid multiplier should be lowered to one class to that of the minimum single lowest hazard indicator. The final score (SQR-score) ranging from about 0 to 100. SQR were classified as < 20 = Very poor, 20 - 40 = Poor, 40 - 60 = Moderate, 60 - 80 Good, > 80 = Very good. The advantage of this scoring method was easily transferable to landscapes and also climatic conditions.

**Fig. 3**. Scheme of the Muencheberg SQR



**Method 3. S**oil quality index (SQI) in this methodology involves integration of physical and chemical properties of soils into a single indicator of overall soil quality. Thus, in concept, this index would serve as a measure of the soil's "vital sign." soil properties along with threshold levels, interpretations, and associated soil index values are listed and given in Table 2 . The individual index values for all the mineral soil properties measured on an FI A plot are summed to give a total SQI:Total SQI = Σ individual soil property index values (Amacher, *et al*., 2007).

**Table 2**. Soil quality index values and associated so property threshold values and interpretations

| Parameter | Level | Interpretations | Index |
|---|---|---|---|
| 1.Bulk density($Mgcm^{-3}$) | >1.5 | Possible adverse effects | 0 |
| | ≤1.5 | Adverse effects unlikely | 1 |
| 2.Coarse fragments | >50 | Possible adverse effects | 0 |
| | ≤50 | Adverse effects unlikely | 1 |
| 3.SoilpH | <3 | Severely acid – almost no plants can grow in this environment | -1 |
| | 3.1 to 4.0 | Strongly acid – only the most acid tolerant plants can grow in this pH range and then only if organic matter levels are high enough to mitigate high levels of extractable Al and other metals | 0 |
| | 4.1 to 5.5 | Moderately acid – growth of acid intolerant plants is affected depending on levels of extractable Al, Mn, and other metals | 1 |
| | 5.51 to 6.8 | Slightly acid – optimum for many plant species, particularly more acid tolerant species | 2 |
| | 6.81 to 7.2 | Near neutral – optimum for many plant species except those that prefer acid soils | 2 |
| | 7.21 to 7.5 | Slightly alkaline – optimum for many plant species except those that prefer acid soils, possible deficiencies of available P and some metals (for example, Zn) | 1 |
| | 7.51 to 8.5 | Moderately alkaline – preferred by plants adapted to this pH range, possible P and metal deficiencies | 1 |
| | >8.5 | Strongly alkaline – preferred by plants adapted to this pH range, possible B and other oxyanion toxicities | 0 |
| 4. Total organic carbon (percent) | >5 | High – excellent buildup of organic C with all associated benefits | 2 |
| | 1-5 | Moderate – adequate levels | 1 |
| | <1 | Low – could indicate possible loss of organic C from erosion or other processes, particularly in temperate or colder areas | 0 |
| 5. Exchangeable Na percentage | > 15 | High – sodic soil with associated problems | 0 |
| | ≤15 | Adverse effects unlikely | 1 |
| 6. Ca (mg/kg) | > 1000 | High – excellent reserve, probably calcareous soil | 2 |
| | 101 to 1000 | Moderate – adequate levels for most plants | 1 |
| | 10 to 100 | Low – possible deficiencies 0 | 0 |
| | < 10 | Very low – severe Ca depletion, adverse effects more likely | -1 |
| 7. Mg(mg/kg) | > 500 | High – excellent reserve | 2 |
| | 50 to 500 | Moderate – adequate levels for most plants | 1 |
| | <50 | Low – possible deficiencies | 0 |
| 8.K(mg/kg) | >500 | High – excellent reserve | 2 |
| | 100-500 | Moderate – adequate levels for most plants | 1 |
| | <100 | Low – possible deficiencies | 0 |
| 9.Mn(mg/kg) | >100 | High – possible adverse effects to Mn sensitive plants | 0 |
| | 11-100 | Moderate – adverse effects or deficiencies less likely | 1 |
| | 1-10 | Low - adverse effects unlikely, possible deficiencies | 1 |
| | <1 | Very low – deficiencies more likely | 0 |
| 10.Fe(mg/kg) | >10 | High – effects unknown | 1 |
| | 0.1 to 10 | Moderate – effects unknown | 1 |
| | <0.1 | Low – possible deficiencies, possibly calcareous soil | 0 |
| 11.Cu(mg/kg) | >1 | High – possible toxicity to Cu sensitive plants, may indicate mining areas or industrial sources of Cu | 0 |
| | 0.1 to 1 | Moderate – effects unknown, but adverse effects unlikely | 1 |
| | <0.1 | Low – possible deficiencies in organic, calcareous, or sandy soils | 0 |

| | | | |
|---|---|---|---|
| 12.Zn(mg/kg) | > 10 | High – possible toxicity to Zn sensitive plants, may indicate mining areas or industrial sources of Zn | 0 |
| | 1-10 | Moderate – effects unknown, but adverse effects unlikely | 1 |
| | <1 | Low – possible deficiencies in calcareous or sandy soils | 0 |
| 13.S(mg/kg) | >100 | High – may indicate gypsum soils, atmospheric deposition, mining areas, or industrial sources | 0 |
| | 1-100 | Moderate – adverse effects unlikely | 1 |
| | <1 | Low – possible deficiencies in some soils | 0 |
| 14.olsen's P(mg/kg) | >30 | High – excellent reserve of available P in slightly acidic to alkaline soils, possible adverse effects to water quality from erosion of high P soils | 0 |
| | 10 to 30 | Moderate – adequate levels for plant growth | 1 |
| | <10 | Low – P deficiencies likely | 0 |

The maximum value of the total SQI is 18 if all 14 soil properties are measured. The total SQI is then expressed as a percentage of the maximum possible value of the total SQI for the soil properties that are measured:

SQI, % = (total SQI /maximum possible total SQI for properties measured) x 100

Thus, missing properties do not contribute to the index. However, we recommend that SQIs based on only a few of the 19 measured soil properties not be included in any data analysis since these values could provide a distorted assessment of soil quality because they are based on too few measured properties. The criteria of categorizing soil quality rating used in the method were further grouped as High (% Q rating > 65), medium (% Q rating 35 to65) and low (% Q rating <35). This methodology was applied in assessing soil quality of Idoffa in Ogun state of Southwestern Nigeria (Oluwatosin et al., 2006) and for rice growing soils of Majuli in India (Bhaskar and Sarkar, 2013) but not tested with reference to any crop.

### 2.4.5. Land evaluation

The soil map on 1:25000 scales 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 (Arachis *hypogeae* L) and banana (Musa acuminate) were used to determine suitability classes. Crop requirements were matched with land characteristics and applied to determine overall suitability for groundnut / banana. The criteria used for groundnut / banana suitability analysis was done as per the scheme of FAO (1983) and Sys, *et al.* (1991). 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 type about 9 farm households (3 each of marginal, small and large farm households) were selected and collected data for 20 soil types. The flow chart of methodology adopted in the present study is given in Fig.4.

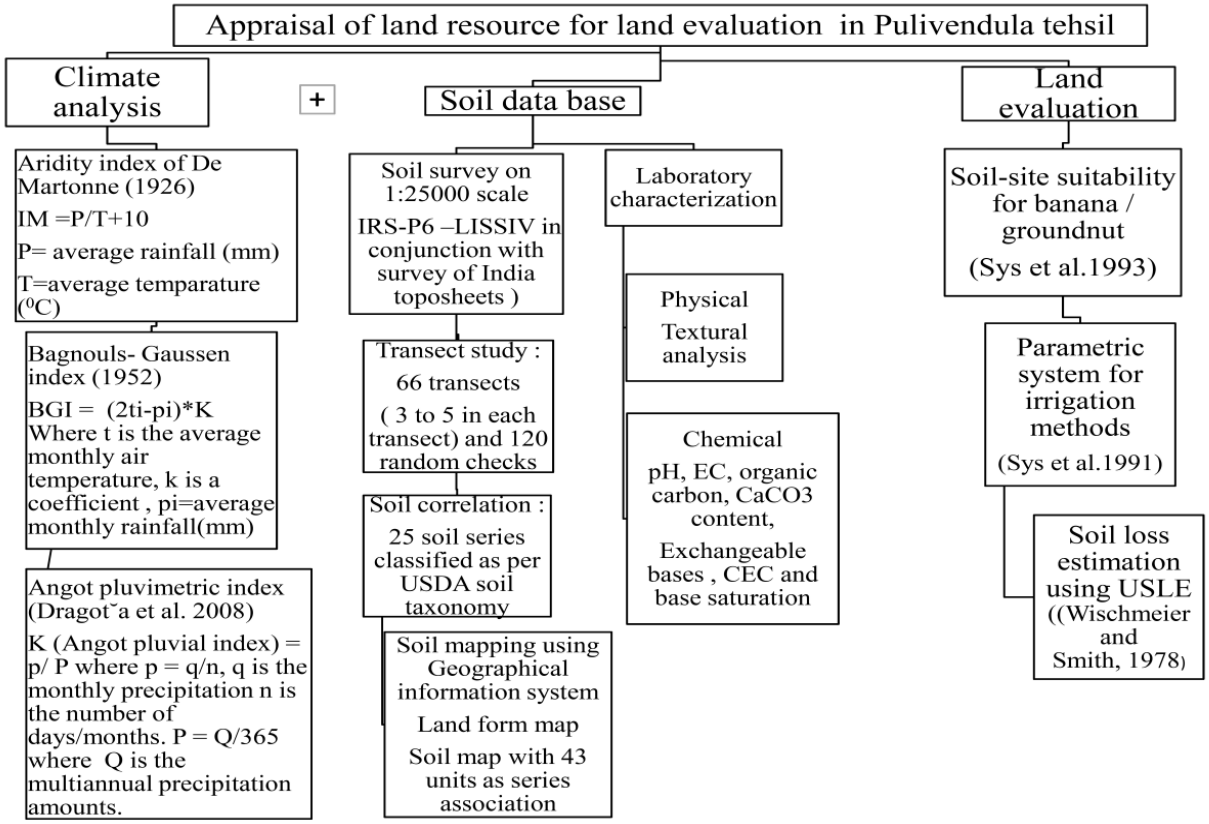



**Fig.4.** Flow chart of methodology used in the study

### 2.4.5.1. Land suitability for Groundnut

The soil map on 1:25000 scales 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 (FAO, 1983, Table 3) was given below:-

**Table. 3.** Land evaluation guidelines for groundnut suitability

| Soil-climate requirements | Diagnostic property | Soil suitability class | | | |
|---|---|---|---|---|---|
| | | S1 | S2 | S3 | N |
| Climate | | | | | |
| | Rainfall(mm) | >700 | 600-700 | 500-600 | <500 |
| | Temperature($^0$C) | 22-28 | 18-22 | 15-18 | <15 |
| Soil physical characteristics | | | | | |
| Root condition(r) | Soil depth(cm) | >120 | 75--120 | 30-7540-70 | <30 |
| Soil workability(w) | Soil textural class | sl,sil, ls | sicl,cl | s,sc,sic | c |
| Soil workability(k) | Soil structure | Moderately developed | Moderately developed | Weakly to strongly to very strongly developed | Strongly to very strongly developed/ structure less |
| topography | | | | | |
| Erosion hazard(e) | Slope (%) | 0-2 | 2-5 | 5-8 | >8 |
| Oxygen availability(g) | Drainage class | Well drained | Moderately well drained | Imperfectly drained | Poorly drained |
| Moisture availability(m) | Available water holding capacity (%) | >12 | 9-12 | 6-9 | <6 |
| Soil fertility status | | | | | |
| Nutrient availability(a) | pH | 5.8-6.2 | 5.5-5.7 6.3-6.5 | 5.0-5.4 6.4-8.0* | <5 >8.0* |
| | CEC(coml./kg) | >12 | 6-12 | 4-6 | <4 |
| | Exchangeable Ca(coml./kg) | 5-10 | 3.8-4.9 | 2.6-3.9 | <2.6 |
| | Exchangeable Mg(coml./kg) | 0.9-1.4 | 0.6-0.9 | 0.3-0.59 | <0.3 |
| | Exchangeable K(coml./kg) | 0.3-0.5 | 0.2-0.29 | 0.1 – 0.19 | <0.1 |
| Nutrient retention(n) | Per cent base saturation | >80 | 50 - 80 | 40-50 | <40 |
| Nutrient retention(n) | Organic carbon(g/kg) | >12 | 8-12 | 5-8 | <5 |
| Excess salt(s) | EC($dSm^{-1}$) | 0-2 | 2-3 | 3-4.5 | >4.5 |
| | ESP (%) | 1.0-10 | 10-15 | 15-20 | >20 |

Note: LS = Loamy Sand, SL = Sandy Loam, CL = Clay loam, Sill = Silt Loam, Sic = Silt Clay Loam, C-Clay, S = Sand, SC = Sandy Clay * pH for marginal suitability is given 6.4 to 8 and not suitable pH>8.0

### 2.4.5.2. Land suitability for banana:

In this study, the twenty five soil series were collected and horizon wise soil samples were used for determination of particle size distribution and chemical properties. The soil map with 43 units was used for land evaluation for banana (Table 4) and parametric approach for irrigation suitability in GIS environment (Arc info. version 10.3, Sys *et al*., 1991, 1993). The land requirements for banana were used to determine suitability classes as given as under:

**Table 4.** Criteria for land suitability evaluation for banana

| Land –climate suitability | Suitability class | | | |
|---|---|---|---|---|
| | S1 | S2 | S3 | N1 |
| Climatic parameters | | | | |
| Altitude(meters above mean sea level) | <1200 | 1200-1500 | 1500-2000 | >2000 |
| Rainfall(mm/year) | 1500-2500 | 1250-1500 | 1000-1250 | <1000 |
| Period of dry month(month) | 0-3 | 3-4 | 4-6 | >6 |
| Slope (%) | <8 | 8-16 | 16-40 | >40 |
| soil parameters | | | | |
| Total N (%) | >0.4 | 0.1-0.4 | 0.05-0.1 | <0.05 |
| Olsen's P(mg/kg) | >20 | 15-20 | 8-15 | <8 |
| Exchangeable K(coml./kg) | >0.8 | 0.4-0.8 | 0.1-0.4 | <0.1 |
| pH | 6.0-7.5 | 5.5-6.0&7.5-8.0 | 5.0-5.5&8.0-8.5 | <5.0 &>8.5 |
| Depth to mottling(cm) | >110 | 85-110 | 60-85 | <60 |
| Ground water table(cm) | >150 | 125-150 | 100-125 | <100 |
| Bulk density($Mgm^3$) | <1.31 | 1.31-1.47 | >1.47 | |
| Permeability(cm/h) | >7.9 | 7.9 - 5.00 | <5.0 | |
| Clay CEC | >12.4 | 8.9-12.4 | <8.93 | |

### 2.4.5.3. Land evaluation for irrigation

The steps in land evaluation for irrigation were listed as under:-

Step 1- Soil map and present land use/land cover map was prepared as an input into GIS;

Step 2- Development of capability index using soil texture, soil depth, $CaCO_3$ content, salinity/alkalinity, drainage and slope for each soil series identified in the district (Sys, *ET al.*1991).

Step 3. Soil units were rated by multiplying the proportion of each soil type by its respective soil rating. Rating of non-irrigable portions of a complex should not be added to irrigable portions to determine the final soil category.

Step.4- Decision rules were proposed for irrigation and derived priority areas suitable for irrigated agriculture using Arc info version.10.4.

Parametric evaluation: The parametric evaluation system was applied using standard granulometrical and physico-chemical characteristics of a soil profile. The different land characteristics that influence the soil suitability for irrigation are rated and a capability index for irrigation (Ci) is calculated according to the formulae: Ci = A * B/100 * C/100 * D/100 * E/100 * F/100 Where: Ci: capability index for irrigation; A: rating of soil texture; B: rating of soil depth; C: rating of CaCO3 status; D: salinity/alkalinity rating; E: drainage rating and F: slope rating. The capability classes are defined according to the value of the capability (or suitability) index (Ci) Capability Index Class Definition Symbol >80 1 Excellent S1 60-80 ii.Suitable S2 45-60 iii slightly suitable S3 30-45 IV. Almost unsuitable N1 (Table 5).

Rating soil mapping units: Soil units mapped as complexes were rated by multiplying the pro portion of each soil type and its summation to get respective final soil rating (AAFRD, 2004).

For example: - Soil mapping unit Ahm-Spm

| Proportion of unit | Capability index | Partial soil rating |
|---|---|---|
| Agraharam (Ahm)-60 | 80 | 80*60=4800 |
| Simhadripuram (Spm)-40 | 90 | 90*40=3600 |
| | Final total | 8400/100=84 |

| Texturaclasses | Rating for surface irrigation | | | | | Rating for drip irrigation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fine gravel(%) | | | Coarse gravel (%) | | Fine gravel(%) | | | Coarse gravel(%) | |
| | <15 | 15-40 | 40-75 | 15-40 | 40-75 | <15 | 15-40 | 40-75 | 15-40 | 40-75 |
| CL | 100 | 90 | 80 | 80 | 50 | 100 | 90 | 80 | 80 | 50 |
| SiCL | 100 | 90 | 80 | 80 | 50 | 100 | 90 | 80 | 80 | 50 |
| SCL | 95 | 85 | 75 | 75 | 45 | 95 | 85 | 75 | 75 | 45 |
| L | 90 | 80 | 70 | 70 | 45 | 90 | 80 | 70 | 70 | 45 |
| SiL | 90 | 80 | 70 | 70 | 45 | 90 | 80 | 70 | 70 | 45 |
| Si | 90 | 80 | 70 | 70 | 45 | 90 | 80 | 70 | 70 | 45 |
| SiC | 85 | 95 | 80 | 80 | 40 | 85 | 95 | 80 | 80 | 40 |
| C | 85 | 95 | 80 | 80 | 40 | 85 | 95 | 80 | 80 | 40 |
| SC | 80 | 90 | 75 | 75 | 35 | 95 | 90 | 85 | 80 | 35 |
| SL | 75 | 65 | 60 | 60 | 35 | 95 | 85 | 80 | 75 | 35 |
| LS | 55 | 50 | 45 | 45 | 25 | 85 | 75 | 55 | 60 | 35 |
| S | 30 | 25 | 25 | 25 | 25 | 70 | 65 | 50 | 35 | 35 |

**Table 5**. Rating system for irrigation suitability

(a)rating for texture and gravels

Note: CL=clay loam, SiLC=silty clayloam, SCL=sandy clay loam, L=loam, SiL=silty loam, ,Si=silty,SiC=silty clay, C=clay,SC=sandy clay, SL=sandy loam, LS=loamy sand, S:sandy

(b) Rating for soil depth, $CaCO_3$ (%) and salinity classes

| Soil depth(cm) | Surface | Drip | $CaCO_3$(%) | Surface | Drip | Salinity EC,($dSm^{-1}$) | Surface | | Drip | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | C,SIC,SICL,S,SC | Others | C,SIC,SICL,S,SC | Others |
| <20 | 25 | 35 | 0-0.3 | 90 | 90 | <4 | 100 | 100 | 100 | 100 |
| 20-50 | 60 | 70 | 0.3-10 | 95 | 95 | 4-8 | 90 | 95 | 95 | 95 |
| 50-80 | 80 | 90 | 10-25 | 100 | 95 | 8-16 | 80 | 50 | 85 | 50 |
| 80-100 | 90 | 100 | 25-50 | 90 | 80 | 16-30 | 70 | 30 | 75 | 35 |
| >100 | 100 | 100 | >50 | 80 | 70 | >30 | 60 | 20 | 65 | 25 |

© Rating for drainage classes for surface and drip irrigation

| Drainage class | Surface | | Drip | |
|---|---|---|---|---|
| | C,SIC,SICL,S,SC | Others | C,SIC,SICL,S,SC | Others |
| Well drained | 100 | 100 | 100 | 100 |
| Moderately drained | 80 | 90 | 100 | 100 |
| Imperfectly drained | 70 | 80 | 80 | 90 |
| Poorly drained | 60 | 65 | 70 | 80 |
| Very poorly drained | 40 | 65 | 50 | 65 |
| Drainage status not known | 70 | 80 | 70 | 80 |

(d) Rating for slope

| Slope classes(%) | Surface irrigation | | Drip irrigation | |
|---|---|---|---|---|
| | Non terraced | terraced | Non terraced | terraced |
| 0-1 | 100 | 100 | 100 | 100 |
| 1-3 | 95 | 95 | 100 | 100 |
| 3-5 | 90 | 95 | 100 | 100 |
| 5-8 | 80 | 90 | 90 | 100 |
| 8-16 | 70 | 80 | 80 | 90 |
| 16-30 | 50 | 65 | 60 | 75 |
| >30 | 30 | 45 | 40 | 55 |

2.5. Statistical analysis

The Microsoft excel and free online statistical tools viz., stats blue and data tab were used to work out descriptive statistics, correlation matrix , multiple regression and cluster techniques for understanding relationships, variability and similarity of major soil series under the study. The weighted means were calculated by multiplying with individual horizon thickness and their summation divided by total thickness.

**3.0. Agrogeographic characteristics**

The per capita land available in each mandal is worked out and presented in Table (6). From the literature, it is clear that Andhra Pradesh is 4$^{th}$ largest in terms of area with projected population of 8.4 crores as on 2010. It is 5$^{th}$ most populous state in India. The total geographical area is 275.04 lakh ha. Out of which 39.8% is under the net area sown (109.58 lakh ha) with cropping intensity of 1.26. Average annual rainfall in the state is 940 mm. About 72% of the population lives in rural areas with

62.2% of workers dependent on agriculture (out of which 22.5% are cultivators and the remaining 9.6% are agricultural labourers). The contribution of agriculture to GSDP (Gross State Domestic Product) defined as a measure, in monetary terms, of the volume of all goods and services produced within the boundaries of the State during a given period of time, accounted without duplication) is decreased from 40% of its share in 1980 to about 17% in 2009. The unweighted average Poverty ratios and monthly per capita expenditure (MPCE) for the year 2004 to 2005 calculated from NSSO 61$^{st}$ Round as reported (Chaudhuri and Gupta, 2009) indicates that the percent of poor is quite low (7.6%) in the Coastal region when compared to both Telangana (12.1%) and Rayalaseema (16.5%) regions (Amarender Reddy, 2011). The census data of YSR Kadapa district for the year (Directorate of Census Operations, 2011) was collected to workout population pressure on land both at mandal and village level (Table 6.1, Appendix). Arable land (hectares per person) in India was reported at 0.11813 in 2016, according to the World Bank collection of development indicators, compiled from officially recognized sources. India - Arable land (hectares per person) - actual values, historical data, forecasts and projections were sourced from the World Bank on February of 2021.The per capita land is an important socioeconomic indicator widely used in identifying vulnerable areas of agroecoregions for degradation under semiarid conditions.

### 3.1. Demographic analysis

Pulivendula with the total geographical area of 1, 27463 ha and has six mandals viz., Simahadripuram (27959.00 ha) > Lingala (26012ha) > Tondur (24417 ha) > Vemula (21417 ha) > Vempalli (17564 ha) and Pulivendla (9807ha). The data shows that per capita available land is below or equal to 1 ha in all mandals whereas per capita net sown area is 0.2ha in Vempalli to 0.7ha Pulivendula. The mean per capita net sown area is 0.4 ± 0.1 with coefficient of variation of 35.5 per cent. The per capita irrigated land is 0.1 ha except in Lingala where it is 0.2ha with coefficient of variation of 29 per cent (moderate variation). Demographic statistics shows that Pulivendula tehsil has 50563 farm house holds with 66 per cent of small and marginal farmers owning 87409ha. The population consists of 15 percent of cultivators and 16.5 per cent of agricultural labourers. The Pulivendula tehsil has six mandals viz., Simhadripuram (21.9% of total area), covering total area of 127463.0ha (Table 6_). Lingala (20.4%) > Thondur (19.4%) > Vemula (16.8%), Vempalli (13.8) and Pulivendula (7.7%). The total population is 190410

with total house holdings of 47134 but is in the ascending order of Vempalli (32.2%) > Simhadripuram (17.2%) > Lingala (15.7%) > Vemula (15.3%) > Thondur (12.6%) and Pulivendula (6.9%).

**Table 6**. Mandal wise total area, Net sown and irrigated area (ha) with respect to population

| Mandal | Area (ha ) | | | | | | | | Per cent of total | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total area(ha) | Total population | Number of house holds | Net area sown(ha) | Irrigated land (ha) | Per capita land(ha) | Per capita net sown (ha) | Per capita irrigated land(ha) | Total area(ha) | Total population | Number of house holds | Net area sown(ha) | Irrigated land (ha) | Per capita land(ha) | Per capita net sown (ha) | Per capita irrigated land(ha) |
| simhadripuram | 27959.0 | 32819.0 | 8534 | 13735.1 | 4030.7 | 0.9 | 0.4 | 0.1 | 21.9 | 17.2 | 18.1 | 20.0 | 25.5 | 18.9 | 17.4 | 20.2 |
| lingala | 26012.0 | 29945.0 | 7681.0 | 13837.3 | 4630.5 | 0.9 | 0.5 | 0.2 | 20.4 | 15.7 | 16.3 | 20.2 | 29.3 | 19.2 | 19.2 | 24.9 |
| pulivendula | 9807.0 | 13178.0 | 3436.0 | 4500.0 | 1030.3 | 0.7 | 0.3 | 0.1 | 7.7 | 6.9 | 7.3 | 6.6 | 6.5 | 16.5 | 14.2 | 14.7 |
| thondur | 24704.0 | 23964.0 | 6120.0 | 14002.3 | 2259.3 | 1.0 | 0.6 | 0.1 | 19.4 | 12.6 | 13.0 | 20.4 | 14.3 | 22.8 | 24.3 | 12.8 |
| vemula | 21417.0 | 29160.0 | 7477.0 | 12825.5 | 2207.5 | 0.7 | 0.4 | 0.1 | 16.8 | 15.3 | 15.9 | 18.7 | 14.0 | 16.3 | 18.3 | 14.4 |
| vempalli | 17564.0 | 61344.0 | 13886.0 | 9773.4 | 1639.6 | 0.3 | 0.2 | 0.1 | 13.8 | 32.2 | 29.5 | 14.2 | 10.4 | 6.3 | 6.6 | 13.1 |
| **Sum** | **127463.0** | **190410.0** | **47134.0** | **68673.6** | **15797.9** | **4.5** | **2.4** | **0.7** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **100** | **100.0** |
| **Mean** | **21243.8** | **31735.0** | **7855.7** | **11445.6** | **2633.0** | **0.8** | **0.4** | **0.1** | **28.6** | **16.7** | **16.7** | **16.7** | **16.7** | **16.7** | **16.7** | **16.7** |
| **SD** | **6695.9** | **16077.7** | **3450.9** | **3753.4** | **1401.4** | **0.3** | **0.1** | **0.0** | **5.3** | **8.4** | **7.3** | **5.5** | **8.9** | **5.6** | **5.9** | **4.8** |
| **Cv(%)** | **31.5** | **50.7** | **43.9** | **32.8** | **53.2** | **33.5** | **36** | **29.0** | **0.0** | **0.0** | **0.1** | **0.1** | **0.3** | **742.5** | **1474.4** | **4057.7** |

Note:SD = standard deviation, CV = coefficient of variation

The graphical representation of village wise mandal data (Fig.5) clearly shows that the per caita land is in the ascending order of Maddulapalya (5.9 ha) > Theliki (3.17 ha) > Devathapuram (2.61 ha) and Pydipalem (2.3 ha)/Ravulakolam (2.06 ha) in Simhadripuram mandal. Among 18 villages in Lingala mandal, the Narasingaraopalle has 7ha of per capita land but 3.39 ha in Herojipuram and 2.56ha in Lopatnuthala village but in other areas, the per capita land is less or equal to a 1ha. The Linagala mandal has mean per capita net sown area of 0.67 ± 0.57 ha and per capita irrigated land of 0.21±0.23 ha with CV of 106.38 per cent. Pulivendula has 7 villages with per capita available land is 3.32ha in Rayapuram village.The mean per capita land is 1.49±1.05ha and CV of 70.52 per cent. The mean per capita net sown area is 0.67±0.52 ha and CV of 77.35% .This mandal has per capita irrigated land of 0.08±0.04 ha with CV of 51 per cent. The Thodur mandal has 17 villages. Out of 17 villages in Thondur mandal, 9 villages have per capita land is above 1ha with a mean of 1.03±0.49 and CV of 47.52 per cent. The mean per capita net sown area is 0.57±0.26 ha and CV of 45.44 per cent. The mean per capita irrigated land is 0.08±0.07 ha with95% of variation. Twleve villages in Vemula mandal have a mean per capita land of 0.82 ha with CV of 45.91 per cent (Fig.5). The mean per capita irrgated land is 0.08±0.04 ha and CV of 42.1 per cent. 7 villages have below mean per capita land and net sown area. 11 villages in Vempalli mandal has a mean per capita land of 0.71±0.46 ha, net sown area of 0.39 ± 0.24ha and irrigated land of 0.06±0.04ha.

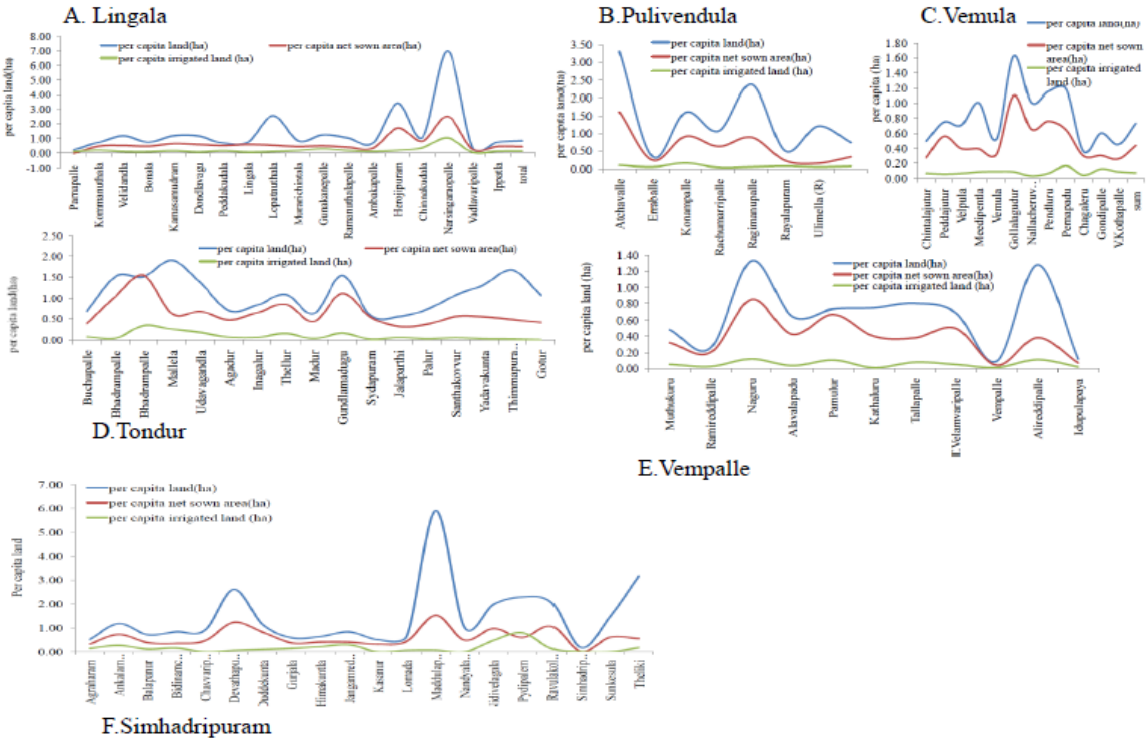



**Fig.5.**Village wise in each mandal of per capita land statistics showing in line diagram

### 3.2. Land Utilization Particulars

The land utilization statistics shows that this tehsil has fifty six per cent of gross cropped area (90674ha, based on land use data of 2015).The net sown area is only 40 per cent of total geographical area (68673.6ha) and 15797.9ha of irrigated land. Bore well irrigation is the main source covering 23 per cent of total cropped area (21161ha) and supports groundnut cultivation in the region. Among mandals, Vemula grows ground nut in 2351ha followed by Vempalli in 1809ha (Table 7). The data shows that the net sown area is high in Thondur (14002.3, 20.4%) whereas irrigated area is reported high in Lingala mandal (4630.5ha, 29.3%).

**Table 7.** Mandal wise area under principal crops in Pulivendula tehsil

| Mandal | Area under principal crops(ha) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rice | | | Jowar | | | Redgram | | | cotton | | | Groundnut | | | sunflower | | |
| | Kharif | rabi | total | Kharif | rabi | total | Kharif | rabi | total | Kharif | rabi | total | Kharif | rabi | total | Kharif | rabi | total |
| Simhadripuram | 10 | 0 | 10 | 145 | 171 | 316 | 51 | 0 | 51 | 126 | 0 | 126 | 862 | 161 | 1023 | 172 | 1287 | 1459 |
| Lingala | 148 | 0 | 148 | 36 | 404 | 440 | 107 | 0 | 107 | 144 | 0 | 144 | 1805 | 325 | 2130 | 126 | 809 | 935 |
| Pulivendula | 0 | 0 | 0 | 10 | 47 | 57 | 20 | 0 | 20 | 383 | 0 | 383 | 981 | 305 | 1286 | 68 | 1131 | 1199 |
| Vemula | 10 | 0 | 10 | 21 | 162 | 183 | 72 | 0 | 72 | 3564 | 0 | 3564 | 2351 | 563 | 2914 | 81 | 2211 | 2292 |
| Thondur | 0 | 0 | 0 | 0 | 656 | 656 | 88 | 0 | 88 | 878 | 0 | 878 | 1584 | 102 | 1686 | 194 | 1534 | 1728 |
| Vempalli | 535 | 0 | 535 | 0 | 76 | 76 | 20 | 0 | 20 | 4292 | 0 | 4292 | 1809 | 420 | 2229 | 58 | 2484 | 2542 |
| Total | 703 | 0 | 703 | 212 | 1516 | 1728 | 358 | 0 | 358 | 9387 | 0 | 9387 | 9392 | 1876 | 11268 | 699 | 9456 | 10155 |

## 4.0. Rainfall characterization

### 4.1. Rainfall analysis

The rainfall analysis is crucial and critical parameter in dry land regions of Cuddapah where frequency of droughts is common and regular phenomenon. The normal rainfall is 501.6mm in Vemula with a deficit of 38.5% over normal during 2012 – 2013(Table 8). The normal rainfall varies from 501.6mm in Vemula to 673.8 mm in Vempalli but above normal in all mandals over three years under study except Lingala mandal. The rainfall analysis with respect to normal shows that Vemula receives normal rainfall of 673.8mm with excess percent of 23.2 % during 2010-2011 but deficit of 13.9% of normal (2011-12) and 28.55% (2012-2013). This area receives mean annual rainfall (actual) of 714 ± 96.6 mm with coefficient of variation (CV) of 13.5% during 2010-2011 but recorded lowest of 340.9 ± 87.1 mm with CV of 25.52% during 2012-2013. The contribution of southwest monsoon to total rainfall during 2012 -2013 is 50.27% (Pulivendula) to 66% (Simhadripuram). July and August are the peak rainfall months exceeding 100mm rainfall in Lingala mandal (123.8mm). The actual rainfall in south-west monsoon is below to that of normal except rains in July exceeds normal in all mandals. In the present study, the PCI, proposed by Oliver (1980) and developed by De Luis *et al.* (2011), was used for the calculation of the annual PCI, as indicated in Equation as given under :

$$\mathrm{PCI} = \frac{\sum_{i=1}^{12}(\mathrm{pi})^2}{(\sum_{i=1}^{12}\mathrm{pi})^2}$$

Where $p_i$ represents the monthly precipitation in month $i$ that is calculated for each studied station and for each year throughout the observation period. The PCI Value considered categorizing rainfall in the study station as: PCI ≤ 10 Uniform Precipitation (low precipitation concentration), PCI >10≤ 15 Moderate Precipitation Distribution, PCI >16 ≤ 20 Irregular Precipitation Distribution and PCI > 20 Strong Irregularity of Precipitation Distribution. The Precipitation Concentration Index (PCI) calculated and classified as irregular (PCI =15.7) to moderate for 2012-2013 (PCI = 12.76, Table 9).

**Table 8.** Mandal wise normal and actual rainfall (mm) with statistical summary

| Mandal | Normal | Actual | | | | |
|---|---|---|---|---|---|---|
| | | 2010-2011 | 2011-12 | 2012-13 | mean | CV(%) |
| Simhadripuram | 643.20 | 719.90 | 620.20 | 347.60 | 562.57±192.73 | 34.26 |
| Lingala | 606.30 | 548.20 | 493.40 | 388.00 | 476.53±81.42 | 17.09 |
| Pulivendula | 618.40 | 760.20 | 620.80 | 290.00 | 557.00±241.51 | 43.36 |
| Vemula | 501.60 | 749.40 | 578.00 | 308.40 | 545.27±222.31 | 40.77 |
| Thondur | 624.30 | 675.40 | 520.80 | 230.40 | 475.53±225.93 | 47.51 |
| Vempalli | 673.80 | 833.20 | 579.60 | 481.40 | 631.40±181.53 | 28.75 |
| mean | 611.27± 58.66 | 714.38± 96.55 | 568.80± 52.03 | 340.97± 87.02 | 541.38± 58.91 | 35.29 |
| CV(%) | 9.60 | 13.52 | 9.15 | 25.52 | | |

Note:CV = coefficient of variation (%)

**Table 9**. Precipitation concentration index

| Month | Precipitation concentration index (PCI) | | |
|---|---|---|---|
| | Normal | 2011-2012 | 2012-2013 |
| January | 0.00 | 0.00 | 0.03 |
| February | 0.00 | 0.00 | 0.26 |
| March | 0.00 | 0.00 | 0.02 |
| April | 0.03 | 0.24 | 0.02 |
| May | 0.31 | 0.18 | 0.15 |
| June | 1.10 | 0.34 | 0.52 |
| July | 2.14 | 3.34 | 4.64 |
| August | 2.98 | 6.83 | 2.31 |
| September | 2.96 | 0.66 | 0.41 |
| October | 3.99 | 3.14 | 1.74 |
| November | 2.00 | 2.05 | 1.69 |
| December | 0.15 | 0.00 | 0.99 |
| Sum | 15.66 | 16.79 | 12.76 |
| Classification | irregular | Irregular | moderate |

### 4.2. Growing Degree days (GDD)

Growing Degree Days (GDD) is defined as the sum over the growing season of a crop of the difference between the daily temperature and a reference temperature. GDD was expressed in terms of °C day. The growing degree days (GDD) was worked out by considering the base temperature of 10 for groundnut °C (Patel, *et al*., 1999). The heat unit concept of Growing Degree Days also worked out for individual sowing windows.

Among the sowing dates, 05.01.2019 recorded essential GDD of 1651.3°C and higher growth attributes, yield attributes and yield (2370 kg ha) in Eachangkottai during Margazhi pattam 2019 (Baskaran, *et al*., 2020).It was reported that the average value of accumulated GDD from sowing to maturity was 2303$^{o}$C days with co-efficient of variation of 11 percent (Babu *et al*., 2004). The GDD for groundnut, was calculated as per the formulae given below

GDD = [(Tmax + Tmin)/2] – Tbase

Where Tmax and Tmin are the daily maximum and minimum air temperature, respectively, and the Tbase is the base temperature of 10°C. The GDD from planting to the various growth stages mentioned above were calculated for Ground nut (*Arachis hypogeae* L.) as main kharif crop in the region (June to September). The concept of degree days is based on the premise that the higher the temperature, the faster plants and insects are able to grow. Differences in the degree-day during the duration of gynophore formation to maturity were largely related to the number of developing pegs and timing of pod filling. The degree day during gynophore formation to maturity gradually decreased with delayed planting in both years. The cultivars planted between June 5 - 20 were exposed to high air temperature and were thus rapidly stressed. The stages of developing pegs and the timing of filling pods of peanut were exposed to low temperature (Table 10). The two earliest plantings supply the longer growth for the peanut cultivars that is needed to reach the required 1450 and 1550 Growing Degree Days (GDD) for gynophore formation to maturity. The GDD for this region is 1476 full filling the requirement for gynophores formation to maturity.

**Table 10.** Growing degree days for ground nut in Pulivendula

| Month | Growing Degree Days (GDD) | | |
|---|---|---|---|
| | Normal | 2011-2012 | 2012-2013 |
| June | 577.50 | 624.00 | 450.00 |
| July | 585.90 | 602.95 | 589.00 |
| August | 561.10 | 551.80 | 558.00 |
| September | 261.75 | 279.75 | 262.50 |
| mean | 496.56 | 514.63 | 464.88 |
| SD | 156.88 | 159.49 | 147.49 |
| CV(%) | 31.59 | 30.99 | 31.73 |

**Table11.** Month wise descriptive statistics for rainfall and air temperature

| Year Statistics | January | February | March | April | May | June | July | August | September | October | November | December | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | | | | | | | | | | | | | |
| mean | 0.72 | 3.06 | 6.67 | 21.97 | 58.05 | 50.15 | 70.97 | 92.2 | 154.4 | 123.9 | 72.37 | 17.25 | 672.2 |
| Sd | 1.00 | 6.09 | 10.28 | 23.71 | 44.31 | 28.27 | 32.73 | 50.08 | 69.82 | 66.35 | 53.76 | 18.97 | 111.6 |
| CV(%) | 139.6 | 198.5 | 154.1 | 107.9 | 76.3 | 56.3 | 46.1 | 54.2 | 45.2 | 53.5 | 74.2 | 109.9 | 16.59 |
| Skewness coefficient | 1.42 | 1.48 | 1.56 | 0.99 | 0.85 | 0.48 | 0.57 | 0.053 | 0.20 | 0.31 | 0.68 | 1.19 | |
| Air temperature(0C) | | | | | | | | | | | | | |
| mean | 22.57 | 24.69 | 27.70 | 30.24 | 30.63 | 28.40 | 26.99 | 26.55 | 26.30 | 25.38 | 23.33 | 22.01 | 26.23 |
| Sd | 0.67 | 0.76 | 0.77 | 0.62 | 0.81 | 0.70 | 0.54 | 0.46 | 0.57 | 0.46 | 0.66 | 0.61 | 0.38 |
| CV(%) | 2.98 | 3.11 | 2.78 | 2.07 | 2.66 | 2.46 | 2.00 | 1.76 | 2.17 | 1.84 | 2.82 | 2.79 | 1.43 |
| Skewness coefficient | -0.04 | 0.07 | 0.22 | 0.35 | -0.09 | -0.02 | 0.14 | -0.002 | 0.30 | 0.08 | 0.06 | -0.24 | |

### 4.3. Descriptive statistics for long term rainfall and mean air temperature characteristics

From the table 11, it is clear that the mean annual rainfall is 672.17±111.55mm and CV of 16.59 per cent. The monthly rainfall data shows that September and October receives more than 100mm rainfall with CV less than 55 per cent. The coefficient of variation is more than 100 per cent for January, February, March, April and December. The skewness coefficients are positive (skewed to the right) indicating that the low rainfall occurs regularly, while high value rainfall happens very often. The monthly rainfall is more skewed. The skewness coefficient for August, September and October is identical to or nearly identical to zero indicating the data follows a normal distribution. The mean air temperature is $26.23^0$C±$0.38^0$C with CV of 1.43 per cent. The monthly mean air temperature more than $30^0$C is recorded for April and May but rest of the months, the mean air temperature is 22.01±0.61 $^0$C for December and $28.4^0$C±$0.7^0$C for June. The air temperature shows negatively skewed for January, May, June, August and December and closed to zero indicating the normality of data .The trend analysis of rainfall shows no significant relation between year and the yearly rainfall (Fig. 6). The

regression equation is given as: Rainfall (mm) = 0.816 (year) - 924.6mm with coefficient of determination ($R^2$ = 0.034, number of years 101). This result indicates that the rainfall is erratic and unpredictable with wide variations in the season.

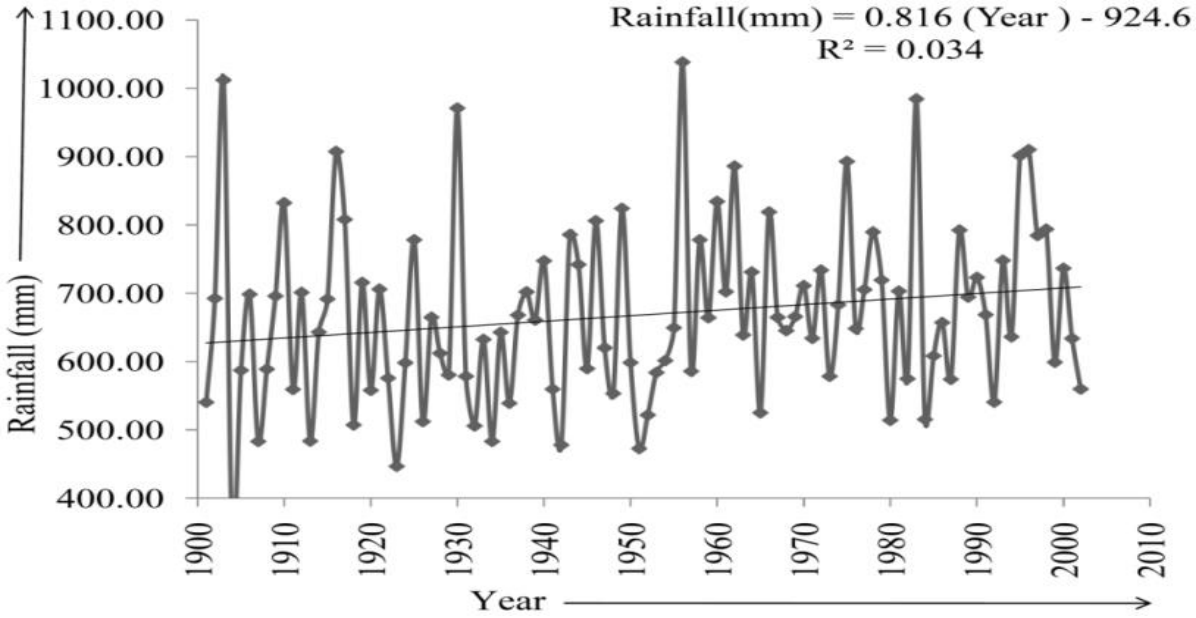



**Fig.6.** Decadal rainfall pattern in Kadapa district

### 4.4.Rainfall anamoly

The Rainfall Anomaly Index (RAI) was derived by van Rooy (1965) and it can be expressed as follows:

RAI = $\frac{[3(p-\bar{P}]}{[(\overline{m}-\bar{p}]}$ for positive anomalies and:

RAI = -3[(p-$\bar{p}$)/ ($\bar{x}-\overline{p}$)] for negative anomalies,

Where p is the actual rainfall, $\bar{p}$ is the long term average rainfall, m is the mean of the ten highest values of p in the time series, and x is the mean of the ten lowest values of p. The classification of RAI is given below in Table11 as per Fretias (2005) adapted by Araujo, *et al.*, 2009

**Table 12.** Classification RAI intensity

| RAI range | Classification |
|---|---|
| >4 | Extremely humid |
| 4-2 | Very humid |
| 0-2 | humid |
| -2-0 | Dry |
| -4 - -2 | Very dry |
| <-4 | Extremely dry |

The rainfall data of 1901 to 2002 was used to workout anomaly index and presented in Fig.7. The graph shows that 11 years experienced extremely humid conditions (1956, 1903, 1983, 1930, 1996, 1916, 1995, 1975, 1962, 1960, 1910) and 17 years of extremely dry conditions (1992, 1901, 1936, 1965, 1952, 1984, 1980, 1926, 1918, 1932, 1913, 1934, 1907, 1942, 1951, 1923, 1904). Out of 102 years of data, RAI is classified into six classes viz., extremely humid (>4), very humid (4-2), humid (0-2), dry (0 - -2), very dry (-2 - -4) and extremely dry (>-4.0). The frequency was worked out and grouped into six classes (Table 13).This area experiences 17 extremely dry years, 20 each of very dry and dry years, 22 humid years, and 11 extremely humid years.

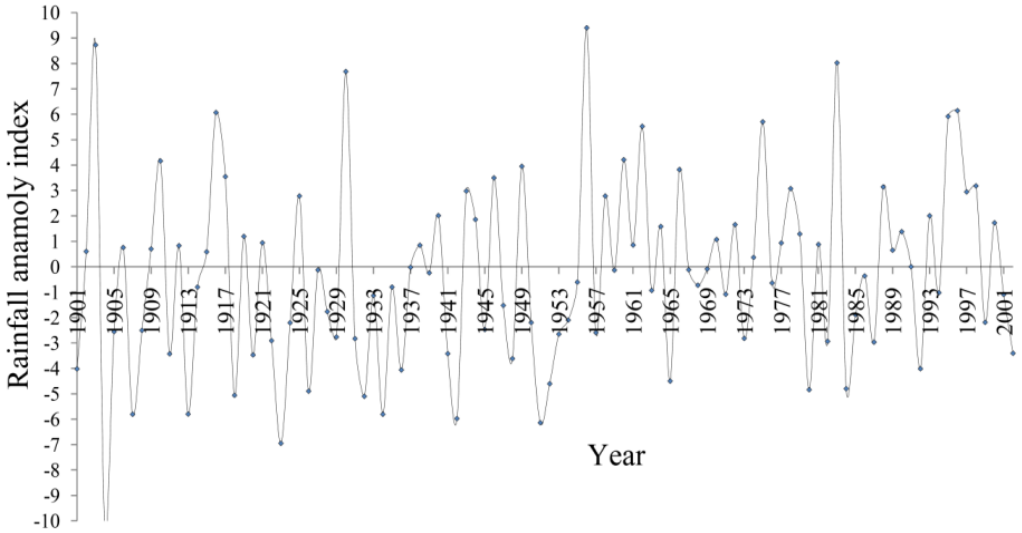



**Fig.7**. Decadal variations in RAI for Kadapa district

**Table 13.** RAI classification and frequency in Kadapa district

| Frequency | Classification of RAI | Per cent |
|---|---|---|
| 17 | Extremely dry | 16.67 |
| 20 | Very dry | 19.61 |
| 20 | Dry | 19.61 |
| 22 | Humid | 21.57 |
| 12 | Very Humid | 11.76 |
| 11 | Extremely humid | 10.78 |
| 102 | | 100.00 |

### 4.5. Decadal rainfall characteristics

We initially defined "cultivable areas by month, setting criteria of minimum monthly rainfall of 100 mm and minimum temperature of 21 °C based on commercial groundnut requirements of 500mm and $25^0$C to $30^0$C optimal air temperature over the entire growing period (Cox, 1979). To define appropriate thresholding criteria defined by sufficiently warm and wet monthly conditions, we calculated, the total cultivable area resulting from different combinations of mean air temperature and mean rainfall or aridity criteria. The final criteria applied across the three field systems were (1) monthly temperature > $21^0 \approx 23^0$ C and with a Tfp (bud temperature) of $40^0$C based on Prasad, *et al.* (2003) and monthly rainfall > 40mm 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 and presented in Table 14. 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 $30.7^0$C to $36.9^0$C 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 186.82 ± 81.56mm mean and 43.61 per cent of coefficient of variation in rainfall during 1981 to 1990. Next to September, October receives mean rainfall of 100.28 ± 60.01mm (1941-1950) but 152.24 ± 88.70 mm (1971-1980) and august with irregular rainfall trends from 65.26 ± 30.25mm (1921-1930) to 119.87±40.78mm (1991-2002 , Table 14). The De Martonne Aridity Index (I'm) below 15 is reported for monthly decadal data sets for June to September to define climate as semiarid and I'm 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 rain fed 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 millimeter of rainfall. For dry land peanuts, in the region at 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 60mm but receives >135 mm rainfall during pod development phase (September).

**Table 14.** Descriptive statistical analysis of decadal month wise rainfall patterns

| Climatic variables | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| Monthly average temperature ($^{o}$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- | **28.35±** | **31.15±**0.87 | **34.34±** | **36.63±** | **36.65±** | **33.29±** | **31.62±** | **31.06±** | **31.05±** | **30.08±** | **28.27±** | **28.35±** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.66 | | 0.62 | 0.45 | 0.70 | 0.86 | 0.47 | 0.42 | 0.51 | 0.42 | 0.39 | 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 |
| 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** |

### 4.6. 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 sub unitary 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 15). There with, 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 15) and increased erosive potential of high-quantity or high-intensity rainfalls with a probability of occurrence > 50% occur (Dragot˘a, 2006). Over 109 years of monthly rainfall data was used to compute the angot index and worked out the wet-dry spells. It is estimated that 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 is 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 is found that for 64% of cases in June there is no risk of pluvial erosion, in 50 % of cases in September / October (43%) favorable for triggering pluvial linear erosion.

**Table 15.** Decadal variation in Angot pluviometric analysis in Kadapa district

| 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 |

The resulted index values were used to determine the rainy intervals by grouping them under the pluvial classes corresponding to the assigned rainfall attributes. 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. 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 16) and increased erosive potential of high-quantity or high - intensity rainfall with a probability of occurrence > 50% occur (Dragot˘a 2006). The month wise decadal Angot pluvial indices ahow that the rainfall events during August, September and October have severe to very severe erodibility class exceeding the value more than 2 and in the rest of months , it is very low to low with an indices less than 1.5. Different shading and its definition is given in table 16.The damaging aspects of the heavy rainfalls depend on the intensity, duration, water quantity fallen and particular features of the active surface: lithology, presence/absence of the vegetation cover, slope, and occurrence period (after long periods of drought when the soil is extremely dry). In such conditions, the heavy precipitation amounts trigger accelerated erosion processes such as slope failure or landslides. Having a negative effect on the environment, they are likely to affect crops, infrastructure (roads, bridges, railways, sewage pipes, water and gas supply).

**Table 16.** Decadal variation in Angot pluviometric analysis in Kadapa district

| 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 | | 3.25 | | 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 | | 0.26 |
| 1921-1930 | 0.02 | 0.03 | 0.15 | 0.21 | 1.06 | 0.67 | 1.16 | 1.39 | 3.14 | 2.08 | | 0.26 |
| 1931-1940 | 0.01 | 0.13 | 0.10 | 0.57 | 0.84 | 0.97 | 1.21 | 1.55 | 2.71 | 2.09 | | 0.23 |
| 1941-1950 | 0.01 | 0.06 | 0.08 | 0.33 | 1.04 | 0.89 | 1.20 | 1.78 | 3.12 | | 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 | | 2.83 | | 0.98 | 0.43 |
| 1971-1980 | 0.01 | 0.07 | 0.05 | 0.39 | 1.21 | 0.83 | 1.21 | | 2.39 | 2.54 | 1.47 | 0.23 |
| 1981-1990 | 0.01 | 0.10 | 0.23 | 0.36 | 0.84 | 0.87 | 1.40 | | 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 | | 2.40 | 2.09 | | 0.27 |

| Pluvimetric attributes | very dry | dry | normal | rainy | Very rainy |
|---|---|---|---|---|---|
| Pluvimetric erodability class | verylow | low | moderate | severe | Very severe |
| Angot index(K) | <0.99 | 1.00-1.49 | 1.50 -1.99 | 2.00-2.49 | >2,45 |
| Shading as given in Table 1 | | | | | |

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## 4.7. Modified Fournier index

In this study, the modified Fournier index (MFI) was used (Arnoldus, 1980) and worked out as per the formulae given under: MFI = $\sum_{i=1}^{12} \frac{pi^2}{P}$ in which MFI is the modified Fournier index, pi is the monthly rainfall and P is the total annual rainfall. The classification of erosivity was made into five classes and expressed erosivity as very low to very severe as given under: .

| Erosivity class | Modified fournier index ($F_m$) |
|---|---|
| very low | 0-60 |
| low | 60-90 |
| moderate | 90-120 |
| severe | 120-160 |
| very severe | >160 |

Colotti (2004) reported that the Food and Agriculture Organization (FAO) of the United Nations used the modified Fournier index as an erosion estimate according to the following general equation: R =· + a MFI b. In the present study, Erosivity -R-factor ($MJ \cdot cm \cdot ha^{-1} \cdot h^{-1} \cdot year^{-1}$) was calculated using regression equation as R = 1.05*MFI with

$R^2$ of 0.96 (Hernando and Romana, 2015). The 109 years of rainfall data used to calculate MFI and R factor). The area has low to very high intensity of rainfall and also influence on computed MFI values. The data of 109 years shows that the mean MFI is 101.37 ± 48.25 and CV of 47.87 per cent. The variations in MFI with respect to mean are depicted in Fig.8. The very high rainfall events favoured high rates of erosivity in 11 years, out of it, the more pronounced erosivity with very high MFI values viz., 262.54 for the year 1960 and 200.43 for the year 1975 (Table 17). There are only three very low erosivity occurred in the year 1904 (MFI of 56.90), 1907 (MFI of 74.03) and in 1951 (MFI of 60.03). The region experiences 40 moderate(36.7%) and 38 high (34.86% ) erositivity events with CV of around 8 per cent (table 18). The very high erosivity class has mean of 189.08±28.29 with CV of 14.96 per cent .

**Table 17**. Year wise MFI, R factor and Erosivity class

| Year | MFI | erosivity class | R ($MJ \cdot cm \cdot ha^{-1} \cdot h^{-1} \cdot year^{-1}$) |
|---|---|---|---|
| 1901 | 78.46 | low | 82.38 |
| 1902 | 129.23 | high | 135.69 |
| 1903 | 161.00 | very high | 169.05 |
| 1904 | 56.90 | very low | 59.75 |
| 1905 | 120.83 | moderate | 126.88 |
| 1906 | 133.63 | high | 140.31 |
| 1907 | 74.03 | very low | 77.73 |
| 1908 | 179.99 | very high | 188.99 |
| 1909 | 159.26 | high | 167.23 |
| 1910 | 150.69 | high | 158.23 |
| **1911** | 80.16 | low | 84.16 |
| 1912 | 139.74 | high | 146.73 |
| 1913 | 105.84 | moderate | 111.14 |
| 1914 | 121.51 | high | 127.59 |
| 1915 | 127.22 | high | 133.58 |
| 1916 | 168.40 | very high | 176.82 |
| 1917 | 139.89 | high | 146.89 |
| 1918 | 100.31 | moderate | 105.32 |
| 1919 | 123.67 | high | 129.86 |
| 1920 | 111.81 | moderate | 117.40 |
| 1921 | 127.63 | high | 134.01 |
| 1922 | 114.98 | moderate | 120.73 |
| 1923 | 108.86 | moderate | 114.31 |
| 1924 | 149.11 | high | 156.57 |
| 1925 | 103.90 | moderate | 109.10 |
| 1926 | 74.26 | low | 77.97 |
| 1927 | 143.78 | high | 150.97 |

| | | | |
|---|---|---|---|
| 1928 | 97.27 | low | 102.13 |
| 1929 | 118.08 | moderate | 123.98 |
| 1930 | 170.33 | very high | 178.85 |
| 1931 | 93.90 | moderate | 98.60 |
| 1932 | 75.87 | low | 79.66 |
| 1933 | 90.55 | moderate | 95.08 |
| 1934 | 70.74 | low | 74.27 |
| 1935 | 131.97 | high | 138.57 |
| 1936 | 80.43 | low | 84.45 |
| 1937 | 103.08 | moderate | 108.24 |
| 1938 | 199.71 | very high | 209.70 |
| 1939 | 123.46 | high | 129.64 |
| 1940 | 113.62 | moderate | 119.30 |
| 1941 | 101.63 | moderate | 106.71 |
| 1942 | 77.54 | low | 81.42 |
| 1943 | 154.61 | high | 162.34 |
| 1944 | 114.64 | moderate | 120.37 |
| 1945 | 100.35 | moderate | 105.37 |
| 1946 | 114.23 | moderate | 119.94 |
| 1947 | 117.60 | moderate | 123.48 |
| 1948 | 83.12 | low | 87.28 |
| 1949 | 155.79 | high | 163.58 |
| 1950 | 114.87 | moderate | 120.61 |
| 1951 | 60.03 | very low | 63.04 |
| 1952 | 100.66 | moderate | 105.69 |
| 1953 | 145.41 | high | 152.68 |
| 1954 | 120.97 | high | 127.02 |
| 1955 | 105.60 | moderate | 110.88 |
| 1956 | 150.29 | high | 157.81 |
| 1957 | 82.27 | low | 86.38 |
| 1958 | 156.37 | high | 164.19 |
| 1959 | 89.15 | low | 93.61 |
| 1960 | 262.54 | very high | 275.67 |
| 1961 | 110.02 | moderate | 115.52 |
| 1962 | 150.38 | high | 157.90 |
| 1963 | 103.75 | moderate | 108.94 |
| 1964 | 183.53 | very high | 192.70 |
| 1965 | 92.02 | moderate | 96.62 |
| 1966 | 131.86 | high | 138.45 |
| 1967 | 103.48 | moderate | 108.66 |
| 1968 | 99.38 | low | 104.35 |
| 1969 | 120.71 | high | 126.74 |
| 1970 | 135.42 | high | 142.19 |
| 1971 | 101.66 | moderate | 106.74 |
| 1972 | 133.57 | high | 140.25 |
| 1973 | 115.67 | moderate | 121.45 |
| 1974 | 140.45 | high | 147.47 |

| | | | |
|---|---|---|---|
| 1975 | 200.43 | very high | 210.45 |
| 1976 | 118.73 | moderate | 124.67 |
| 1977 | 106.91 | moderate | 112.26 |
| 1978 | 133.56 | high | 140.23 |
| 1979 | 136.01 | high | 142.81 |
| 1980 | 72.48 | low | 76.11 |
| 1981 | 131.75 | high | 138.34 |
| 1982 | 91.17 | moderate | 95.73 |
| 1983 | 204.34 | very high | 214.55 |
| 1984 | 92.23 | moderate | 96.85 |
| 1985 | 98.58 | moderate | 103.51 |
| 1986 | 107.90 | moderate | 113.30 |
| 1987 | 82.40 | low | 86.52 |
| 1988 | 138.52 | high | 145.45 |
| 1989 | 132.05 | high | 138.65 |
| 1990 | 122.52 | high | 128.65 |
| 1991 | 104.31 | moderate | 109.52 |
| 1992 | 77.92 | low | 81.82 |
| 1993 | 111.56 | moderate | 117.14 |
| 1994 | 122.53 | high | 128.65 |
| 1995 | 155.39 | high | 163.16 |
| 1996 | 131.20 | high | 137.76 |
| 1997 | 116.17 | moderate | 121.98 |
| 1998 | 131.81 | high | 138.40 |
| 1999 | 87.34 | low | 91.71 |
| 2000 | 119.35 | moderate | 125.32 |
| 2001 | 110.02 | moderate | 115.52 |
| 2002 | 93.00 | moderate | 97.64 |
| 2004 | 126.42 | high | 132.74 |
| 2005 | 179.49 | very high | 188.46 |
| 2006 | 84.88 | low | 89.12 |
| 2007 | 170.14 | very high | 178.65 |
| 2008 | 108.82 | moderate | 114.26 |
| 2009 | 110.99 | moderate | 116.53 |
| 2010 | 136.10 | high | 142.91 |

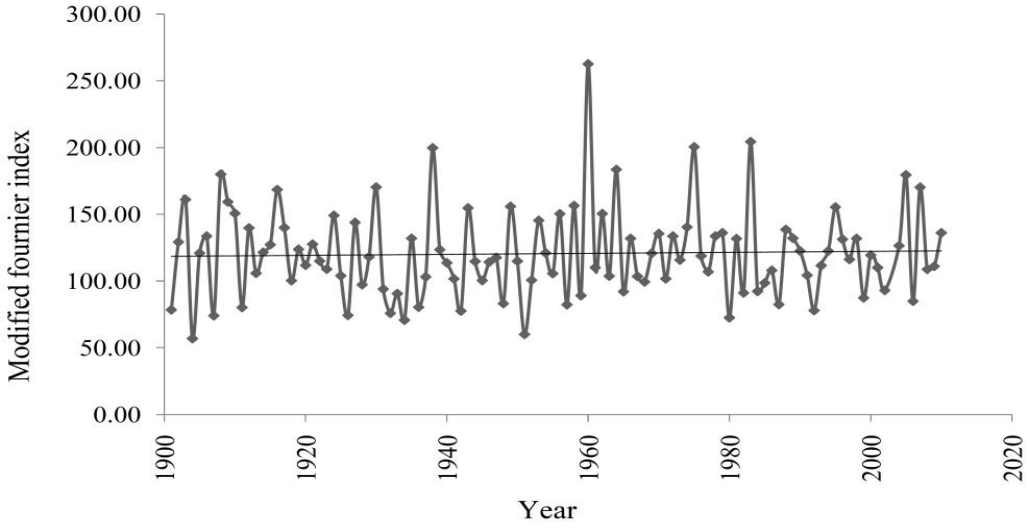



**Fig.8.** Graphical representation of MFI variations from the mean of study area

**Table 18 .** Number and per cent of erosivity class with means and CV (%)

| Erosivity class | Frequency of occurrence | | MFI | |
|---|---|---|---|---|
| | number | per cent | mean±SD | CV(%) |
| very high | 11.00 | 10.09 | 189.08±28.29 | 14.96 |
| high | 38.00 | 34.86 | 136.7±11.4 | 8.34 |
| moderate | 40.00 | 36.70 | 106.79±8.60 | 8.06 |
| low | 17.00 | 15.60 | 81.98±7.88 | 9.62 |
| very low | 3.00 | 2.75 | 63.65±9.12 | 14.32 |
| Total | 109.00 | 100.00 | | |

Note: SD=standard deviation .CV =coefficient of variation, MFI=modified fournier index

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

The livelihood system of the rain fed 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) in study area. 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 southwest monsoon (1988-99 to 2011-12) for Cuddapah district as a whole is presented in Figure.9. The data clearly 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±110.53mm 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 lakhs with low productivity of 280kg/ha. It is interesting to note that maximum yield of groundnut is 1080kg/ha is recorded under the south west monsoon rainfall of 259mm. It is true to say that sowing of groundnut between 26$^{th}$ to 27$^{th}$ standard weeks; reasonably a good crop can be produced on as little as 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 given below:

Yield =15.01+1.892 June+2.301 July+1.582 August+0.648 September with $R^2$ (coefficient of determination) of 0.48 (Parmer, 2013). Here, the influence rainfall on area and productivity of groundnut in Cuddapah district is expressed in polynomial 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)

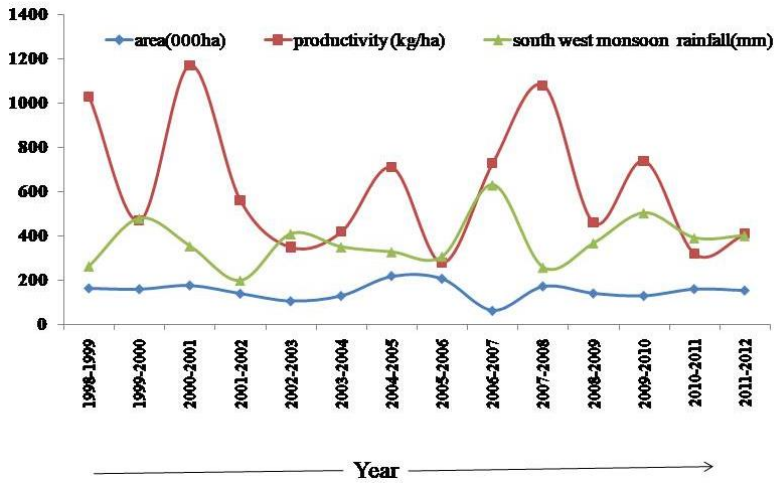



**Fig. 9.**Year wise area and productivity of groundnut in Kadapa district in relation to rainfall

## 5.0. Geological Background

The Cuddapah Basin was first mapped in the 19$^{th}$ century (King, 1872; Ball, 1877), but gained significant attention in mid-20$^{th}$ century with the focus on the

classification of the Cuddapah succession and reconstruction of the stratigraphy (Ramakrishnan and Vaidyanadhan, 2008; Saha, *et al*., 2009). The outcrops of the basin-fill successions cover an area of about 45 000 $km^2$ in the eastern part of the East Dharwar Craton. Nagaraja Rao, *et al.* (1987) suggested that the Cuddapah Basin is a composite of four subbasins, the Papaghni, Kurnool, Srisailam and Palnad. The study area comes under Papagni subbasin and consists of rocks belong to Gulcheru formation of Papagni group and Pulvendula formation of Chitravathi group of Cuddapah Supergroup. The Penninsular granitic –gneiss complex is observed near Nallamada as depicted in Fig.10.A and the quartzitic lands have lighter to darker tone with course to medium texture and subdendritic, coarse drainage pattern with good vegetation and thin soil cover (Fig.10B) in the westward fringes of Pulivendula. Mostly the area is dominated with quartzitic structural hills that support thin sparse forest cover of semiarid thorny bushes. The Peninsular gneissic complex is present in the fringes of SW portion of Pulivendula/Kadiri tehsils having lighter tone with even texture and subdendritic drainage pattern in satellite image (Fig.11a). The Gulcheru quartzitic formation (Fig.11b) consists of a basal conglomerate, feldspathic sandstone and sand - mud heterolithic rocks, deposited in alluvial to shallow marine shelf environments. The geological records were well documented and revealed the paleo evidences in Cuddapah basin (Sarbani Patranabis deb, *et al.,* 2012).The massive or normally graded basal conglomerate beds have a thickness from 10 cm to 65 cm with plane parallel or cross-stratified in minor proportion (exhibit poorly developed planar cross-stratification in the upper part representing sheet flood deposit). The fresh angular grains of feldspar in the region indicate rapid uplift of the fresh bedrock, arid climatic conditions and rapid transfer of the detritus to the depositional site whereas at the lower part of the succession within coarse-grained sandstone indicating fluid escape structures. In the geological literature, the evidences clearly shows the unimodal palaeocurrent towards the east with a wide dispersal of fluvial deposits in an alluvial fan setting and sheet flood deposits with poorly developed planar cross stratification. The facies association in the region suggests a tectonically controlled alluvial fan system with multiple cycles of basement uplift and erosion. The massive, ungraded conglomerate beds represent debris-flow deposits and dominate the lower part of the section. The shallow scour pools mantled with ripple marks of diverse morphology suggest development of intertidal flats at the upper part of the Gulcheru Quartzite.

Gulcheru Quartzite (thick bedded quartzite layer with a basement of granite – gneissic complex)

The Nallamada granitic soil landscape unit :Steep Rocky Hills with exposed rockout crops and slopes of 10 to 15 %. These landscapes have gravelly red brown sany loam to dark brownish red subsoils

Fig.10. A. Nallamada granitic landscapes and b. Gulcheru quartiztic

Limestone rounded hills near vemula : gently sloping foot slopes under drip irrigated banana cultivation

Pulivendula Quartzitic hills with no forest cover : foot slopes are under banana/onion cultivation

Fig.11 A.Pulivendula quartzitic hills and B. rounded dolomitic vempalli formation

**5.1. Pulivendula Quartzite** (Fig.12A) is important in the study (This Quartzite with an average thickness of ~90 m) crops out around the northwest of Yagantipalli village, and unconformably overlies the Vempalle Formation with a ~10 m-thick zone of pebbly sandstone and conglomerate. The geological evidences such as shoaling up bars (upward passes of conglomerate to well sorted quartz-arenite) and fillings of poorly sorted fine grained sandstone and siltstone (interbars). The upper surfaces of the cross crested conglomerated beds are sculptured to straight-crested ripples pointing to wave–tide dominated setting of deposition. The high maturity of the sandstone indicates that the sediment accumulation and deposition was at or very close to the mean sea-level.

**5.2. Vempalle Formation**

The Vempalle Formation next to pulivendula quartzite hills constitutes the lowermost carbonate dominant unit of the Cuddapah Supergroup, and overlies 'the Gulcheru Quartzite with a gradational contact in the study site (Fig. 12B). The extensive occurrence of thin beds of alternate red mudstone with siliciclastic and calcarenite beds at the basal part of the formation is observed during field survey. The upper part is dominated by bedded dolomite with variable bed thickness of 10 cm to 90 cm and occurs as lens - shaped bodies, slightly convex upward. The tectonic perturbations are evident with the common occurrence of thinner dykes of basalt (Fig.13A) and / or dolerite within brown shale and dolomite at the upper part of the Vempalle succession (Fig.13B). The conglomerates and the pebbly sandstone above this unconformity consists of clasts of chert with stromatolite, vein quartz, chert, jasper and volcanics derived from the lower stratigraphic successions (Dasgupta and Biswas, 2006).

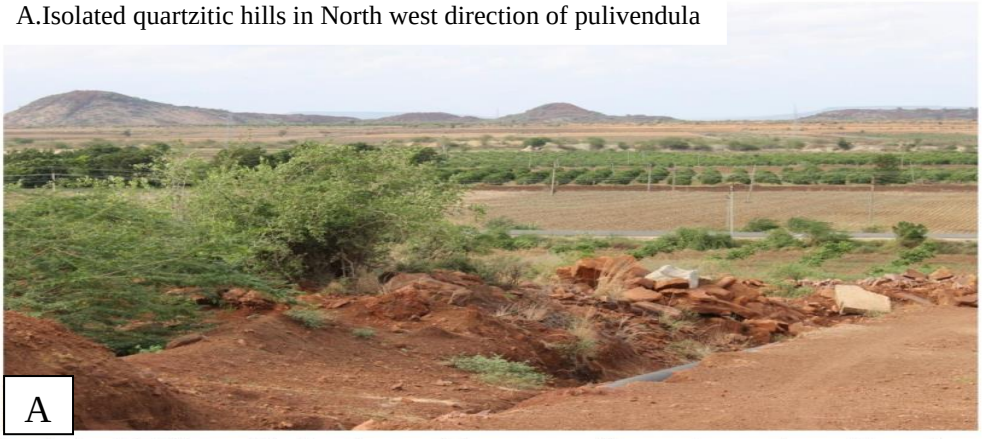
It is also observed in the field the dominance of Algal laminites dominate in the lower part and an isolated stacked stromatolites hemispheroids (SH) to laterally linked hemispheroidal forms (Logan, *et al.*, 1964) in the upper part of the carbonate succession. The colluvio- alluvio sectors in between pulivendula quartzitic hills are used mostly for banana cultivation wherein colluvial stones of round to irregular gravel are noticed over subsoils (Fig.14A). The multiple cycles of sea changes are evident with appearance of bar-interbar dolomite, stromatolites (Fig.14B) and mudstones of the Vempalle Formation.

**Fig. 12.A**. Quartzitic hills with interhill basins and land clearing with stone bunding for banana cultivation

**Fig.12 B.** Vempalle formations just below quatrzitic hills and shale beds in hill cuts nearby

Basaltic cover near simhadripuram

A.Isolated quartzitic hills in North west direction of pulivendula



A

Isolated hills with broken ridges: pediments under citrus/banana cultivation

**Fig.13. A**.Isolated quartzitic hills B.Basaltic boulders spread over pediplains of simhadripuram

B.Dominal stramatolites from vempalli formation


Colluvio-alluvial sectors in quartzitic hills of pulivendula under paddy /banana cultivation

**Fig.14A**. Colluvio-alluvial sectors and B.Dominal stramatolites from Vempalle formations

## 6.0. Landforms

The study area is underlain by various rock types belong to Late Archaean or Early Proterozoic era with rock types viz., quartzite's, shales, limestones, phyllites, granites, granodiorites and granite gneiss. The Archaean comprises the Peninsular Gneissic Complex, represented by granite, granodiorite, granite-gneiss and migmatite in the southwestern. The Cuddapah super group is further sub-divided into three sub-groups viz., Nallamalai group, Chitravathi group and Papaghni group. In the study region, mainly have Papaghni group consisting of Pulivendula quartzites, Vempalle limestones, Gulucheru quartzite/Arkose with conglomerate. These landforms are distinctly different from one another with respect to their relief amplitude, drainage morphometry, network evolution and position in top sequence with visual interpretation of satellite imagery IRS-P6 and field photos of Cuddapah basin (Fig.15 and 16) and the image interpretation legend is given in Table 19. They are briefly summarized below: as described below:

1. **Elongated ridges**: (Cuesta forms) (750-350 m MSL)

This landform occurs as a distinct protuberance all along the southern portion of Pulivendula, bordering Ananthapuramu district. The highest elevation is 750 m above

MSL showing discontinuity at 360m with a sharp angular break of slope. Thus, it has the relief amplitude of about 390 m. On the north facing slopes, the contours are very closely spaced indicating a very steeply sloping escarpment and rock outcrops. On the south facing side, however, the contours are wide spaced with moderately sloping facets. Thus, this ridge is in fact a Cuesta landform, with dip and strike slopes, formed and slightly titled due to the deformation of sedimentary strata during the regional metamorphism. The uniform fingertip tributaries arranged subparallely all along the inner side (strike) of the ridge, the presence of few trunk streams straight lined at places and its rectangular bends at other places are all indicative of the folding and faulting that undergone here. The circum-denudation of the fingertip tributaries also indicate that the ridge is consisting of extremely resistance layers of rock such as Quartzite over sandstone and conglomerate, which again confirm the theory of "the Law of Structure" postulated by G.K Gilbert, Perfect "weathering limited' condition prevails here, wherein whatever the weathering products that are produced are washed down along the slope rendering only a thin veneer of weathering. This land unit covers 8442.90ha (6.62% of total area) and mostly kept as barren land.

2. **Dissected Hills/summits** (550 – 260 m above MSL)

This landform is available all along the southern portion of the Pulivendula mandal adjoining the elongated ridges, covering Lingala, Pulivendula, Vemula and Vempalle mandals. They appear to be the remnants detached and dissected by fluvial action, after the regional metamorphism. The maximum elevation is 550 m above MSL and the minimum is of 260 m and thus the relief amplitude is 290 m. The landform is aligned parallel to the elongated ridges but more highly dissected and denuded, indicating the sedimentary beds here are less resistance to weathering and erosion. Thus, circum-denudation of the various sandstone beds by numerous fingertip tributaries is the dominant geomorphic processes. Occasional quartzite capping, which stands out prominently over the sandstone beds, indicate the extreme resistance of these rocks and the presence of 'weathering limited" conditions here. Based on colour tonal variations this landform has been further subdivided into four photomorphic units namely, pinkish brown representing forest vegetation; bluish green tones depicting sandstone rock exposures; yellowish green tone showing reticulated joint patterns of quartzite and dark grayish tone representing barren ground. This land unit covers 2.32 per cent of total area

(32962.15ha). These hills sparsely covered with forest cover dominant with xerophytic vegetation.

3. **Highly dissected plateau remnants** (550-240 m above MSL)

This landform is occurs on the northern part of the Pulivendula dominantly covering the Simhadripuram and Tondur mandals. The maximum elevation is 550 m above MSL and the minimum of 240 m and thus, this landform has the relief amplitude of 310 m. Numerous plateaux like structure having Gandikota quartzite and Tadpatri dolomite/limestone formations and have highly dissected and denuded hills having 'Sills' ( is a tabular sheet intrusion that has intruded between older layers of sedimentary rock, beds of volcanic lava or tuff, or along the direction of foliation in metamorphic rock. A *sill* is a *concordant intrusive sheet*, meaning that a sill does not cut across preexisting rock beds) which attained table top summits with short escarpments.

Numerous fingertip tributaries originate on these plateau remnants and flow radially outward forming incipient gullies. At places basic diorite dykes are seen cross cutting the landform and such lineaments are responsible for the formation of thrusts, fault and folds of the sedimentary formation. Spheroidal weathering is the dominant geomorphic process and such typical weathering patterns are seen near Mallela on Pulivendula Jammalamadagu road. Based on tonal variations, this landform has been subdivided into three units; greenish pink with yellow and blue patches, bluish green with pink patches and dark brown with pink patches. These divisions represent variations in surficial materials.This land unit cover 16.18% of total area (20263.65ha) and are used mainly for jowar, cotton and groundnut in the region.

4. **Isolated hills/mounds** (430-260 m above MSL)

Scattered throughout the tehsil. The isolated hills and mounds represent the remnants of erosion and denudation. Mostly capping of quartzite and with occasional conglomerate beds, they are the result of differential erosion and structural control. The maximum elevation encountered is 430 m above MSL and the minimum is 260 m and thus the relief amplitude is 230 m. On ground examination, it is ascertained that these hills and mounds have widely spaced joint system and black separation is the most dominant weathering process. This might have been the main reason for withstanding the fluvial erosion when compared to the surrounding areas, wherein the joint patterns are

predominantly narrow. Thin veneer of regolith cover is seen on the short scarps and whereas the hill tops and narrows summits is having exposed quartzite/sandstone blocks. Based on tonal variations this landform has been further subdivided into three sub units having (1) bluish green tone with red specks (2) yellowish green tones and (3) dark grey tones. This unit covers 6.87% of total area (8756.61ha). This unit is mostly barren with no forest cover and surface cover is mostly of rock outcrops.

5. **Inter-hill basins** (360-320 m above MSL)

This landform represent elongated narrow strip of lowlands situated in between the elevated hill ranges and ridges. Dominantly spread out on the south west and south eastern parts of Pulivendula mandal. This unit marks the sudden discontinuity of slope with clear cut, knife-edged break of slope formed by local subsidence on well defined fault line scarps. Shale is the predominant rock type here and when compared to the surrounding quartzite, sandstone and conglomerate beds. These are more easily weathered, eroded and transported by fluvial action. Pink shales are dominant on the southwestern portions, whereas calcareous shales are confined to the southeastern part of the tehsil. Thus, there is contrast on the nature of weathering front and the formation of regolith in which the pinkish shale gives rise to red loams, whereas those of calcareous nature gives rise to black earths. When compared to the surrounding elevated landforms, the inter-hill basins represent gentle and flat terrain with a maximum of 0 to 3 per cent slopes and thus, this is the zone of 'through flow' emerging out as 'return flow'. Hence a contrasting water regime is encountered in this landform when compared to the upper reaches. Thus, deep chemical weathering is the dominant geomorphic process in this unit. Based on tonal variability three sub units are identified and they are (1) greenish pink tones with blue patches (2) pink and green parcels mostly cultivated and (3) greenish yellow parcels. This unit is mostly used for banana cultivation under drip irrigation. This unit covers 5815.34ha(4.56% total area).

6. **Undulating Upper sectors** (360-300 m above MSL)

The landform represents the mid way between the upper reaches of the landforms and to that of the valley bottom represented by the tributary stream of rivers. The maximum elevation encountered here is 360 m above MSL and the minimum is 300 m. Thus, the relief amplitude of this landform is 60 m. This landform occurs on almost all the mandals but dominantly in Lingala, Pulivendula and Vemula. Because of undulating

nature with concave and convex facets dominanting the slope lengths are shorter, ranging between 50 and 100 m. As in the case of Inter-hill basins, pink and calcareous shales dominate this landform. The dominant slope categories are in the order of 1-3, 3-5, and 5 - 10 per cent. Because of extremely shallow and short slopes the depth of the weathering front increases to around 100 cm. Road cuts examined at few locations show the presence of conglomerate pebbles at depths between 2 and 5 m. The nature of weathering front however, is highly influenced by the presence of increased 'through flow'. This unit covers 10205.83ha (8.01%) but used for banana based cropping systems in the region

7. **Gently sloping middle sectors** (300-240 m above MSL)

The landform dominantly occurs in the central and northwestern parts of the tehsil representing Pulivendula, Lingala and Simhadripuram mandals. This unit has the maximum elevation of 300 m above MSL and the minimum being 240 m. Thus, unit has the maximum elevation of 300 m above MSL and the minimum being 240 m. Thus, the relief amplitude is 60 m. Very gentle slopes predominant in most stretches and the slope length ranges between 150 and 200 m. Unlike the undulating slopes of the upper sectors, rectilinear slopes are more common here. Weathering front increased to around 150 cm in the western parts of the mandal with calcium carbonate nodules spread out dominantly on the surface. Shales and tuffs of Tadipatri formation are encountered here. The whole middle sectors are the zone of 'entrainment' of sediments and their enrichment by the influence of through flow. Because of this reason, unlike the upper reaches, 'transport limited' conditions prevail here. Based on tonal variability, this unit has been divided conveniently into four sub units, namely (1) pink and brown parcels (2) bluish green parcels (3) pink and green mixed parcels and (4) whitish blue parcels. This unit covers 35535.58ha (27.88%). This unit is dominant one with majority of area is under rain fed cotton/jowar.

8. **Colluvial lower-sectors** (240-200 m above MSL)

This landform represents the lower fringes adjoining the central main valley floor of the mandal. It occurs dominantly on the central and eastern parts of the region represented by Vemula, Vempalle, Tondur and some parts of Pullivendula mandals. The maximum elevation is 240 m above MSL and the minimum is marked by the 200 m contour. Thus, the relief amplitude of this unit is only 40 m. The slope angles here are much gentler and shallower than the above occurring units. Very gently sloping and at places, almost flat segments are very common here. The slope lengths are also increased

remarkably and it ranges between 200 and 250 m. A very gentle curved inflexion differentiates this unit with that of the middle sectors. Almost flat nature of the terrain and the increased slope lengths resulted in increased weathering fronts at places more than 200 cm as confirmed from some of the open well cuts. Calcium carbonate nodules on the surface as well as its availability as powdery lime on the regolith shows the influence of excessive water regime by overland flow, through flow and return flow at places. However, the entrainment nature of sediment as observed on the middle sectors is not present here. This may be due to the fact that there are numerous tributaries of Hortion's $3^{rd}$ and $4^{th}$ orders that cut across this unit, which influence the somewhat shallow nature of the regolith. Surficial features such as wide cracks due to swell-shrink nature and micro relief's such as oriented gilgai are observed throughout this unit. Based on image interpretation and the tonal variability, this unit has been divided conveniently into seven photomorphic units' namely (1) bluish white with pink patches (2) pink tone with blue and yellow patches, (3) bright pink tone with checker-board pattern (4) greenish yellow with pink patches (5) medium gray tones (6) bluish white tones and (7) pinkish gray tones. This unit covers 27457.79ha (21.54%). This unit is second to gently sloping lands under rain fed agriculture.

9. **Narrow valley floors** (220-180 m above MSL)

Numerous narrow tributary drainage networks are originating on the southern and northern upper reaches and join the main trunk stream that flows North West-South East in the north central portion of the mandal. This trunk stream itself is a tributary to the main river Papaghni, which runs touching the southeastern corner of the taluk. The elevation ranges between 220 and 150 m above MSL. Dendiritic pattern of drainage network is observed in general on the upper reaches, whereas sub-parallel networks are seen in the middle and lower sectors. Rectangular networks with straight line segments are observed wherever there is subsidence due to the influence of fault and lineaments. Such networks are more pronounced on the elongated ridges and the adjoining dissected hills/summits. Most of the drainages are ephemeral in nature and the dominantly available shales and other soft rocks influence more percolation and subsurface seepage, thus rendering the surface expression of valley floors less developed and integrated when compared with the valleys of the basement complex elsewhere. This unit covers only 3.48% of 4440.84ha.This unit is used mainly for rice cultivation whenever canal water is released.

**10. Rock outcrops**

Bare rock exposures and local rises are scattered in the area, especially in the south central portions. They are mostly of sandstone and conglomerate, which are metamorphosed at places to quartzite, and as such stands out prominently against fluvial erosion and denudation. Block disintegration is more common phenomena than that of exfoliation or spheroidal weathering. The presence of wider joint systems with broader horizontal interconnections is responsible for these local rises to standout prominently over the surrounding terrain. This unit is barren with grass cover and has 3222.27ha (2.53%)

**Table19.** Area and extent of each land form unit along with brief description

| S. NO | Land forms | Image characteristics | Area | | Field descriptions |
|---|---|---|---|---|---|
| | | | Ha | % | |
| 1 | Elongated ridges/cuesta landforms (750-360 m above MSL) | Bluish tone with pink and green patches<br>Pinkish green | 8442.90 | 6.62 | In the northern part of the study area the rocks have conformable beds of quartzite, shale and dolomite. Due to the differential erosion and fractured zones, the erosional resistant rocks (quartzites, cherty dolomites and dolomites with shale inter calations) were remained as hills whereas the calcareous dolomites are eroded and developed in valleys. The structural hills served as the runoff zones. |
| 2 | Dissected hills/summits ( 550-260 m above MSL) | Pinkish brown<br>Bluish green (barren rock)<br>Yellowish green<br>Dark gray | 2962.15 | 2.32 | These are present as arrow ridges and are characterized by massive structure and high resistance to erosion. They exhibit dark tone, coarse texture and linear or curvilinear pattern. Major linear ridges occupy the southern part of the study area and their trending is E-S |
| 3 | Highly dissected plateau remnants (550-240 m above MSL) | Greenish pink with yellow & blue patches<br>Bluish green with pink patches<br>Dark brown with | 20263.65 | 16.18 | Denudational hill are covered out of gneissic and granites occupied in the southern part of area as low relief undulatory and isolated hill. Denudational hills are observed in the area around |

| | | | | | |
|---|---|---|---|---|---|
| | | pink patche | | | Enumulavaripalli, Nakkalapalli tanda, and Dampalli. It generally acts as runoff zone and is considered very poor to poor in terms of groundwater prospects. |
| 4 | Isolated hills/mounds /monadnocks (430-260 m above MSL) | Bluish green tone with red tinges<br>Yellowish green with red tinges<br>Dark gray tone | 8756.61 | 6.87 | Residual hills occur as isolated hills and hillocks and are formed by the prolonged erosion and weathering of pre-existing surface features. This geomorphic unit is the end product of pediplanation. Radial drainage pattern is the characteristic feature of residual hills; these features act as runoff zones and are considered to be very poor to poor in terms of groundwater prospects. In Southern part of the area around Nakkalapalli tanda, Enumulavaripalli, Gajjappagaripalli isolated low relief residual hills have been demarcated. |
| 5 | Inter hill basins (360-320 m above MSL) | Greenish pink with blue patches<br>Pink and green parcels (cultivated)<br>Greenish yellow parcels | 5815.34 | 4.56 | In the study area Valleys occupied narrow low land area bounded by hills and commonly filled with adjacent hill sediments. In groundwater point of view these valleys are considered as very good to good groundwater potential zones. |
| 6 | Undulating upper sectors (360-300 m above MSL) | Greenish pink tone<br>Bluish green with pink patches<br>Greenish pink | 10205.83 | 8.01 | A pediment is a broad, gently sloping erosional rock surface at the base of a steeper slope, often covered with loose rock fragments, formed primarily by erosion. The pediment in the area is developed on quartzites and shows 20-50 slope and is developed on quartzites / shales. It is weathered considerably to the depth of few cm to 5 m and possess poor to moderate groundwater potential. |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Gently sloping middle sectors (300-240 m above MSL) | Pink and brown parcels(dominantly pink-black soils) | 35535.58 | 27.88 | Pediplain is a broad, relatively flat rock surface formed by the joining of several pediments. In the study area the pediplain is noticed in the gneissic terrain. It is gently sloping ramp of 10 - 20 slope originated by coalescence of several pediments and finally merges with major tributary stream valley and floodplain. The fractured pediplain area is considered as moderate to good groundwater potential whereas the pediplain (unweathered / less fractured) has very poor to poor groundwater potential. |
| | | Bluish green parcels with pink tinges (shallow) | | | |
| | | Pink and green mixed parcels (red soils) | | | |
| | | Whitish blue patches eroded & $CaCo_3$ exposed | | | |
| 8 | Colluvial lower sectors (240-200 m above MSL) | Bluish white with pink patches (degraded) | 27457.78 | 21.54 | Mostly confined to foot slopes of hills and covered with surface stony and presence of round gravels in subsoils. It is transitional zone of allvial plains to pediplains. Mostly productive and used for banana with varied soils showing lithological breakups in the profiles. |
| | | Pink tone with blue and yellow patches | | | |
| | | Bright pink tone (cropped area) Greenish yellow with pink patches Medium gray tone | | | |
| | | Bluish white tone (eroded) | | | |
| | | Pinkish gray tone | | | |
| 9 | Narrow valley floors | | 44440.84 | 3.48 | |
| 10. | Rock outcrops/ Tor boulders/ Domical rises | | 3222.27 | 2.53 | Severely eroded , rock outcrops fairly covered with xerophytic vegetation of cactus spps. |
| | | Sum | 1,27,462.9 | 100 | |

A.Interhill basins

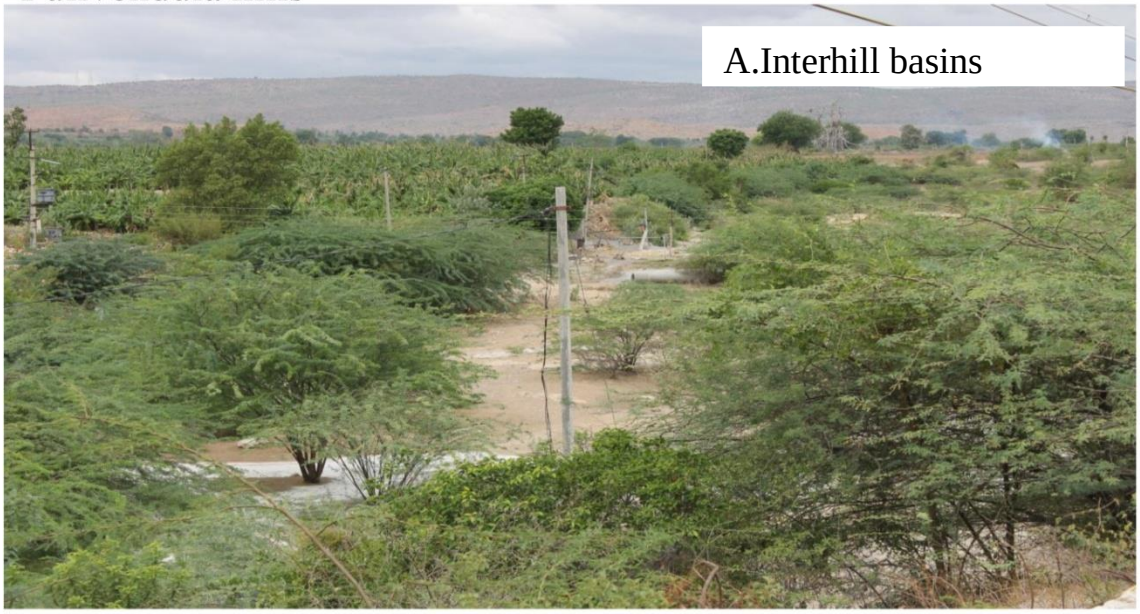
Interhill basins used for banana cultivation in Pulivendula

B. Rock bunded fields on hill tops

Rock bunding on hill slopes for banana cultivation

**Fig.15.** A. Interhill basin floors of Pulivendula B.Rock bunding on hill slopes

Banana cultivation on hills(>700m above mean sea level ) of Pulivendula hills




Interhill basin floors heavily infested with prosopis Juliflora with sporadic cultivation of banana on terraces

**Fig.16.A.** Interhill basins with sporadic cultivation of banana B. Rock bunded fields adjacent to banana fields on hill top

## 7.0. Soil –landscape systems

The east - west section of landscape section as depicted in Fig.17. It shows the two distinct geological formations of Pulivendula quartzitic with breakup of Vemula limestone formations with in a distance of 5km from Pulivendula town. The high peaks of quartzitic hills are sharp and very steeply sloping front (wind ward) in southern side with steep slopes in northern part. The rounded moderately sloping hills with undulating terrain in Vemula formations with sporadic cultivation of banana in the region. The severely eroded river terraces in western direction with alluvium and rock exposures all along the ephemeral river bank. The rounded colluvial boulders in the river cut of banks and mostly affected with strong alkalinity. The upper reaches are mostly used for traditional banana growing region in Pulivendula. The Pulivendula series (P1) on hill tops is deep and have dark brown clay surface horizon and dark brown clay subsoil. This soil is strongly alkaline with low organic carbon and moderate CEC. This has >15% of exchangeable sodium and electrical conductivity more than 6dSm$^{-1}$. Typically Vemula soils (P2) are moderately shallow and well drained. This soil has dark reddish brown, strongly alkaline, clay A horizons; dark reddish brown, strongly alkaline, gravelly clay B horizons underlain by hard quartzite rock. Velpula soils (P3) have dark reddish brown, moderately alkaline, sandy clay loam a horizons and dark reddish brown to dark red, moderately alkaline, sandy clay B horizon. They have developed from weathered shales and occur on very gently sloping mid sector with 1-3 per cent slope at an elevation of about 260 m above MSL. Typically, Balapanur soils (P4) have dark brown, strongly alkaline, clay a horizons, and dark brown, strongly alkaline, clay B horizons. These soils are very deep and have prominent intersecting slickenside’s and wedge shape aggregates with high ESP (>15%). Parnapalle soils (P5) are very deep and well drained. This soil have dark grayish brown, strongly alkaline, sandy loam A horizon and dark grayish brown to dark yellowish brown, strongly alkaline, sandy loam C horizon. They have developed from alluvium and occur on nearly level to very gently sloping lands with 0 to 3 per cent slope at an elevation of 280 M above MSL.

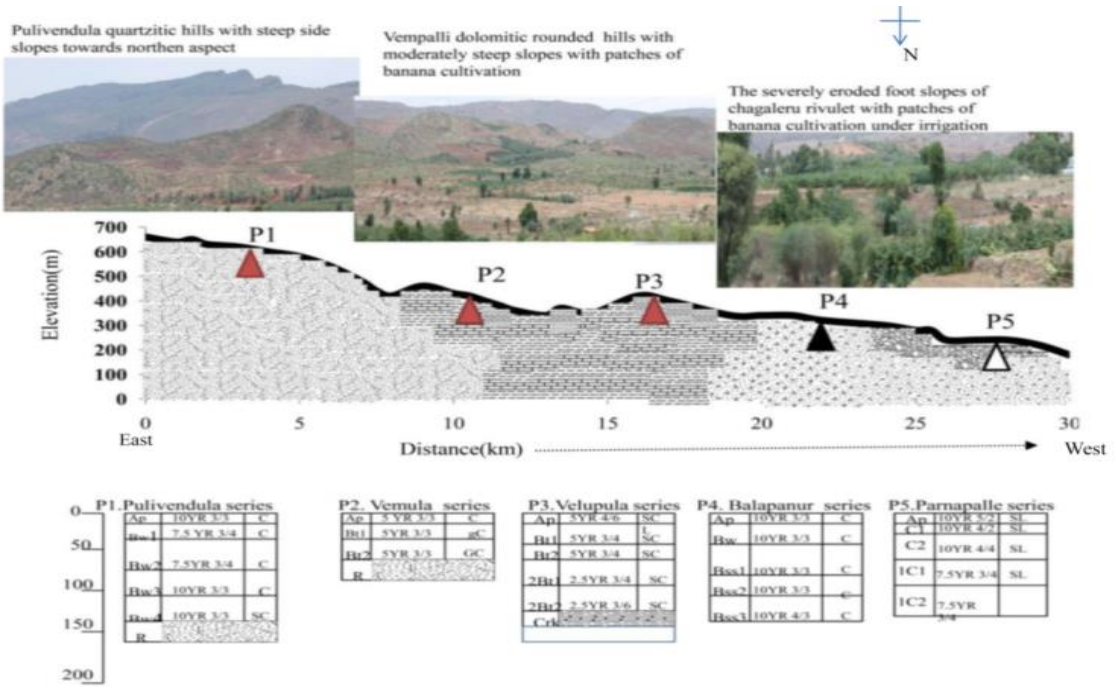



**Fig.17.** Soil-landscape diagram along with profile morphology and depth functions of particle size distribution

### 8.0. Soil morphology

The brief morphological properties of soils are given in table 20. The description each soils series is given as under:

### 8.1. Soils with A-C/R Horizons

Typically, Kanampalli soils (P1) have dark reddish brown, moderately alkaline gravelly sandy clay loam a horizon overlying hard quartzite. They have developed from quartzite and occur on moderately steeply sloping lands with 15-25 per cent slope at elevation of about 540 m above MSL. The Ganganapalle series (P2) have red, neutral, sandy clay a horizon overlying hard quartzite. They have developed from quartzite and occur on moderately steeply sloping lands with 15-25 per cent slope at elevation of about 540 m above MSL.

Parnapalle soils (P18) have dark grayish brown, strongly alkaline, sandy loam A horizon and dark grayish brown to dark yellowish brown, strongly alkaline, sandy loam C horizon. They have developed from alluvium and occur on nearly level to very gently sloping lands with 0 to 3 per cent slope at an elevation of 280 M above MSL.

### 8.2. Soils with Ap-Bw horizons (red soils)

The Lingala (P3) have dark reddish brown, moderately alkaline, gravelly clay loam A horizons, dark red, slightly alkaline, gravelly clay loam B horizon. They have developed from quartzite rock and occur on moderately sloping lands with 5-10 per cent slope at elevation of about 380 m above MSL. The Rachakuntapalle series (P4) have yellowish red, neutral, gravelly sandy clay loam a horizons and yellowish red, slightly alkaline, gravelly sandy clay B horizon with 60-85 per cent gravel. They have developed from quartzite and occur on strongly sloping lands with 10-15 per cent slope at an elevation of about 540 m above MSL. Typically Mupendranpalle series (P5) have dark reddish brown, moderately strong alkaline, gravelly sandy clay loam a horizons and strongly alkaline, gravelly sandy clay B horizon with 70 per cent gravel. They have developed from Shales and occur on very gently sloping lands with 1-3 per cent slope at an elevation of about 320 m above MSL. The Tallalapalle series (P6) have dark reddish brown, strongly alkaline, gravelly sandy clay loam a horizon and dark reddish brown, moderately alkaline, gravelly sandy clay B horizon with 65 per cent gravel and stones. They have developed from shale's and occur on very gently sloping inter hill basin with 1-3 per cent slope at an elevation of about 300 m above MSL. The Santakovur series (P7) have dark reddish brown, moderately alkaline, sandy clay loam a horizons and very strongly alkaline, sandy clay and gravelly sandy clay loam B horizon. They have developed from shale's and occur on very gently sloping interhill basin with 1-3 per cent slope at an elevation of about 200 m above MSL.

### 8.3. Soils with argillic horizons (red soils)

The Kottalu series (P10) have dark reddish brown, strongly alkaline, sandy loam A horizons and dark red to dark reddish brown, strongly alkaline, sandy clay loam to sandy clay B-horizon. They have developed from shale's and occur on very gently sloping interhill basin with 1 to 3 per cent slope at an elevation of about 360 m above MSL. The Murarichintala series (P11) have reddish brown to dark reddish brown sandy loam a horizons and dark red to dark reddish brown, strongly alkaline, sandy clay loam to clay B horizons. Typically Vemula soils (P12) have dark reddish brown, strongly alkaline, clay A horizons; dark reddish brown, strongly alkaline, gravelly clay B horizons underlain by hard quartzite rock. The Velpula series (P15) have dark reddish brown, moderately alkaline, sandy clay loam A horizons and dark reddish brown to dark red, moderately alkaline, sandy clay B horizon. They have developed from weathered shales

and occur on very gently sloping mid sector with 1-3 per cent slope at an elevation of about 260 m above MSL.

### 8.4. Soils with A-Bw horizons (black soils)

The Tatireddipalle series (P8) have very dark grayish brown, moderately alkaline, clay A horizon and B horizon. They have developed from shales and occur on very gently sloping inter hill basin with 1-3 per cent slope at an elevation of about 360 m above MSL. The Cherlapalle series (P9) have dark brown, strongly alkaline, clay A horizons and dark yellowish brown to dark brown, strongly alkaline, clay B horizon. They have developed from weathered shales and occur on very gently sloping interhill basin with 1 to 3 per cent slope at an elevation of about 220 m above MSL. Sunkesula soils (P13) have brown, moderately alkaline, sandy clay loam A horizons and dark yellowish brown to dark brown, moderately alkaline, clay B horizon. They have developed from shales and occur on very gently sloping middle sector with 1 to 3 per cent slope at an elevation of 320 m above MSL. Gondipalle soils (P19) have dark brown, strongly alkaline, gravelly clay A and B horizons. They have developed from shales and occur on nearly level to very gently sloping colluvial lower sector with 0-3 per cent slope at an elevation of 220 m above MSL. Goturu soils (P20) have dark yellowish brown, very strongly alkaline, clay A horizon and dark brown to dark yellowish brown, very strong to strongly alkaline, clay B horizon. They have developed from weathered shales and occur on nearly level to very gently sloping colluvic lower sector with 0 to 3 per cent slope at an elevation of 200 m above MSL.

Pulivendula soils (P21) have, dark brown clay surface horizon followed by dark brown clay subsoil. They have developed from weathered shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at an elevation of 220 m above MSL. Pernapadu soils (P22) have dark yellowish brown, moderately alkaline, clay A horizon and dark yellowish brown, moderate to strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at elevation of 210 m above MSL. Agadur soils (P23) have dark brown, moderately alkaline, clay A horizon and dark brown to very dark grayish brown, strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at an elevation of 200 m above MSL. Tondur soils (P24) have dark brown, very strongly alkaline, clay A horizon

and very dark grayish brown, very strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at an elevation of 210 m above MSL.

### 8.5. Soils with slicken sided horizons

The Simhadripuram series (P14) have very dark grayish brown, strongly alkaline clay A horizons and dark brown stronly alkaline, clay B horizons over hard shale rock. This soil has intersecting slickensided horizons with wedge shape aggregates. Agraharam soils (P16) have dark brown, strongly alkaline, clay A horizons and dark brown to very dark grayish brown, strongly alkaline, clay B horizon with intersecting slickenside's and wedge shaped aggregates. They have developed from shales and occur on very gently sloping middle sector with 1 to 3 per cent slope at an elevation of 260 m. Typically, Balapanur soils (P17) have dark brown, strongly alkaline, clay A horizons, and dark brown, strongly alkaline, clay B horizons. Bhadrampalle soils (P25) have dark brown, strongly alkaline, sandy clay A horizon and very dark grayish brown to dark yellowish brown, strongly alkaline, clay B horizons. They have developed from shales and occur on nearly level to very gently sloping lands with0-3 per cent slope at an elevation of 220 m above MSL.

**Table 20.**Soil morphology

| Deth(cm) | Horizon | Matrix colour | Texture | Structure | Consistency | Roots | Boundary | pH | Other features |
|---|---|---|---|---|---|---|---|---|---|
| P1. Kanampalli(Kpl) | | | | | | | | | |
| 0-21 | A | 5YR4/4 | gscl | m1sbk | h,fr,ss,sp | f-m | cs | 8.3 | 85% stony layer |
| 21+ | R | Hard quartzitic rock | | | | | | | |
| P2.Ganganapalle(Ggp) | | | | | | | | | |
| 0-15 | A | 2.5YR4/8 | c | m2sbk | fr,s,p | f,m-c | cs | 7.1 | |
| 15+ | R | Hard quartzitic rocks | | | | | | | |
| P3.Lingala(Lgl) | | | | | | | | | |
| 0-18 | Ap | 5YR4/4 | gcl | m1sbk | h,fr,ss,sp | vf-c | cs | 8.1 | 60% gravels in Ap and 50%fine coarse |
| 18-47 | Bw | 2.5YR3/6 | gcl | m1sbk | h,fr,ss,sp | vf,f-c | as | 7.8 | garvels in Bw horizon |
| 47+ | R | Hard quartzitic rock | | | | | | | |
| P4. Rachakuntapalle(Rkp) | | | | | | | | | |
| 0-14 | A | 5YR4/6 | gc | m1sbk | sh,fr,ss,sp | vf-m | cs | 7.2 | 60 per cent gravels in Ap horizon but , 85% |
| 14-40 | Bw | 5YR4/6 | gc | m1sbk | fr,s,p | vf-c | as | 7.5 | in Bw horizon |
| 40+ | R | Hard quartzitic rock | | | | | | | |
| P5. Mupendranpalle(Mpl) | | | | | | | | | |
| 0-20 | Ap | 5YR3/4 | gc | m1sbk | sh,fr,ss,sp | vf-m | cs | 8.4 | 30 per cent gravels, slightly effervescent Ap |
| 20-40 | Bw | 5YR3/3 | gc | m1sbk | fr,s,p | vf-c | as | 8.5 | horizon but , 70%gravel in Bw horizon |
| 40+ | R | Shale | | | | | | | |
| P6. Tallalapalle(Tpl) | | | | | | | | | |
| 0-19 | Ap | 5YR4/6 | gcl | m1sbk | sh,fr,ss,sp | vf-m | cs | 8.5 | 30 per cent gravels, slightly effervescent Ap |
| 19-40 | Bw | 5YR3/3 | gc | m1sbk | fr,s,p | vf-c | as | 8.4 | horizon, 65%gravel ,strong effervescent in Bw horizon |
| 40 | R | Shale | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| P7. Santakovur(Skv) | | | | | | | | | |
| 0-17 | Ap | 5YR4/4 | gcl | m1sbk | fr,ss,sp | vf,f-c | cs | 8.3 | 15 to 20 gravels in Ap /Bw1 horizons but |
| 17-42 | Bw1 | 5YR3/3 | cl | m2sbk | fr,s,p | f-c | cs | 9.3 | increased to 65% in Bw2 horizon,medium |
| 42-62 | Bw2 | 5YR3/3 | gcl | m1sbk | fr,s,p | f-f | as | 9.4 | many lime nodules |
| P8 Tatireddipalle(Trp) | | | | | | | | | |
| 0-15 | Ap | 10YR3/2 | c | c2sbk | h,fi,s,p | c-f | cs | 8.3 | Slight effervescenceand slightly alkaline |
| 15-33 | Bw1 | 10Yr3/2 | c | c3sbk | fi,vs,vp | f-c | gs | 8.4 | |
| 33-55 | Bw2 | 10YR3/2 | c | m2sbk | fi,vs,vp | f-f | as | 8.3 | |
| 55+ | R | | | | | | | | |
| P9. Cherlapalle(Cpl) | | | | | | | | | |
| 0-20 | Ap | 10YR3/3 | c | m2sbk | vh,fi,s,p | f-c | cs | 9.1 | Strongly effervescentwith few,fine lime |
| 20-40 | Bw1 | 10YR3/4 | c | m2sbk | fi,s,p | vf-c | cs | 8.8 | nodules |
| 40-72 | Bw2 | 10YR3/3 | c | m2abk | fi,vs,vp | f-c | gs | 8.5 | |
| 72-105 | Bw3 | 10YR3/3 | c | m2sbk | fi,vs,vp | f-f | | 8.7 | |
| 105+ | Cr | | | | | | | | |
| P10. Kottalu(Ktl) | | | | | | | | | |
| 0-18 | Ap | 5YR4/4 | sl | m1sbk | sh,vfr,ss,sp | f-c | cs | 8.6 | Moderately thick continuous clay cutans |
| 18-45 | Bt1 | 2.5YR3/6 | sc | m2sbk | fr,s,p | f-f | gs | 8.5 | present in Bt layers, strongly alkaline with |
| 45-76 | Bt2 | 2.5YR3/6 | sc | m2sbk | fr,s,p | f-f | gs | 8.5 | fine, few lime nodules from 2$^{nd}$ layer |
| 76-108 | Bt3 | 2.5YR3/4 | scl | m2sbk | fr,s,p | f-f | gs | 8.5 | onwards |
| 108-142 | Bt4 | 2.5YR4/6 | scl | m2sbk | fr,s,p | f-f | - | 8.6 | |
| 142+ | R | Hard shale rock | | | | | | | |
| P11 Murarichintala(Mct) | | | | | | | | | |
| 0-20 | Ap | 2.5YR4/4 | sl | m1sbk | h,fr,ss,sp | f-c | cs | 8.6 | Moderately thick continuous clay cutans |
| 20-60 | Bt1 | 2.5YR3/4 | scl | m1sbk | fr,ss,sp | f-c | gs | 8.6 | present in Bt layers, strongly alkaline with |
| 60-98 | Bt2 | 2.5YR3/6 | scl | m2sbk | fr,ss,sp | c-f | gs | 8.5 | fine, few lime nodules from 2$^{nd}$ layer |
| 98-135 | Bt3 | 5YR3/4 | cl | m2sbk | fr,s,p | f-f | gs | 8.0 | onwards. |
| 135-155 | Bt4 | 5YR3/4 | c | m2sbk | fr,s,p | f-f | - | 7.7 | |
| P12. Vemula(Vml) | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0-20 | Ap | 5YR3/3 | c | m2sbk | fr,s,p | vf,f-m | cs | 8.6 | Increase of coarse fragments from 10% in |
| 20-41 | Bt1 | 5YR3/3 | gc | m2sbk | fr,s,p | vf,f-c | gs | 8.5 | Ap to 20% in Bt1 and 70% in Bt3,strongly |
| 41-72 | Bt2 | 5YR3/3 | gc | m1sbk | fr,s,p | vf,f-f | cs | 8.5 | alkaline throughout depth , violent effervescence with fine,few lime nodules. |
| 72+ | R | Hard quartzite rock | | | | | | | |
| P13. Sunkesula(Skl) | | | | | | | | | |
| 0-20 | Ap | 10YR4/3 | scl | m2sbk | sh,fr,s,p | f-f | cs | 8.4 | Strongly effervescentwith few,fine lime |
| 20-38 | Bw1 | 10YR3/3 | c | m2sbk | fi, vs,vp, | f-f | gs | 8.3 | nodules |
| 38-70 | Bw2 | 10YR3/4 | c | m2sbk | fi,vs,vp | vf-f | gs | 8.0 | |
| 70+ | R | Hard shale | | | | | | | |
| P14 Simhadripuram(Spm) | | | | | | | | | |
| 0-20 | Ap | 10YR3/3 | c | m3sbk | h,fi,s,p | f-c | cs | 8.4 | Strongly effervescent with few fine lime |
| 20-42 | Bw | 10YR3/3 | c | m3abk | fi,vs,vp | f-c | gs | 8.9 | nodules, presence of pressure faces on ped |
| 42-65 | Bss1 | 10YR3/3 | c | m3abk | fi,vs,vp | f-f | gs | 8.8 | surface in cambic and intersecting slicken |
| 65-92 | Bss2 | 10YR3/3 | c | m3abk | fi,vs,vp | f-f | cs | 9.0 | sides in 3rd layer onwards and extended to |
| 92+ | R | Hard shale | | | | | | | 90cm |
| P15 Velpula(Vpl) | | | | | | | | | |
| 0-20 | Ap | 5YR4/6 | scl | m1sbk | h,fr,ss,sp | vf-c | gs | 8.3 | Presence of fine patchy thick clay skins in |
| 20-43 | Bt1 | 5YR3/4 | sc | m2sbk | fr,s,p | vf-c | cs | 8.4 | Bt layers , presence of fine,medium lime |
| 43-68 | Bt2 | 5YR3/4 | sc | m2sbk | fr,s,p | f-c | cs | 8.4 | nodules, strongly effervescent |
| 68-100 | Bt3 | 2.5YR3/4 | sc | m2sbk | fr,s,p | f-f | gs | 8.4 | |
| 100-138 | Bt4 | 2.5YR3/6 | sc | m2sbk | fr,s,p | f-f | - | 8.2 | |
| P16 Agraharam(Ahm) | | | | | | | | | |
| 0-16 | Ap | 10YR3/3 | c | c/m2sbk | h,fi,s,p | f-f | cs | 8.8 | Strongly effervescent with few fine lime |
| 16-36 | Bw1 | 10YR3/2 | c | m2sbk | fi,vs,vp | f-f | gs | 8.8 | nodules, presence of pressure faces on ped |
| 36-71 | Bss1 | 10YR3/2 | c | m2abk | fi,vs,vp | f-f | gs | 8.9 | surface in cambic and intersecting slicken |
| 71-103 | Bss2 | 10YR3/2 | c | m2abk | fi,vs,vp | f-f | gs | 8.8 | sides in 3rd layer onwards and extended to |
| 103-120 | Bss3 | 10YR4/3 | c | m2abk | fi,vs,vp | f-f | as | 8.8 | depth of 150cm |
| 120+ | Ck | Weathered parent material (shale) with carbonate | | | | | | | |
| P17 Balapanur(Bpr) | | | | | | | | | |
| 0-14 | Ap | 10YR3/3 | c | c/m2sbk | h,fi,s,p | f-f | cs | 8.8 | Strongly effervescent with few fine lime |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14-50 | Bw1 | 10YR3/3 | c | m2sbk | fi,vs,vp | f-f | gs | 8.6 | nodules, presence of pressure faces on ped |
| 50-98 | Bss1 | 10YR3/2 | c | m2abk | fi,vs,vp | f-f | gs | 8.5 | surface in cambic and intersecting slicken |
| 98-118 | Bss2 | 10YR3/3 | c | m2abk | fi,vs,vp | f-f | gs | 8.5 | sides in 3rd layer onwards and extended to |
| 118-150 | Bss3 | 10YR4/3 | c | m2abk | fi,vs,vp | f-f | - | 8.3 | depth of 150cm |
| P18 Parnapalle(Prp) | | | | | | | | | |
| 0-21 | Ap | 10YR5/2 | sl | f1sbk | sh,fr,so,po | f-m | cs | 8.7 | Strongly alkalinewith fine lime nodules, |
| 21-43 | C1 | 10YR4/2 | sl | f1sbk | vfr,so,po | f-f | cs | 8.9 | parent material is river alluvium |
| 43-75 | C2 | 10YR4/4 | sl | f1sbk | vfr,so,po | f-f | gs | 8.7 | |
| 75-109 | C3 | 7.5YR3/4 | sl | f1sbk | vfr,so,po | - | gs | 8.6 | |
| 109-150 | C4 | 7.5YR3/4 | sl | f1sbk | vfr,so,po | - | - | 8.7 | |
| P19 Gondipalle(Gpl) | | | | | | | | | |
| 0-22 | Ap | 10YR3/3 | gc | m2sbk | sh,fr,s,p | m,f-c | cs | 8.5 | 15 to 20% fine gravel in Ap horizon, |
| 22-44 | Bw1 | 10YR3/3 | gc | m2sbk | fi,s,p | fm-m | as | 9.0 | strongly effervescent throughout depth with |
| 44+ | Hard shale | | | | | | | | fine lime nodules. |
| P20 Goturu(Gtr) | | | | | | | | | |
| 0-21 | Ap | 10YR3/4 | c | m2sbk | h,fi,s,p | vf,c | cs | 9.1 | 10% fine gravel in Ap horizon, strongly |
| 21-48 | Bw1 | 10YR3/4 | c | m2sbk | fi,vs,vp | f-c | cs | 9.1 | effervescent throughout depth with fine lime |
| 48-70 | Bw2 | 10YR3/3 | c | m2abk | fi,vs,vp | f-f | cw | 9.0 | nodules. |
| 70 | Crk | Weathered shale with carbontes | | | | | | | |
| P21 Pulivendla(Pvd) | | | | | | | | | |
| 0-19 | A | 10YR3/3 | c | m2sbk | h,fi,s,p | vf,f | as | 9.3 | Preence of dark brown 7.5YR hue B |
| 19-44 | Bw1 | 7.5YR3/4 | c | m2sbk | fi,vs,vp | vf-c | gs | 9.1 | horizons and strongly alkaline with |
| 44-76 | Bw2 | 7.5YR3/4 | c | m2abk | fi,vs,vp | f-c | cs | 9.5 | common, medium lime nodules |
| 76-110 | Bw3 | 10YR3/3 | c | m2abk | fi,vs,vp | - | gs | 9.1 | |
| 110-135 | Bw4 | 10YR3/3 | c | M2sbk | fr,ss,sp | - | | 9.5 | |
| 135+ | Ck | Weather shale mixed up with carbonate | | | | | | | |
| P22. Pernapadu(Ppd) | | | | | | | | | |
| 0-22 | Ap | 10YR3/4 | c | m2sbk | h,fi,s,p | f,f | cs | 8.4 | Strongly effervescent in Ap horizon but |
| 22-54 | Bw1 | 10YR3/4 | c | m2sbk | fi,vs,vp | - | cs | 8.4 | violent effervescent in B horizons, fine, |
| 54-80 | Bw2 | 10YR3/4 | c | m2abk | fi,vs,vp | - | gs | 8.4 | fewlime nodules |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80-103 | Bw3 | 10YR3/4 | c | m2abk | fi,vs,vp | - | cw | 8.5 | |
| 103+ | Cr | Weathered black shale | | | | | | | |
| P23. Agadur(Agd) | | | | | | | | | |
| 0-19 | Ap | 10YR3/3 | c | m2sbk | h,fi,s,p | m-vf,f | cs | 8.3 | Slightly effervescent throughtout depth with |
| 19-49 | Bw1 | 10YR3/3 | c | m2sbk | fi,vs,vp | vf-c | cs | 8.6 | few fine lime nodules are present upto 2nd |
| 49-91 | Bw2 | 10YR3/2 | c | m2abk | fi,vs,vp | vf-c | cs | 8.8 | layers but increased to many, medium lime |
| 91-125 | Bw3 | 10YR3/3 | c | m2abk | fi,vs,vp | f-f | gs | 8.9 | nodules. |
| 125-145 | Bw4 | 10YR3/3 | c | m2abk | fi,vs,vp | f-f | | 8.8 | |
| P24 Tondur(Tdr) | | | | | | | | | |
| 0-20 | Ap | 10YR3/3 | c | m2sbk | h,fi,s,p | m-vf,f | cs | 9.1 | Slightly effverscenct in top two layers but |
| 20-47 | Bw1 | 10YR3/2 | c | m2sbk | fi,vs,vp | vf-c | cs | 9.4 | increased to strongly effervescent in cambic |
| 47-74 | Bw2 | 10YR3/2 | c | m2abk | fi,vs,vp | vf-c | gs | 9.5 | B horizons |
| 74-105 | Bw3 | 10YR3/2 | c | m2abk | fi,vs,vp | f-f | gs | 9.4 | |
| 105-152 | Bw4 | 10YR3/3 | c | m2abk | fi,vs,vp | f-f | gs | 9.3 | |
| P25 Bhadrampalle(Bpl) | | | | | | | | | |
| 0-12 | Ap | 10YR3/3 | sc | m2sbk | h,fi,s,p | f,m | cs | 8.7 | Strongly effervescent through out depth, |
| 12-36 | Bw | 10YR3/2 | c | c2sbk | fi,vs,vp | f,f | gs | 8.9 | pressur faces on ped surfaces of 2nd layer, appearance of wedge shaped aggregates and |
| 36-63 | Bss1 | 10YR3/2 | c | c2abk | fi,vs,vp | f,f | gs | 8.6 | prominent, intersecting slickensides and |
| 63-85 | Bss2 | 10YR3/2 | c | c2abk | fi,vs.vp | f,f | gw | 8.8 | polished shiny surfaces from 3rd layer to |
| 85-107 | Bss3 | 10YR3/4 | c | c2abk | fi,vs,vp | f,f | gw | 8.6 | 150cm |
| 107-150 | Bss4 | 10YR3/4 | c | c2abk | fi,vs,vp | f,f | gw | 9.0 | |

**Note :** munsell colour notation: 10YR3/2=very dark grayish brown, 10YR3/1=very dark grey, 10YR4/2 =dark grayish brown,10YR4/3 =brown, 10YR3/3 =dark brown,7.5YR3/2=dark brown, 7.5YR3/3=dark brown, 7.5YR3/4= dark brown, 7.5YR3/3 = dark reddish brown, 7.5YR4/3=brown, 7.5YR4/2 = brown, 5YR4/6= yellowish red, 2.5YR=4/6=red, 2.5YR3/4= dark reddish brown,
Texture[1]:cl=clay loam, sicl=silty clay loam, scl=sandy clay loam, sl=sandy loam, c=clay, sc=sandy clay
Structure[2]:m=medium, 2=moderate, sbk=subabular blocky, C=coarse, 3=strong,abk=angular blocky, f=fine, sg=single grain
Consistence[3]: h=hard, fi=firm, s=sticky,p=plastic,sh=slightly hard, ss=slightly sticky,sp=slightly plastic, so=nonsticky, po=non plastic, vh=verhard,vs=very sticky, vp=very plastic
Effervescence[4]:ev=strongly effervescent
Boundary [5]:c=clear, s=smooth, d=diffuse, w=wavy,a =abrupt,s=smooth, Root[6]:f=fine, f=fine, vf=very fine,c=coarse,c=common
Source:Soil Science Division Staff (2014)

## 9.0. Textural and chemical characteristics of soil series

### 9.1.Textural characteristics

The Kanampalli (P1) and Ganganapalli (P5) have lithic contact within 50cm but varied in particle size class as loamy skeletal for P1 and clayey for Ganganaepalli (P2). The A horizon has clay of 23.6% in P1 and 47.4% for P2 but have silt to clay ratio of 0.18 for P1 and 0.43 for P2.

The Kottalu (P3) and Rachanukuntepalli (P4) have A and Bw horizon sequence within 50cm of lithic contact. These soils display an increase of clay more than 1.2 times from A horizon to B horizon. The clay content is B horizons is 39.7% as against 31.8% of A horizon in P3. The silt to clay ratio is 0.75 to 0.88 and sand to silt ratio of 1.87 for A horizon to 0.76 in B horizons of P3. The trends are similar in Rachanukuntapalli series (P4) with an illuvial coefficient of 1.31, clay of 32.2%in B horizon to 24.4% in A horizon, silt to clay ratio. The particle size class is clayey skeletal for P3 and loamy skeletal for P4. Mupendra palli (P5) and Tallalapalle (P6) have clayey skeletal paticle size with a clay increase less than 1.2 times. The B horizons have clay of 45.9% in P5 and 55.1 % in P6 with silt to clay ratio of 0.68 in P5 and 0.37 in P6. The Vemula soil (P12) has more than 40% clay with gradational increase and an illuvial coefficient of 1.09 o 1.17 in B horizons. This soil has an irregualar sand to silt ratio of 1.1 to 2.1 and silt to clay ratio of 0.33 to 0.59. Parnapalle (P18) shows irregualr sand to silt ratio with an abrupt increase from 6.88 (C2) to 17.89 (1Bw2). The profile distribution clay is irregular with its contents from 11.7in C2 to 18.6% in 1Bw1. The silt to clay ratio shows irregular but is values less than 0.4 in B horizons. The profile distribution of clay shows gradational increase in Gondipalle series (P19 from 40 to 59.1%), Pernapadu (P22, from47.3 to 58.8%), Agadur (P23) and Vempalle series (P24, 47.9 to 70.0%). These soils show irregular trends of silt to clay ratio and sand to silt ratio. The silt to clay is less than 0.4 whereas sand to silt ratio is more than 1.0.

The Santhakovur (P7) series have clay increase in cambic B horizon (32.5 to 38.8%) but its increase is less than 1.2 times. The gradational decrease of silt to clay (0.58 to 0.49) is noticed in this profile with sand to silt ratio more than 2. The Tatireddipalli series (P8) and Cherlapalle series (P9) have very fine particle size with clay content

exceeding more than 60% and showing increase of clay in B horizons but less than 1.2 times to that of A horizon in case of P8 but more than 1.2 times in P9. In P8, the decreasing silt to clay ratio (0.49 to 0.37) and less than 1 of sand to silt ratio is observed**.** In P9, the silt to clay ratio shows gradational decrease with depth from 0.46 to 0.27 and sand to silt ratio of 1.53 to 0.55.

The fine loamy Kottalu soil (P10) and Murarichintala (P11) shows clay enriched B horizons with an illuvial coefficient exceeding 2 in P10 and P11. In P10, The clay content shows decreasing its content in Bt3 /Bt4 layers as reflected in silt to clay ratio of 0.5 to 1.66. The sand to silt ratio is gradually decreasing with depth (from 7.76 to 1.06). In P11, It is interesting to pinpoint that the dark red horizons upto 60 cm have dark reddish brown horizons below is showing irregular depth trends of sand and silt with its ratio. The silt to clay ratio > 0.7 up to Bt2 layer but less than 0.65 in Bt3 / Bt4 layers. Sunkesula soil (P13) shows gradational increase of clay from 34.5 in A to 65.3% in Bt2 layer and an illuvial coefficient of 1.71 to 1.89 in clay rich B horizons. The silt shows increasing depth trends from 15.4 to 19.3 with decreasing depth trends of silt to clay ratio (0.29 to 0.45) and sand to silt ratio (3.25 to 0.81). Velpula (P15) shows irregular depth distribution of sand and silt with high inflictions of sand to silt ratio exceeding more than 3.0.The clay distribution shows gradational increase from 25.8% in A horizon to 38.5% in B horizons. The eluvial-illuvial coefficient is 1.4 times more in B horizons. The silt to clay ratio varies from0.26 to 0.52 (Table 21).

Simhadripuram soil (P14) has more than 55 per cent of clay in A horizon but increased to 62% in B horizons. The profile distribution of sand (13.7 to 23.2%) and silt (19.5 to 24.5%) is irregular with values less than 1 in some B horizons .The silt to clay ratio is less or equal to 0.4. The agraharam soil (P16) has clay content more than 60% in control section (25 -100cm) with illuvial coefficient of 0.90 to 1.12. The silt to clay ratio is 0.31 to 0.44 and sand to silt ratio less than 1 in B horizons. The depth trends are irregular for sand, silt and clay. The Balapanur soil (P17) shows increasing clay content from 53 to 68.5% with an illuvial coefficient of 1.07 to 1.29.The sand to silt ratio shows less than 1 and is irregular throughout the depth. The silt to clay ratio is decreasing with depth from 0.45 to 0.37. The Bhadrampalle series (P25) has a clay content of 47 to 67 % with an increasing depth trends. The depth trends of silt to clay and sand to silt ratio (>1 throughout depth). The clay illuvial coefficient is more than 1.2 times in Bss3 / Bss4

horizons. The silt content in Pulivendula series (P21) is irregular with depth but its content is less than 4%. Similar depths trends are noticed in for clay with its content vary from 39.1 in Bw4 to 63.6% in Bw2 horizon. The sand to silt ratio is more than 10 and reached to maximum of 45.85 in Bw4. The silt to clay ration is less than 00.06 with irregular distribution. When 90 samples of soil separates are plotted and constructed ternary diagram (Fig.18), more than 65 per cent are concentrated in clay textural class , 8 per cent in sandy clay loam and sandy clay textural class.

**9.2. Chemical characteristics**

The pH of the soils in groundnut producing areas of Pulivendula tehsil of Kadapa district 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. These soils contained extremely low organic carbon of 2.6gkg$^{-1}$ in Pulivendula soil (P21) but are more than 10gkg$^{-1}$in P8, P13 and P19 in soils developed over shale with mean of 7.26 ± 3.13gkg$^{-1}$(Table 21). 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 10gkg$^{-1}$ and can be used for sustainable groundnut production (Table 21). The remaining soils with low to extremely low organic carbon status. The Cation Exchange Capacity (CEC) of soils of Pulivendula tehsil is varied from 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 ± 7.64cmol(+)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 (12-25cmol/kg), high (25-40cmol/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. It is pertinent to say that low CEC can be attributed to the high sand and low organic matter content of soils. The relation of CEC of soils is expressed in a regression equation that can explain 80 per cent of variability as given below:

- CEC (cmol/kg) = -12.4 + 0.8(clay, %) + 0.5 (OC, g / kg) + 0.3(silt, %) with R2 of 0.8 and F statistics of 70.8 on 4 and 85 degree of freedom.

The calcium carbonate ($CaCO_3$) content is varied from 10g/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 ± 46.57g/kg as against the soils on quartzite with mean of 20 ± 10gkg-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 (Table 22). The calcium carbonate has a positive relation with clay (r =0.62**) significant at 1% level. The one way ANOVA analysis shows that there is a significant difference between the horizons for sand, clay, organic carbon and CEC at p <0.01 where as pH, EC and ESP at p < 0.05 level (Table 23). These soils have mean bulk density of 1.27±0.9 with CV of 7.05 indicating below the critical values (1.63g/$cm^3$, Amusan, *et al*., 2006). The A horizons have a mean clay content of 39.54±14.25 % with high variability (CV >35%) whereas Bw/Bss horizons have 58.06±9.01% of clay with low variability and in argillic horizons, the mean clay is 36.72±7.32% and moderate variability. The sand to silt ratio shows high variability in all horizons with maximum mean of 4.54± 6.77 for A horizons and 2.79±1.19 for Bt horizons (Table 21.1, Appendix).The chemical properties shows high variability for all horizons but moderate for CEC and Ex Ca for Bw/Bsshorizons.

**Table 21** .Textural and chemical properties of soil series

| Horizon | Depth (cm) | Particle size distribution (mm) | | | pH | EC | O.C. | $CaCO_3$ | Extractable Bases | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | | g $kg^{-1}$ | g $kg^{-1}$ | Ca | Mg | Na | K | sum | CEC (cmol/kg) |
| | | <----------%---------> | | | | d $Sm^{-1}$ | | | | | | | | |
| | | (2.0-0.05) | (0.05-0.002) | (<0.002) | | | | | <----------cmol kg-1----------> | | | | | |
| P1 -Kanampalli | | | | | | | | | | | | | | |
| A | 0-21 | 72.1 | 4.3 | 23.6 | 8.3 | 0.14 | 1.63 | 1 | 6.7 | 2 | 0.02 | 0.22 | 8.9 | |
| | Ẁ | 72.1 | 4.3 | 23.6 | 8.3 | 0.14 | 1.63 | 1 | 6.7 | 2.0 | 0.02 | 0.22 | 8.9 | 12.6 |
| P2- Ganganapalle | | | | | | | | | | | | | | |
| A | 0-15 | 32.1 | 20.5 | 47.4 | 7.1 | 0.23 | 17.7 | 30 | 30.9 | 6.3 | 0.12 | 0.32 | 37.6 | 30.5 |
| | Ẁ | 32.1 | 20.5 | 47.4 | 7.1 | 0.23 | 17.7 | 30 | 30.9 | 6.3 | 0.12 | 0.32 | 37.6 | 30.5 |
| P3-Lingala | | | | | | | | | | | | | | |
| Ap | 0-18 | 44.4 | 23.8 | 31.8 | 8.1 | 0.22 | 11.9 | 20 | 24.6 | 3.6 | 0.04 | 0.14 | 28.4 | 26.6 |
| Bw | 18-47 | 26.3 | 34.8 | 39.7 | 7.8 | 0.18 | 11.0 | 00 | 10.5 | 1.4 | 0.07 | 0.06 | 12.0 | 16.7 |
| | Ẁ | 33.23 | 30.59 | 36.67 | 7.91 | 0.20 | 11.34 | 7.66 | 15.90 | 2.24 | 0.06 | 0.09 | 18.28 | 20.49 |
| P4-Rachakuntapalle | | | | | | | | | | | | | | |
| Ap | 0-14 | 57.3 | 18.3 | 24.4 | 7.2 | 0.16 | 8.4 | 0 | 9.5 | 1.9 | 0.04 | 0.47 | 11.9 | 25.7 |
| Bw | 14-40 | 41.1 | 26.9 | 32.0 | 7.5 | 0.13 | 8.6 | 0 | 10.4 | 2.1 | 0.04 | 0.49 | 13.0 | 30.9 |
| | Ẁ | 46.8 | 23.9 | 29.3 | 7.4 | 0.1 | 8.5 | 0.0 | 10.1 | 2.0 | 0.0 | 0.5 | 12.6 | 29.1 |
| P5- Mupendranpalle | | | | | | | | | | | | | | |
| Ap | 0-20 | 29.5 | 29.0 | 41.5 | 8.4 | 0.38 | 10.7 | 40 | 48.3 | 15.4 | 0.22 | 1.00 | 69.9 | 29.1 |
| Bw | 20-40 | 22.7 | 31.4 | 45.9 | 8.5 | 0.23 | 8.5 | 30 | 44.6 | 13.7 | 0.40 | 0.42 | 59.1 | 31.1 |
| | Ẁ | 26.1 | 30.2 | 43.7 | 8.45 | 0.305 | 9.6 | 35 | 46.45 | 14.55 | 0.31 | 0.71 | 64.5 | 30.1 |
| P6- Tallalapalle | | | | | | | | | | | | | | |
| Ap | 0-19 | 40.9 | 19.6 | 39.5 | 8.5 | 0.19 | 9.7 | 70 | 56.5 | 8.7 | 0.32 | 1.33 | 66.9 | 28.3 |
| Bw | 19-40 | 24.7 | 20.2 | 55.1 | 8.4 | 0.15 | 6.6 | 60 | 53.6 | 8.1 | 0.17 | 0.92 | 32.8 | 30.7 |
| | Ẁ | 21.99 | 19.92 | 47.69 | 8.45 | 0.17 | 8.07 | 64.75 | 54.98 | 8.39 | 0.24 | 1.11 | 49.00 | 29.56 |
| P7-Santakovuru | | | | | | | | | | | | | | |
| Ap | 0-17 | 48.8 | 18.7 | 32.5 | 8.3 | 0.29 | 9.2 | 150 | 52.9 | 11.7 | 0.60 | 1.04 | 66.2 | 21.7 |
| Bw1 | 17-42 | 44.8 | 18.4 | 36.8 | 9.3 | 0.30 | 5.5 | 200 | 74.5 | 10.7 | 2.58 | 0.34 | 88.1 | 26.4 |
| Bw2 | 42-62 | 42.0 | 19.2 | 38.8 | 9.4 | 0.31 | 5.1 | 200 | 81.9 | 9.7 | 2.21 | 0.38 | 94.2 | 30.9 |
| | Ẁ | 44.99 | 18.74 | 36.27 | 9.06 | 0.30 | 6.39 | 186.29 | 70.96 | 10.65 | 1.92 | 0.54 | 84.06 | 26.56 |
| P8- Tatiredipalle | | | | | | | | | | | | | | |
| Ap | 0-15 | 14.9 | 27.8 | 57.3 | 8.3 | 0.22 | 11.2 | 40 | 43.4 | 12.6 | 0.14 | 1.83 | 58.0 | 54.5 |
| Bw1 | 15-33 | 11.5 | 23.9 | 64.6 | 8.4 | 0.19 | 10.5 | 40 | 42.8 | 15.1 | 0.17 | 0.68 | 58.8 | 58.8 |
| Bw2 | 33-55 | 9.9 | 24.3 | 65.8 | 8.3 | 0.13 | 8.9 | 40 | 46.2 | 16.2 | 0.21 | 0.61 | 63.2 | 58.8 |
| | Ẁ | 11.79 | 25.12 | 63.09 | 8.33 | 0.17 | 10.05 | 40.00 | 44.32 | 14.86 | 0.18 | 0.97 | 60.34 | 57.63 |
| P9- Cherlapalle | | | | | | | | | | | | | | |
| Ap | 0-20 | 32.5 | 21.2 | 46.3 | 9.1 | 0.34 | 6.02 | 110 | 56.6 | 9.2 | 7.85 | 0.76 | 74.4 | 33.2 |
| Bw1 | 20-45 | 22.6 | 20.0 | 57.4 | 8.8 | 1.95 | 4.7 | 80 | 37.1 | 6.7 | 29.76 | 0.75 | 74.3 | 37.9 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bw2 | 45-72 | 14.9 | 20.2 | 64.9 | 8.5 | 2.97 | 4.0 | 60 | 31.2 | 8.3 | 34.60 | 0.93 | 75.0 | 41.9 |
| Bw-3 | 72-105 | 10.5 | 19.0 | 70.5 | 8.7 | turbid | 3.6 | 70 | 38.7 | 9.4 | 31.77 | 1.04 | 80.9 | 43.0 |
| | Ẁ | 18.70 | 19.97 | 61.33 | 8.75 | 1.86 | 4.43 | 77.43 | 39.80 | 8.44 | 27.46 | 0.89 | 76.57 | 39.64 |
| P10-Kottalu | | | | | | | | | | | | | | |
| Ap | 0-18 | 79.9 | 10.3 | 14.8 | 8.6 | 0.16 | 3.6 | 20 | 21.7 | 1.7 | 0.15 | 0.26 | 2.08 | 7.6 |
| Bt 1 | 18-45 | 51.4 | 13.2 | 35.4 | 8.6 | 0.15 | 2.0 | 30. | 30.1 | 2.8 | 0.22 | 0.23 | 33.4 | 15.8 |
| Bt 2 | 45-76 | 50.9 | 13.7 | 35.4 | 8.5 | 0.17 | 1.4 | 30 | 28.3 | 4.8 | 0.21 | 0.21 | 33.5 | 16.8 |
| Bt 3 | 76-108 | 54.4 | 15.2 | 30.4 | 8.5 | 0.19 | 1.1 | 70 | 41.7 | 7.1 | 0.25 | 0.21 | 49.3 | 17.3 |
| Bt 4 | 108-142 | 54.2 | 51.1 | 30.7 | 8.6 | 0.20 | 0.1 | 80 | 36.6 | 6.7 | 0.24 | 0.20 | 43.7 | 15.7 |
| | Ẁ | 56.3 | 22.5 | 30.5 | 8.6 | 0.2 | 1.4 | 49.7 | 32.8 | 5.0 | 0.2 | 0.2 | 35.5 | 15.3 |
| P-11 Murarichintala | | | | | | | | | | | | | | |
| Ap | 0-20 | 71.1 | 14.2 | 14.7 | 8.6 | 0.25 | 4.7 | 10 | 12.5 | 1.8 | 0.01 | 0.58 | 14.9 | 7.2 |
| Bt 1 | 20-62 | 45.5 | 27.6 | 26.9 | 8.6 | 0.21 | 3.8 | 10 | 23.4 | 2.4 | 0.04 | 0.36 | 26.2 | 15.5 |
| Bt 2 | 62-98 | 55.4 | 19.1 | 25.5 | 8.5 | 0.16 | 3.5 | 20 | 22.6 | 2.2 | 0.05 | 0.38 | 25.2 | 12.6 |
| Bt 3 | 98-135 | 42.7 | 21.9 | 35.4 | 8.0 | 0.12 | 3.3 | 10 | 19.5 | 2.5 | 0.08 | 0.41 | 22.5 | 17.9 |
| Bt 4 | 135-155 | 19.9 | 31.6 | 48.5 | 7.7 | 0.15 | 3.1 | 10 | 26.3 | 3.0 | 0.40 | 0.46 | 30.2 | 23.2 |
| | Ẁ | 47.13 | 23.05 | 29.82 | 8.32 | 0.17 | 3.64 | 12.32 | 21.25 | 2.38 | 0.09 | 0.42 | 24.14 | 15.32 |
| P-12 Vemula | | | | | | | | | | | | | | |
| Ap | 0-20 | 32.8 | 24.9 | 42.3 | 8.6 | 0.20 | 7.0 | 160 | 36.1 | 14.0 | 0.54 | 0.57 | 111.2 | 30.1 |
| Bw 1 | 20-41 | 34.3 | 16.3 | 49.4 | 8.5 | 0.20 | 6.7 | 170 | 108.0 | 23.6 | 0.67 | 0.39 | 132.7 | 37.1 |
| Bw 2 | 41-72 | 28.2 | 25.7 | 46.1 | 8.5 | 0.19 | 3.9 | 220 | 99.1 | 19.8 | 0.70 | 0.30 | 119.9 | 30.4 |
| | Ẁ | 31.26 | 22.74 | 46.01 | 8.53 | 0.20 | 5.58 | 188.75 | 84.20 | 19.30 | 0.65 | 0.40 | 121.2 | 32.27 |
| P-13 Sunkesula. | | | | | | | | | | | | | | |
| Ap | 0-20 | 50.1 | 15.4 | 34.5 | 8.4 | 11.1 | 0.30 | 40 | 33.0 | 13.9 | 0.45 | 2.68 | 50.0 | 28.0 |
| Bw1 | 20-38 | 21.8 | 19.3 | 58.9 | 8.3 | 8.8 | 0.33 | 40 | 44.7 | 18.4 | 1.16 | 1.01 | 65.3 | 49.8 |
| Bw 2 | 38-70 | 15.5 | 19.2 | 65.3 | 8.0 | 8.1 | 0.55 | 50 | 48.0 | 17.5 | 1.29 | 0.53 | 67.3 | 51.9 |
| | Ẁ | 27.0 | 18.1 | 54.9 | 8.2 | 9.1 | 0.4 | 44.6 | 42.9 | 16.7 | 1.0 | 1.3 | 61.8 | 44.5 |
| P-14 Simhadripuram | | | | | | | | | | | | | | |
| Ap | 0-20 | 23.2 | 21.5 | 55.3 | 8.4 | 0.25 | 8.4 | 140 | 104.3 | 12.7 | 2.76 | 0.79 | 120.6 | 42.7 |
| BW 1 | 20-42 | 19.3 | 21.4 | 59.3 | 8.9 | 0.36 | 6.0 | 130 | 88.1 | 18.4 | 5.25 | 0.60 | 112.4 | 48.4 |
| 2Bss2 | 42-65 | 20.5 | 19.5 | 60.0 | 8.8 | 0.46 | 6.5 | 140 | 85.9 | 14.4 | 8.45 | 0.63 | 109.4 | 47.4 |
| 2Bss 3 | 65-92 | 13.7 | 24.5 | 61.8 | 9.0 | 0.58 | 6.2 | 120 | 79.0 | 16.0 | 9.46 | 0.69 | 105.2 | 52.1 |
| | Ẁ | 18.80 | 21.86 | 59.34 | 8.80 | 0.43 | 6.71 | 131.74 | 88.40 | 15.46 | 6.74 | 0.68 | 111.3 | 48.00 |
| P-15 Velpula | | | | | | | | | | | | | | |
| Ap | 0-20 | 60.7 | 13.5 | 25.8 | 8.3 | 0.14 | 3.3 | 50 | 34.8 | 9.5 | 0.30 | 0.57 | 45.2 | 13.0 |
| Bt 1 | 20-43 | 46.4 | 15.5 | 38.1 | 8.4 | 0.12 | 2.8 | 100 | 51.9 | 17.4 | 0.49 | 0.36 | 70.2 | 17.6 |
| Bt 2 | 43-68 | 46.9 | 16.9 | 36.2 | 8.4 | 0.20 | 1.6 | 120 | 50.4 | 17.1 | 0.87 | 0.36 | 68.7 | 18.1 |
| Bt 3 | 68-100 | 51.3 | 10.2 | 38.5 | 8.4 | 0.20 | 0.7 | 80 | 47.7 | 21.7 | 0.96 | 0.46 | 70.8 | 15.3 |
| Bt 4 | 100-138 | 47.4 | 15.0 | 37.6 | 8.5 | 0.20 | 1.0 | 90 | 43.2 | 22.8 | 0.78 | 0.42 | 67.2 | 16.8 |
| | Ẁ | 50.0 | 14.1 | 35.9 | 8.4 | 0.2 | 1.7 | 89.0 | 45.8 | 18.7 | 0.7 | 0.4 | 65.6 | 16.3 |
| P-16 Agraharam | | | | | | | | | | | | | | |
| Ap | 0-16 | 23.6 | 18.2 | 58.2 | 8.8 | 0.21 | 9.3 | 110 | 88.0 | 11.0 | 0.98 | 1.90 | 101.9 | 44.2 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bw 1 | 16-36 | 12.3 | 22.3 | 65.4 | 8.8 | 0.25 | 5.4 | 80 | 83.2 | 9.5 | 3.10 | 0.91 | 96.7 | 48.2 |
| Bw 2 | 36-71 | 16.1 | 22.3 | 61.6 | 8.9 | 0.32 | 4.8 | 90 | 72.1 | 7.8 | 5.39 | 0.84 | 86.1 | 47.6 |
| Bw 3 | 71-103 | 14.5 | 21.0 | 64.5 | 8.8 | 0.39 | 4.4 | 80 | 80.0 | 13.2 | 9.43 | 0.84 | 103.5 | 42.5 |
| Bw 4 | 103-120 | 24.6 | 23.1 | 52.3 | 8.8 | 0.40 | 4.2 | 50 | 58.7 | 7.7 | 4.76 | 0.66 | 71.8 | 37.1 |
| | Ẁ | 17.2 | 21.5 | 61.2 | 8.8 | 0.3 | 5.3 | 82.7 | 76.3 | 9.9 | 5.4 | 1.0 | 92.6 | 44.4 |
| P-17 Balapanur | | | | | | | | | | | | | | |
| Ap | 0-14 | 23.0 | 24.0 | 53.0 | 8.8 | 0.41 | 5.7 | 100 | 47.1 | 12.3 | 4.13 | 2.43 | 66.0 | 37.4 |
| Bw 1 | 14-50 | 20.3 | 22.8 | 56.9 | 8.6 | 0.58 | 2.9 | 90 | 43.8 | 12.1 | 7.27 | 1.51 | 64.7 | 36.8 |
| 2Bss1 | 50-98 | 10.6 | 24.4 | 65.0 | 8.5 | 0.56 | 2.9 | 70 | 55.8 | 9.5 | 5.71 | 1.10 | 72.1 | 48.7 |
| 2Bss2 | 98-118 | 5.3 | 26.5 | 68.2 | 8.2 | 1.05 | 2.8 | 60 | 49.8 | 9.5 | 5.61 | 1.18 | 66.1 | 46.8 |
| 2Bss 3 | 118-150 | 6.4 | 25.1 | 68.5 | 8.3 | 1.19 | 1.8 | 40 | 57.4 | 9.3 | 5.16 | 1.23 | 73.1 | 46.5 |
| | Ẁ | 12.48 | 24.41 | 63.11 | 8.47 | 0.75 | 2.91 | 69.87 | 51.65 | 10.34 | 5.81 | 1.36 | 69.17 | 44.07 |
| P-18 Parnapalle | | | | | | | | | | | | | | |
| Ap | 0-12 | 78.4 | 8.9 | 12.7 | 8.7 | 0.31 | 5.0 | 20 | 27.2 | 3.3 | 0.51 | 0.20 | 31.2 | 10.3 |
| C1 | 21-43 | 79.2 | 8.9 | 11.9 | 8.9 | 0.22 | 1.1 | 20 | 25.5 | 3.6 | 0.43 | 0.22 | 29.8 | 6.6 |
| C2 | 43-75 | 77.1 | 11.2 | 11.7 | 8.7 | 0.18 | 0.9 | 10 | 9.3 | 2.2 | 0.34 | 0.19 | 12.0 | 7.1 |
| C3 | 75-109 | 74.6 | 6.8 | 18.6 | 8.6 | 0.26 | 1.0 | 10 | 12.9 | 2.9 | 0.37 | 0.21 | 16.4 | 8.5 |
| C4 | 109-150 | 82.3 | 4.6 | 13.1 | 8.7 | 0.23 | 0.1 | 00 | 7.1 | 2.0 | 0.32 | 0.12 | 9.5 | 5.7 |
| | Ẁ | 73.74 | 6.90 | 12.18 | 7.60 | 0.20 | 1.00 | 8.93 | 12.29 | 2.33 | 0.33 | 0.16 | 15.11 | 6.41 |
| P-19 Gondipalle | | | | | | | | | | | | | | |
| Ap | 0-22 | 29.5 | 19.4 | 51.1 | 8.5 | 0.21 | 14.7 | 150 | 64.1 | 15.9 | 0.31 | 1.45 | 81.8 | 35.8 |
| Bw | 22-44 | 29.4 | 17.6 | 53.0 | 9.0 | 0.35 | 10.3 | 170 | 61.9 | 15.3 | 6.01 | 0.76 | 84.0 | 33.1 |
| | Ẁ | 29.45 | 18.5 | 52.05 | 8.75 | 0.28 | 12.5 | 160 | 63 | 15.6 | 3.16 | 1.11 | 82.9 | 34.45 |
| P-20 Goturu | | | | | | | | | | | | | | |
| Ap | 0-21 | 42.0 | 13.9 | 40.0 | 9.1 | 0.47 | 8.4 | 90 | 73.9 | 8.7 | 5.82 | 1.45 | 89.9 | 36.9 |
| Bw1 | 21-48 | 20.3 | 16.0 | 58.7 | 9.1 | 0.52 | 6.4 | 50 | 71.6 | 4.5 | 12.63 | 0.44 | 89.2 | 51.9 |
| Bw3 | 48-70 | 19.5 | 16.5 | 59.1 | 9.0 | 0.64 | 5.4 | 70 | 67.4 | 6.3 | 12.63 | 0.58 | 86.9 | 81.9 |
| | Ẁ | 26.56 | 15.53 | 53.22 | 9.07 | 0.54 | 6.69 | 68.29 | 70.97 | 6.33 | 10.59 | 0.79 | 88.69 | 56.83 |
| P-21 Pulivendle | | | | | | | | | | | | | | |
| Ap | 0-19 | 38.6 | 1.2 | 60.2 | 9.3 | 1.47 | 2.6 | 110 | 59.9 | 12.7 | 16.43 | 1.41 | 90.4 | 24.2 |
| Bw1 | 19-44 | 38.6 | 3.6 | 57.8 | 9.1 | 6.73 | 2.5 | 90 | 48.6 | 1.2 | 42.93 | 0.79 | 102.5 | 23.2 |
| Bw2 | 44-76 | 34.8 | 1.6 | 63.6 | 9.5 | turbit | 1.0 | 70 | 11.6 | 6.8 | 37.65 | 0.74 | 59.8 | 32.6 |
| Bw3 | 76-110 | 41.4 | 2.4 | 56.2 | 9.1 | turbit | 0.8 | 90 | 41.5 | 6.5 | 44.71 | 0.61 | 93.3 | 26.7 |
| Bw4 | 110-135 | 59.6 | 1.3 | 39.1 | 9.5 | turbit | 0.1 | 70 | 31.3 | 5.2 | 24.38 | 0.45 | 61.3 | 18.8 |
| | Ẁ | 42.29 | 2.06 | 55.65 | 9.30 | | 1.29 | 84.37 | 36.43 | 6.22 | 34.96 | 0.76 | 80.73 | 25.64 |
| P-22 Pernapadu | | | | | | | | | | | | | | |
| Ap | 0-22 | 33.4 | 19.3 | 47.3 | 8.4 | 0.19 | 6.3 | 130 | 86.4 | 3.7 | 0.15 | 0.97 | 91.2 | 45.0 |
| Bw1 | 22-54 | 31.6 | 15.0 | 53.4 | 8.4 | 0.18 | 6.3 | 140 | 86.7 | 4.5 | 0.24 | 0.46 | 91.9 | 48.5 |
| Bw2 | 54-80 | 23.0 | 21.2 | 55.8 | 8.4 | 0.20 | 6.8 | 140 | 85.1 | 5.3 | 0.35 | 0.50 | 91.3 | 50.6 |
| Bw3 | 80-103 | 22.4 | 18.8 | 58.8 | 8.5 | 0.15 | 6.3 | 150 | 95.8 | 5.0 | 0.76 | 0.52 | 102.1 | 52.7 |
| | Ẁ | 27.76 | 18.33 | 53.91 | 8.42 | 0.18 | 6.43 | 140.10 | 88.26 | 4.64 | 0.36 | 0.59 | 93.88 | 49.22 |
| P-23 Agadur | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-19 | 32.6 | 19.8 | 47.6 | 8.3 | 0.19 | 5.4 | 100 | 75.3 | 7.1 | 0.2 | 1.01 | 83.6 | 42.6 |
| Bw1 | 19-49 | 16.8 | 23.4 | 59.8 | 8.6 | 0.17 | 4.2 | 800 | 77.9 | 9.4 | 1.29 | 0.62 | 89.2 | 53.1 |
| Bw2 | 49-91 | 15.1 | 22.0 | 62.9 | 8.8 | 0.211 | 4.2 | 80 | 78.0 | 10.0 | 2.86 | 0.56 | 91.4 | 57.0 |
| Bw3 | 91-125 | 14.0 | 21.8 | 64.2 | 8.9 | 0.27 | 4.0 | 70 | 74.7 | 12.4 | 3.33 | 0.60 | 91.0 | 59.1 |
| Bw4 | 125-145 | 14.2 | 22.9 | 62.9 | 8.8 | 0.28 | 3.9 | 70 | 77.0 | 12.3 | 3.50 | 0.67 | 93.5 | 49.7 |
| | Ẁ | 17.36 | 22.08 | 60.56 | 8.72 | 0.22 | 4.27 | 227.86 | 76.71 | 10.38 | 2.39 | 0.66 | 90.12 | 53.79 |
| P-24 Tondur | | | | | | | | | | | | | | |
| Ap | 0-20 | 29.8 | 22.3 | 47.9 | 9.1 | turbit | 5.8 | 100 | 88.2 | 14.7 | 1.93 | 0.42 | 105.3 | 41.9 |
| Bw1 | 20-47 | 23.6 | 15.8 | 60.6 | 9.4 | turbit | 4.3 | 110 | 83.2 | 9.5 | 6.50 | 0.24 | 99.4 | 47.4 |
| Bw2 | 47-74 | 18.9 | 19.0 | 62.1 | 9.5 | turbit | 3.6 | 120 | 72.3 | 7.9 | 9.64 | 0.28 | 90.1 | 48.2 |
| Bw3 | 74-105 | 18.0 | 17.5 | 64.5 | 9.4 | turbit | 2.5 | 100 | 80.2 | 13.2 | 11.49 | 0.30 | 105.2 | 49.4 |
| Bw4 | 105-152 | 9.2 | 20.8 | 70.0 | 9.3 | turbit | 1.1 | 120 | 58.2 | 7.7 | 13.88 | 0.67 | 81.1 | 50.3 |
| | Ẁ | 17.99 | 19.12 | 62.90 | 9.35 | - | 3.02 | 111.51 | 73.58 | 10.10 | 9.76 | 0.42 | 94.05 | 48.12 |
| P-25 Bhadrampalle | | | | | | | | | | | | | | |
| Ap | 0-12 | 45.0 | 5.9 | 49.1 | 8.7 | 0.33 | 4.1 | 100 | 45.7 | 6.7 | 2.4 | 0.6 | 55.4 | 27.3 |
| Bw | 12-36 | 31.6 | 20.8 | 47.6 | 8.9 | 0.67 | 3.3 | 90 | 44.5 | 9.7 | 10.8 | 0.6 | 65.6 | 40.1 |
| Bss1 | 36-63 | 26.4 | 18.5 | 55.1 | 8.6 | 3.79 | 2.4 | 130 | 74.8 | 16.6 | 19.8 | 0.7 | 111.9 | 45.9 |
| Bss2 | 63-85 | 25.0 | 18.9 | 56.1 | 8.6 | 3.77 | 1.6 | 140 | 75.5 | 17.2 | 21.8 | 0.7 | 115.2 | 46.4 |
| Bss3 | 85-107 | 20.7 | 18.2 | 61.1 | 8.6 | 3.60 | 1.7 | 110 | 86.1 | 18.4 | 23.8 | 0.8 | 129.1 | 48.9 |
| Bss4 | 107-150 | 14.4 | 18.2 | 67.4 | 9.0 | 3.70 | 1.0 | 100 | 55.6 | 22.4 | 22.3 | 0.9 | 101.1 | 50.6 |
| | Ẁ | 24.2 | 17.8 | 58.0 | 8.8 | 3.0 | 2.1 | 111.1 | 63.9 | 16.7 | 18.6 | 0.7 | 99.9 | 45.3 |

**Table.22.** Descriptive statistics of soil properties with respect to geology

| Geology | Descriptive statistics of soil properties with respect to geology | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quartzite (n= 4) | | sand | silt | clay | pH | EC(dSm-1) | organic carbon (g/kg) | $CaCO_3$(g/kg) | CEC(cmol/kg) | PBS | ESP | Depth(cm) |
| | mean | 51.48 | 16.73 | 31.80 | 7.68 | 0.19 | 13.58 | 20.00 | 23.93 | 79.25 | 0.22 | 30.75 |
| | sd | 17.17 | 8.59 | 11.04 | 0.61 | 0.04 | 4.24 | 10.00 | 7.64 | 26.04 | 0.12 | 15.20 |
| | CV | 33.36 | 51.34 | 34.70 | 7.99 | 23.60 | 31.26 | 50.00 | 31.93 | 32.86 | 54.31 | 49.42 |
| Shale (n=21) | mean | 40.73 | 17.57 | 41.50 | 8.01 | 0.32 | 7.26 | 87.62 | 30.52 | 100.00 | 7.61 | 97.81 |
| | sd | 17.73 | 6.99 | 14.37 | 0.20 | 0.28 | 3.13 | 46.57 | 13.12 | 0.00 | 15.03 | 45.48 |
| | CV | 43.54 | 39.77 | 34.62 | 2.47 | 85.94 | 43.19 | 53.15 | 43.00 | 0.00 | 197.60 | 46.50 |

**Table 23**. One way ANOVA analytical data to explain variability of soil propertie

| Source of variation | Sand (%) | Silt (%) | Clay (%) | pH | EC(dSm-1) | OC (g/kg) | CaCO3 (g/kg) | CEC (cmol/kg) | ESP | Depth (cm) | BD ($Mgm^{-3}$) | Erodability index(K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A horizon | | | | | | | | | | | | |
| Mean ±SD | 42.5± 17.7 | 17.6± 7.1 | 39.6± 14.2 | 8.4± 0.5 | 0.30± 0.26 | 8.36± 4.0 | 74.00± 51.8 | 29.3± 12.5 | 4.92± 17.9 | 87.08± 48.81 | 1.27± 0.09 | 0.2± 0.06 |
| CV% | 41.6 | 40.7 | 35.9 | 6.0 | 86.5 | 48.5 | 70.1 | 42.7 | 363.9 | 56.05 | 7.05 | 30.48 |
| B horizon | | | | | | | | | | | | |
| Mean ±SD | 22.14 | 19.61 | 58.0 | 8.76 | 1.05 | 4.80 | 88.94 | 44.19 | 24.4±102.4 | | | |
| CV% | 50.18 | 33.29 | 15.5 | 5.07 | 141.4 | 56.72 | 50.19 | 26.98 | 419.5 | | | |
| F value (Between the horizons) | 27.44** | 0.77 | 36.75** | 5.49* | 5.31* | 18.89** | 0.93 | 31.03** | 6.05 | | | |
| p | 0.01 | - | 0.01 | 0.05 | 0.05 | 0.01 | - | 0.01 | 0.05 | | | |

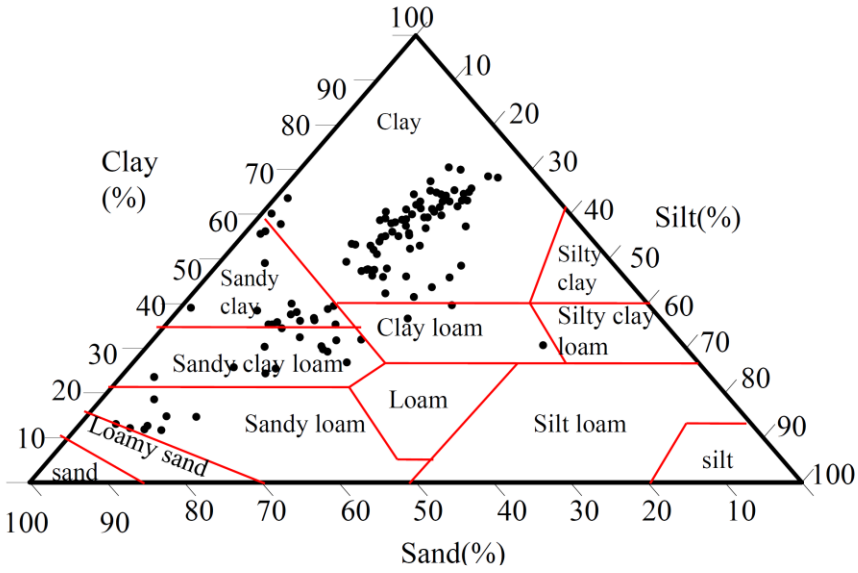



**Fig.18.**Ternary diagram for soil textural class in pulivendula region

### 9.3. Soil organic and inorganic carbon stocks

The study further shows that these soils have mean SOC of 52.47 ± 17.55Mg/ha with CV of 33.46% whereas SIC (Soil inorganic carbon) stock has a mean of 134.52 ± 106.71Mg/ha with high variability (CV of 79.32%). Considering only the soil subgroups under cultivated land use, the total SOC stock above the mean value of 52.47±17.55 Mg/ha followed this trend:. Pernapadu (80.56Mg/ha) < Sunkesula (77.27Mg/ha) < Agadur (73.21Mg/ha) < Simhadripuram (72.43Mg/ha). These soils are mostly occurring in interhill basins and colluvio-alluvial sectors of Pulivendula (Table 24). The SIC stock is relatively more to that of SOC and recorded a maximum of 334.74 Mg/ha in Tondur series (Tdr) and almost nil in Rachkuntapalle series. The mean SIC stock is 134.52 ± 106.71 Mg/ha with CV of 79.32 per cent. Under semiarid conditions of Kadapa basin and lithology of dolomite and calcium carbonate intercalation in shale beds contributed more to $CaCO_3$ contents in soil profiles with increasing depth trends. The SQR is positively and significantly related with SIC stocks with correlation coefficient of 0.5 and t value of 2.75 at 23 degree freedom and p of 0.001 levels. The SOC stock may affect cycling of nutrients, retention of pesticides and water, and soil structure but not plant water use efficiency, crop emergence, N mineralization and immobilization rates, and rooting volume for crop production (Karlen, *et al*., 1997). The changes in SOC content have been

related to a biological soil quality index (SQI) (Gardi, *et al.,* 2002) and serves as a. sensitive basic soil indicator in soils under semi arid regions. Thus, not the single indicator SOC but SQI has been proposed to synthesize soil attributes such as SOM content and stock, bulk density(ρb), respiration rate, soil depth, electrical conductivity, and pH to inform on appropriate management or policy interventions based on an enhanced understanding of soil processes (Obade and Lal, 2016). These soils have mean clay content of 39.64 ± 14.25 % in AP horizons but showed gradual increase up to 58.06 ± 15.52 % in Bss horizons and 36.72 ± 7.32 per cent in clay enriched argillic horizons. The texture is sandy loam to clay with dominates over silt being the least. It is attributed this to the nature of the parent material and mineralogy of the soils in the region (Rajendra Hegde, *et al*., 2018). Even though, soil bulk density is not directly vital to mineralization and stabilization of SOC however, it can define the amount of mineral materials and/or surfaces that can interact with SOC, in addition to the aeration status of the soil which influences rate of C mineralization (Hoyle, *et al*., 2011; Hobley, *et al*., 2015). The mean SOC to SIC ratio is 1.92±3.87 but CV more than 200 per cent. The ratio less than 0.5 in majority of soils but more than 0.5 in Parnapalle (18), Tatireddipalle (6) and Sunkesula (13) but exceeding in soils of Kanampalle (1) and Lingala (3) on hills and ridges.

**Table 24.** Soil series wise SOC and SIC stocks along with their ratio

| soil series /soil taxonomy | Stock (Mg/ha) | | |
|---|---|---|---|
| | Stock (Mg/ha) | | |
| | SOC | SIC | SOC/SIC |
| **1.Kanampalli(Kpl)- Lithic Ustorthents** | 46.89 | 2.93 | 16.00 |
| **2.Ganganapalle(Ggp)- Lithic Ustorthents** | 31.06 | 6.36 | 4.88 |
| **3.Lingala(Lgl)-Lithic Haplustepts** | 63.36 | 5.40 | 11.73 |
| **4.Rachakuntapalle(Rkp) -Lithic Haplustepts** | 43.36 | 0.00 | - |
| **5.Mupendranapalle (Mpl) -Lithic Haplustepts** | 44.98 | 22.46 | 2.00 |
| **6.Tallalapalle(Tlp)-Lithic Haplustepts** | 39.68 | 44.47 | 0.89 |
| **7.Santhakovur(Skv) -Typic Haplustepts** | 50.92 | 199.69 | 0.25 |
| **8.Tatireddipalli(Trp) -Vertic Haplustepts** | 61.95 | 37.89 | 1.63 |
| **9.Cherlapalle(Cpl)-Vertic Halaquepts** | 55.92 | 154.22 | 0.36 |
| **10.Kottalu(Ktl)- Typic Rhodustalfs** | 27.68 | 132.89 | 0.21 |
| **11.Murarichintala(Mct)- Typic Paleustalfs** | 74.40 | 33.89 | 2.20 |
| **12.Vemula(Vml)-Calcic Haplustalfs** | 49.37 | 243.03 | 0.20 |
| **13.Sunkesula(Skl)-Vertic Haplustepts** | 77.27 | 54.44 | 1.42 |
| **14.Simhadripuram(Spm)- Sodic Haplusterts** | 72.43 | 220.73 | 0.33 |
| **15.Velpula(Vpl)- -Typic Haplustalfs** | 30.97 | 232.48 | 0.13 |
| **16.Agraharam(Ahm)- -Sodic Haplusterts** | 74.89 | 185.90 | 0.40 |
| **17.Balapanur(Bpr)-Sodic Haplusterts** | 51.02 | 203.27 | 0.25 |
| **18.Parnapalle(Prp)-Typic Ustorthents** | 28.52 | 26.99 | 1.06 |
| **19.Gondipalle(Gpl) -Lithic Haplustepts** | 65.39 | 113.85 | 0.57 |
| **20.Goturu(Gtr)-Typic Haplustepts** | 58.11 | 86.14 | 0.67 |
| **21.Pulivendula(Pvd)- Aeric Halaquepts** | 22.87 | 234.37 | 0.10 |
| **22.Pernapadu(Ppd)- Vertic Haplustepts** | 80.56 | 262.32 | 0.31 |
| **23.Agadur(Agd)- Vertic Haplustepts** | 73.21 | 217.53 | 0.34 |
| **24.Tondur(Tdr)- Vertic Haplustepts** | 55.28 | 334.74 | 0.17 |
| **25.Bhadrampalle(Bpl)- Sodic Haplusterts** | 31.87 | 307.23 | 0.10 |
| **Mean ±Sd** | 52.47±17.56 | 134.52±106.71 | 1.92±3.87 |
| **CV(%)** | 33.46 | 79.32 | 201.35 |

### 9.4. Classification of soils

Classification is based on morphological properties observed in the field supported by laboratory investigations (Table 25). The soils identified and mapped in the study area fall under four orders (Alfisols, Entisols, Inceptisols and Vertisols), five suborders (Ustalfs, Orthents, Aquepts, Ustepts and Usterts) seven Great groups (Paleustalfs, Rhodustalfs, Haplustalfs , Ustorthents, Halaquepts, Haplustepts and Haplusterts), twelve subgroups, eighteen families and twenty five series. Alfisols cover about 6367 ha (4.8 %), Entisols about 5477 ha (4.1 %), Inceptisols 47342 ha (35.5 %) and Vertisols 31118 ha (23.3 %).

Six soil series possessing argillic horizon namely Murarichintala, Kottalu, Vemula, Rachakuntapalle, Lingala and Velupula are classified in the order of Alfisols under a distinct wet and dry seasons (ustic moisture regime) and then the ratio of clay in B horizon is 1.2 times more than eluvial A horizons. These soils differ in particle size from fine loamy (P10,P11), clay skeletal (Vemula,P12), Loamy skeletal (P4), clayey skeletal (P3) and fine (Velupula, P15). At great group level, these series are classified under Paleustalfs, Rhodustalfs and Haplustalfs but considering lithic contact within 50cm (P3/P4), calcic(P12) and Typic in others. The seven series belongs to vertisols in colluvio-alluvial sectors have high sodium enriched slickensided horizons and qualified to classify as Sodic Haplusterts. Nine soil series are classified under Haplustepts at great group level but classified to three subgroups such as viz., Lithic, Typic and Vertic. Three soil series on hills/ridges classified in two subgroups such as Lithic/Typic Ustorthents.

**Table 25**. Soil Classification-Pulivendla area

| Order | Suborder | Great group | Subgroup | Family | Series |
|---|---|---|---|---|---|
| 1. Alfisols | Ustalfs | Paleustalfs | Typic Paleustalfs | Fine-loamy, mixed | Murarichintala |
| | | Rhodustalfs | Typic Rhodustalfs | Fine-loamy, mixed, calcareous | Kottalu |
| | | Haplustalfs | Calcic Haplustalfs | Clayey-skeletal, calcareous,mixed | Vemula |
| | | | Lithic Haplustalfs | Loamy-skeletal, mixed | Rachakuntapalle |
| | | | | Clayey mixed | Lingala |
| | | | Typic Haplustalfs | Fine , mixed, | Velupula |
| 2. Entisols | Orthents | Ustorthents | Lithic Ustorthents | Loamy skeletal | Kanampalle |
| | | | | Clayey, mixed | Ganganapalle |
| | | | Typic Ustorthents | Coarse-loamy, mixed | Parnapalle |
| 3 Inceptisols | Ustepts | Haplustepts | Lithic Halustepts | Clayey-skeletal, calcareous,mixed | Mupendranpalle |
| | | | | | Gondipalle |
| | | | Vertic Haplustepts | Very-fine, calcareous,smectitic | Sunkesula |
| | | | | | Tatireddipalle |
| | | | | | Tondur |
| | | | | | Agadur |
| | | | | Fine, calcareous, smectitic | Pernapadu |
| | | | Typic Haplustepts | Clayey-skeletal,calcareous,mixed | Santakovuru |
| | | | | Fine, mixed, calcareous | Goturu |
| 4. Vertisols | Usterts | Haplusterts | Sodic Haplusterts | Very fine, calcareous, smectitic | Simhadripuram |
| | | | | | Balapanur |
| | | | | | Bhadrampalle |
| | | | | | Agraharam |
| | | | | | Cherlapalle |
| | | | | | Pulivendula Vempalle |

## 10. Soil mapping

Twenty five soil series were identified and prepared soil map of 43 mapping units (Fig.19). Broadly the soils on quartzitic hills and ridges have eight mapping units mostly associated with rock outcrops, very shallow, somewhat excessively drained, moderately alkaline, sandy loam to clay loam textured soils and covers 54812hectare (42.62% of total area, Table 26). 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 28542ha (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).

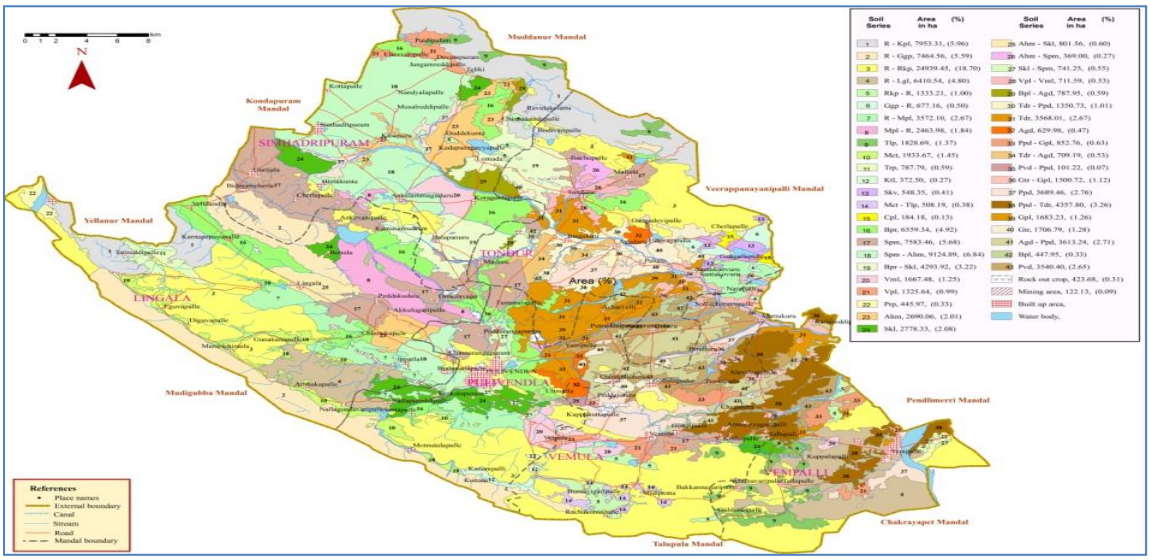



**Fig.19**. Soil map of Pulivendula tehsil, Kadapa district

The soils identified and mapped as associations of soil series in diverse landforms (map units) are described below in terms of their nature, characteristics, and distribution in various sections of the Pulivendla region (Fig 19). Here are brief descriptions of the 43 soil mapping units found in each landform.

**4.1 Hills and ridges soils**

**1. Rockout crops –Kanampalli association**

Rock outcrops with moderately steeply sloping to moderately sloping red gravelly loam soils that are somewhat excessively drained, severely eroded on hill and ridge slopes. This map unit is found on the moderately steeply to moderately sloping side slopes of hills and ridges. It has an area of 7953 ha (5.97 percent) in the mandals of Lingala, Tondur, and Simhadripuram. Kanampalli soils cover 30% of the area, while rocky and bouldary outcrops cover 70%. There is no soil cover on the rock outcrops, which are bouldary and rocky. Kanampalli soils are very shallow, slightly overly drained red soils with moderately alkaline gravelly sandy clay loam.

**2. Rock outcrops – Ganganapalle association:**

Moderately steeply sloping to slightly sloping, rock outcrops with non-gravelly red clay soils that are somewhat excessively drained, severely eroded on slopes of hills and ridges.This map unit occurs on moderately steeply sloping to moderately sloping side slopes of hills and ridges. It covers an area of 7464 ha (5.6%) in Lingala, Pulivendla, and Simhadripuram mandals. Rocky and bouldery outcrops cover about 70 percent area and Ganganapalle soils with 30 percent. The rock outcrops are bouldery and rocky with no soilcover.Ganganapalle soils are very shallow, somewhat excessively drained red soils with neutral, non-gravelly clay. Slope ranges from 5 to 25 percent. Most of these areas in this unit are beneath scrub forest, wildlife habitat, or pasture. Afforestation with suitable species and safety from a wildfire would increase timber yields.

**3. Rock outcrops-Rachukuntapalle association:**

Moderately steeply sloping to moderately sloping, rock outcrops with non-gravelly red loam soils that are somewhat excessively drained, severely eroded on slopes of hills and ridges.This map unit occurs on moderately steeply sloping to moderately sloping side slopes of hills and ridges. It covers an area of 24,939 ha (18.7%) in Lingala,

Pulivendla, Tondur, Simhadripuram, Vemula, and Vempalli mandals. Rocky and bouldery outcrops cover about 70 percent area and Rachakuntapalle soils with 30 percent. The rock outcrops are bouldery and rocky with no soil cover.Rachakuntapalle soils are very shallow, somewhat excessively drained red soils with neutral, gravelly sandy clay loam surface and slightly alkaline clay loam sub-soils. Sub-soil layers have 60-85 percent quartz gravel. Slope ranges from 5 to 25 percent.Most of these areas in this unit are under scrub forest, wildlife habitat, or pasture. Afforestation with suitable species and protection from a wildfire would increase timber yields.

**4. Rock outcrops –Lingala association:**

Gently to moderately sloping rock outcrops with gravelly red clay soils that are somewhat excessively drained, severely eroded on hill and ridge slopes. This map unit is found on the steeply to moderately sloping side slopes of hills and ridges. It covers an area of 6410 ha (4.8 percent) in the mandals of Lingala, Pulivendla, Vemula, and Vempalli. Lingala soils cover 30% of the area, while rocky and bouldary outcrops cover 70%.There is no soil cover on the rock outcrops, which are bouldary and rocky.The soils of Lingala are shallow (50 cm). slightly overdrained red soils with a moderately alkaline gravelly clay loam surface and a slightly alkaline base. Subsoil layers contain 50-80% quartz gravel. The slope ranges from 5% to 15%.The majority of these units' land is covered by scrub forest, wild life habitat, or pasture. Afforestation with suitable species and fire protection would increase timber yield.

**5. Rachakuntapalle-Rock outcrops association:**

Gravelly red loam soils that are moderately steeply sloping to moderately sloping, associated with rock outcrops, and severely eroded on hill and ridge slopes. This map unit is found on the moderately steeply to moderately sloping side slopes of hills and ridges. It covers an area of 1333 ha (1.0 percent) in the mandals of Simhadripuram, Tondur, Vemula, and Vempalli. Rachakuntapalle soils cover approximately 70% of the area, with rock outcrops accounting for the remaining 30%. Rachakuntepalle soils are similar to Unit 3 soils.There is no soil cover on the rock outcrops, which are bouldary, stony, and rocky.The majority of the land is covered in scrub forest.

**6. Ganganapalle-Rock outcrops association:**

Non-gravelly red clay soils that are moderately steeply sloping to moderately sloping, associated with rock outcrops, and severely eroded on hill and ridge slopes. This map unit is found on the moderately steeply to moderately sloping side slopes of hills and ridges. It encompasses 677 ha (0.5 percent) of Tondur and Vemula mandals. The Ganganapalle soils cover approximately 60% of the area, while rock outcrops cover 40%. Ganganapalle soils are similar to Unit 2 soils.There is no soil cover on the rock outcrops, which are bouldary, stony, and rocky.The majority of the land is covered in scrub forest.

**7. Rock outcrops- Mupendranpalle association:**

On the slopes of hills and ridges, gently sloping to moderately sloping rock outcrops with gravelly red clay soils that are somewhat excessively drained, severely eroded. This map unit is found on the gently to moderately sloping side slopes of hills and ridges. It encompasses 3572 ha (2.7 percent) of the Lingala and Pulivendla mandals. The rockout crops cover approximately 75% of the area, while Mupendranpalle soils cover 25%.The rockout crops are rocky and bouldary, with no soil cover.Mupendranpalle soils are shallow, well-drained red soils with a moderately alkaline gravelly clay surface and a strongly alkaline clay subsurface. Subsoil layers contain 50 to 70% quartz gravel. The slope ranges from 3% to 10%. These soils have been heavily eroded.The majority of the areas in this unit are covered by degraded scrub forest and pasture. Afforestation and controlled grazing would help to increase timber as well as pasture yield while decreasing erosion. A portion of these areas are cultivated to groundnut and redgram.

**8**. **Mupendranpalle –Rock outcrops association**:

Well-drained gravelly red clay soils that are gently sloping to moderately sloping, associated with rock outcrops, and severely eroded on hills and ridges. This map unit is found on the gently to moderately sloping side slopes of hills and ridges. It covers an area of 2464 ha (1.8 percent) in the mandals of Lingala, Pulivendla, and Simhadripuram. Mupendrapalle soils cover approximately 60% of the land area, while rock outcrops cover approximately 40%.Mupendranpalle soils are similar to Unit 7 soils.Rockout crops have no soil cover and are bouldary, stony, and rocky.These areas are cultivated with redgram and groundnut crops, as well as scrub forest and grasses.

## 4.2 Soils of interhill basin

### 9. Tallalapalle soils:

Inter-hilly basins have very gently to gently sloping, shallow gravelly clay red soils that are well drained and slightly eroded.This map unit occurs in a very gently to gently sloping interhilly basin. It covers an area of 1829 ha (1.4%) in Simhadripuram, Tondur, Vemula and Vempalli mandals.Tallalapalle soils are shallow, well-drained, strongly alkaline gravelly clayloam surface soils and moderately alkaline gravely clay sub-soil layers. The entire profile has 50-70 per cent gravel. The slope ranges from 1% to 5%.Most of the area is under cultivation for rainfed crops and at places irrigated by borewells. Important crops grown are lemon, bengalgram and redgram.

### 10. Murarichintala soils:

Very gently sloping to gently sloping, very deep, non-gravely red soils that are well drained and slightly eroded are found in inter-hilly basins.This map unit is found in an interhilly basin that is very gently sloping to gently sloping. It covers an area of 1934 ha (1.5 percent) in the mandals of Lingala and Pulivendla.Murarichintala soils are deep, well-drained, strongly alkaline sandy loam surface soils, as well as slightly to strongly alkaline sandy clay loams, clay loams, and clay sub-soils. The gradient varies between 1% and 5%. The majority of the land is under cultivation for rainfed crops, with some areas irrigated by borewells. Banana, watermelon, jowar, groundnut, and redgram are among the important crops grown.

### 11.Tatireddipalle soils:

There are very gently sloping, moderately shallow black soils that are moderately well drained and slightly eroded in the inter-hilly basin.This map unit is located in a gently sloping inter-hilly basin. It takes up 788 ha (0.6 percent) of the land in Lingala mandal.Tatireddipalle soils are calcareous, black clay soils with shrink-swell potential which are moderately shallow. They have surface soils that are moderately alkaline clay and subsoils that are moderately alkaline clayey. The slope varies between 1-3 percent. The majority of the land is under cultivation for both rainfed and irrigated crops. Acid lime, castor, and sunflower are important crops grown.

**12. Kottalu soils:**

In inter-hilly basins, very gently sloping, deep, non-gravelly calcareous red soils that are well drained and slightly eroded.This map unit is located in a gently sloping inter-hilly basin. It covers 372 ha (0.3 percent) of the Pulivendla and Vemula andals. Kottalu soils are deep, well-drained, strongly alkaline non-gravelly sandy loam surface soils with sandy clay loam to sandy clay calcareous subsoil layers. The slopes vary between 1% and 3% and are slightly eroded. The majority of the land is under cultivation for both rainfed and irrigated crops. Groundnut, redgram, onion, bengalgram, and castor are important crops grown.

**13. Santakovur soils:**

Very gently sloping, moderately shallow calcareous red soils that are slightly eroded.This map unit is found in a gently sloping interhilly basin. It covers 548 ha (0.4 percent) of Tondur Mandal.Santakovur soils are moderately shallow, well-drained gravelly clayloam surface soils with moderately alkaline gravelly clayloam subsoils. The slopes vary between 1% and 3% and are slightly eroded. The majority of the land is under cultivation for rainfed crops. Under irrigation, important crops such as castor, sunflower, and acid lime are grown.

**14. Murarichintala-Tallalapalle association:**

Very gently to gently sloping, very deep, non-gravelly red soils that are well drained coexist with very gently to gently sloping, shallow, gravelly clay soils that are well drained and slightly eroded in inter hilly basins.This map unit is found in a gently sloping interhilly basin. It covers 508 ha (0.4 percent) of Vemula mandal.The Murarichintala series covers approximately 70% of the area, while the Tallalapalle soils cover approximately 30% of the area.The soils of Murarichintala are similar to those of Unit 10.Tallalapalle soils are similar to unit 9 soils.

Rainfed and irrigated crops are grown on a large scale. The most important crops grown are jowar, groundnut, redgram, bengalgram, banana. Acid lime and sweet oranges are under irrigation.

**15. Cherlapalle soils:**

In the inter-hilly basin, very gently sloping, deep-cracking clayey soils that are moderately well drained but slightly eroded.This map unit is found in inter-hilly basins with very gentle slopes. It covers 184 ha (0.1 percent) of Tondur mandal. Cherlapalle soils are calcareous black clay soils with shrink-swell potential that are deep and moderately well drained. They have highly alkaline clay surface soils and highly alkaline

clay subsoil. The slopes vary between 1% and 3% and are slightly eroded.The majority of these areas are cultivated with rain-fed crops. Crops grown include bengalgram, redgram, groundnuts, and coriander.

### 4.3 Soils of Gently sloping middle sector

**16. Balapanur soils:**

In the gently sloping middle sector, the soils are nearly level to very gently sloping, very deep, cracking clayey soils that are moderately well drained and slightly eroded.This map unit is found in the middle sector, which is nearly level to gently sloping. It covers an area of 6,559ha (4.9 percent) in the mandals of Lingala, Simhadripuram, Tondur, and Pulivendla. Balapanur soils are calcareous black soils with shrink-swell potential that are very deep and moderately well drained. They have strongly alkaline clay surface soils and subsoils that are strongly to moderately alkaline clay. The slopes are slightly eroded and range from 0% to 3 percent.The majority of these areas are cultivated for rain-fed crops. Cotton and castor oil are important crops.

**17. Simhadripuram Soils:**

Moderately deep, cracking clayey soils that are moderately well drianed and slightly eroded on a gently sloping middle sector.This map unit appears in the middle sector, which is nearly level to gently sloping. It covers an area of 7583 ha (5.7 percent) in the mandals of Simhadripuram, Tondur, Lingala, Pulivendla, and Vemula. Simhadripuram soils are calcareous black soils with shrink-swell potential that are moderately deep and well drained. They have surface soils that are moderately alkaline clay and subsoils that are strongly alkaline clay. The slope ranges from 0% to 3% and is slightly eroded. The majority of these areas are cultivated with rainfed crops. Under irrigation, important crops include bengalgram, redgram, coriander, jowar, sunflower, and sweet orange.

**8. Simhadripuram-Agraharam association:**

Clay soils that are nearly level to very gently sloping, moderately deep to deep, cracking, and moderately well drained in the middle sections but slightly eroded. This map unit appears in middle sectors that are nearly level to very gently sloping. It covers an area of 9,125 ha (6.8 percent) in the mandals of Simhadripuram, Lingala, and Pulivendla. Simhadripuram soils cover roughly 70% of the area, while Agraharam soils cover 30%.

The soils of Simhadripuram are similar to those of Unit 17. Agraharam soils are calcareous, cracking clay black soils with shrink-swell potential that are deep and moderately well drained. They have a highly alkaline clay surface as well as subsoil layers. The slope ranges from 0% to 3% and is slightly eroded. The majority of this unit's land is under cultivation for rainfed crops. Under irrigation, important crops include bengalgram, redgram, coriander, jowar, sunflower, and sweet orange.

**19. Balapanur-Sunkesula Association:**

Cracking clay black soils that are moderately well drained and slightly eroded on the middle sector that are nearly level to very gently sloping, very deep and moderately shallow.

This map unit appears in middle sectors that are nearly level to very gently sloping. It covers an area of 4,294 ha (3.2 percent) in the mandals of Lingala, Tondur, and Simhadripuram. Balapanur soils cover roughly 70% of the area, with Sunkesela soils accounting for the remaining 30%. Soils in Balapanur are similar to soils in Unit 16. Sunkesela soils are calcareous cracking clay black soils with shrink-swell potential that are moderately shallow and moderately well drained. They have a surface that is moderately alkaline sandy clay loam and subsoil layers that are moderately alkaline clayey. The slope is between 0 and 3 percent, and the soils are slightly eroded. The majority of the land is under cultivation for rainfed crops. Under irrigation, important crops grown include groundnut, redgram, coriander, sunflower, cotton, castor, til, and sweet oranges as well as banana.

**20. Vemula soils**:

Calcareous red gravelly clay soils with a gentle sloping profile that is well drained but slightly eroded in the middle sectors. This map unit is found on gently sloping uplands. It is found in 1,667 ha (1.2 percent) of the Vempalli, Vemula, Pulivendla, and Simhadripuram mandals.Vemula soils are calcareous red soils that are moderately shallow and well-drained, with strongly alkaline clay surface soils and strongly alkaline gravelly clay sub-soils with an argillic horizon. The subsoil contains 20 to 70% quartz gravel. The slopes vary between 1% and 3% and are slightly eroded. The majority of these areas are cultivated using rainwater. Sunflower, bengalgram, jowar, and coriander are important crops grown.

**21. Velpula soils**:

Well-drained, gently sloping calcareous, non-gravelly red soils that are slightly eroded in the middle sectors. This map unit is found on gently sloping uplands. It covers an area of 1,326 ha (1.0 percent) in the mandals of Simhadripuram, Pulivendla, Vemula, and Vempalli. Velpula soils are deep, well-drained calcareous red soils with moderately alkaline sandy clay loam surface soils and argillic horizon. The slope ranges from 1% to 3% and is slightly eroded. The majority of these areas are cultivated to rainfed crops. Under irrigation, important crops such as groundnut, sunflower, and sweet orange are grown.

**22. Parnapalle soils:**

Non-gravelly loamy soils that are well drained and slightly eroded in the middle sectors that are nearly level to very gently sloping.This map unit can be found in the nearly level to gently sloping midlands. It is found in 446 ha (0.3 percent) of the Lingala mandal.Parnapalle soils are deep, well-drained brown soils with alkaline sandy loam surface and subsurface horizons. The slope is slightly eroded and ranges from 0% to 3%. The vast majority of these areas are under paddy cultivation.

**23. Agraharam soils**:

Soils are moderately well drained but slightly eroded in the middle sectors of very gently sloping calcareous cracking clayey soils.The map unit is found in the gently sloping midlands. It covers an area of 2,690 ha (2.0 percent) in the mandals of Lingala, Pulivendla, and Simhadripuram.Agraharam soils are similar to unit 18 soils. The majority of this land is under rainfed cultivation. Under irrigation, important crops such as sunflower, redgram, bengalgram, jowar, coriander, and sweet orange are grown.

**24. Sunkesula soils:**

Soils are moderately well drained but slightly eroded in the middle sectors of very gently sloping calcareous cracking clayey soils.This map unit is found in the gently sloping midlands. It covers an area of 2,778 ha (2.1 percent) in the mandals of Lingala, Simhadripuram, Pulivendla, Vemula, and Vempalli. Sunkesela soils are calcareous cracking clayey soils that are moderately shallow and well-drained, with a moderately alkaline sandy clay loam surface and a moderately alkaline clay sub-soil. The slope is

slightly eroded and ranges from 1% to 3%. The majority of these areas are cultivated using rainfed. Groundnut, redgram, coriander, sunflower, jowar, and sweet oranges are important crops grown.

**25. Agraharam-Sunkesula association:**

Cracking clay black soils that are moderately well drained and nearly level to very gently sloping, associated with moderately shallow cracking clay soils that are slightly eroded in the middle sectors.This map unit is found in the gently sloping midlands. It is spread over an area of 802 ha (0.6 percent) in Lingala mandal. Sunkesula soils cover 40% of the area, while Agraharam soils cover 60%.Agraharam soils are similar to unit 18 soils.Sunkesula soils are similar to unit 24 soils. The majority of these areas are cultivated for rain fed crops. Under irrigation, important crops such as sunflower, redgram, bengalgram, jowar, coriander, and sweet orange are grown.

**26. Agraharam-Simhadripuram association:**

In the middle sector, very gently sloping, cracking clay black soils that are moderately well drained are associated with moderately deep, cracking clay soils that are slightly eroded.This map unit is found in the gently sloping midlands. It covers 369 ha (0.3 percent) of Tondur mandal. Agraharam soils cover roughly 70% of the land area, while Simhadripuram soils cover roughly 30%. Agraharam soils are similar to unit 18 soils.The soils of Simhadripuram are similar to those of Unit 17.The majority of these areas are cultivated for rain fed crops. Under irrigation, important crops such as sunflower, redgram, bengalgram, jowar, coriander, and sweet orange are grown.

**27. Sunkesula-Simhadripuram association:**

In the middle sectors, very gently sloping, cracking clay black soils that are moderately well drained are associated with moderately deep, cracking clay soils that are slightly eroded.This map unit is found on gently sloping uplands. It encompasses 741ha (0.6 percent) of the Pulivendla mandal. Sunkesula soils cover approximately 60% of the area, while Simhadripuram soils cover 40%.Sunkesula soils are similar to unit 24 soils.The soils of Simhadripuram are similar to those of Unit 17. The majority of these areas are cultivated for rain fed crops. Irrigation is used to grow important crops such as sunflower, redgram, bengalgram, jowar, coriander, and sweet orange.

**28. Velpula-Vemula association:**

In the middle sectors, calcareous, non-gravelly red soils that are well drained are associated with calcareous red gravelly clay soils that are well drained and slightly eroded.This map unit is found on gently sloping uplands. It covers 712 ha (0.5 percent) of Tondur mandals. Velpula soils cover roughly 60% of the land area, while Vemula soils cover 40%.Velpula soils are similar to unit 21 soils.

Vemula soils are similar to unit 20 soils. The majority of these areas are cultivated using rainwater. Under irrigation, important crops such as sunflower, jowar, redgram, coriander, groundnut, and sweet orange are grown.

**4.4 Soils of colluvic and alluvic sector**

**29. Bhadrampalle-Agadur association:**

Clay soils with deep cracks that are moderately well drained and slightly eroded in colluvial and alluvial sectors that range from nearly level to gently sloping.

This map unit is found in a colluvial lower sector that is nearly level to gently sloping. It encompasses 788 ha (0.6 percent) of the Tondur and Simhadripuram mandals. Bhadrampalle soils cover roughly 70% of the area, while Agadur soils cover 30%. Bhadrampalle soils are calcareous, cracking clayey soils with shrink-swell potential that are very deep and moderately well drained. They have a surface of strongly alkaline cracking clay and subsurface horizons. The slope is slightly eroded and ranges from 0% to 3%. Agadur soils are deep, well-drained cracking clay soils with shrink-swell potential. They have a moderately alkaline clay surface as well as a strongly alkaline cracking clay subsoil. The slope is 0 to 3% and is slightly eroded. The majority of these areas are cultivated using rainwater. Under irrigation, important crops grown include redgram, bengalgram, sunflower, cotton, jowar, coriander, and sweet orange.

**30. Tondur – Pernapadu association:**

Cracking clay black soils that are moderately well-drained and nearly level to gently sloping, with deep cracking clay soils that are slightly eroded on colluvial lower sectors. This map unit is found in colluvic lower sectors that are nearly level to very gently sloping. It is found in Tondur mandal on an area of 1351 ha (1.0 percent). Tondur soils cover roughly 70% of the area, while Pernapadu soils cover 30%. Tondur soils are

deep, well-drained, cracking clay soils with shrink-swell potential. They have a highly alkaline cracking clay surface and subsoil. The slope varies between 0% and 3%, and the soils are slightly eroded. The soils of Pernapadu are deep, moderately well-drained cracking clay soils with shrink-swell potential. They have a moderately alkaline clay surface as well as a moderately to strongly alkaline clay subsoil. The slope ranges from 0% to 3%. These soils have been eroded slightly. The majority of these areas are cultivated using rainwater. Under irrigation, important crops grown include groundnut, sunflower, redgram, coriander, bengalgram, jowar, chilly, and sweet orange.

**31. Tondur soils:**

In colluvial lower sectors, cracking clay black soils were mostly found. This map unit is found in colluvic lower sectors that are nearly level to very gently sloping. It is found in 3,568 ha (2.7 percent) of the Tondur, Simhadripuram, Pulivendla, and Vempalli mandals.Tondur soils are similar to unit 30 soils. The majority of these areas are cultivated using rainwater. Under irrigation, important crops such as groundnut, sunflower, redgram, and sweet orange are grown.

**32. Agadur soils:**

In colluvial lower sectors that are nearly level to very gently sloping, where cracking clay black soils are generally occur and are moderately well drained and slightly eroded.This map unit is found in a colluvial lower sector that is nearly level to gently sloping. It is found in 633 ha (0.5 percent) of Tondur, Pulivendla, and Vemula mandals.The soils of Agadur are similar to those of Unit 29. The majority of these areas are cultivated using rainwater. Under irrigation, important crops such as redgram, bengalgram, sunflower, coriander, jowar, and sweet orange are grown.

**33. Pernapadu-Gondipalle association:**

Nearly level to gently sloping, cracking clay black soils that are moderately well drained are associated with shallow black soils that are well drained and slightly eroded on colluvial lower sectors.

This map unit is found in the colluvic lower sector, which is nearly level to gently sloping. It has an area of 853 hectares. (0.6%) in the Vempalli and Vemula mandals. Pernapadu soils cover approximately 60% of the area, while Gondipalle soils cover 40%.

The soils of Pernapadu are similar to those of Unit 30. Gondipalle soils are calcareous black clay soils that are shallow and well drained. They have a strongly alkaline clay surface and a strongly alkaline gravelly clay subsoil. The slope ranges from 0% to 3%. These soils have been eroded slightly. The majority of the land is under rainfed cultivation. Under irrigation, important crops grown include redgram, groundnut, sunflower, cotton, coriander, bengalgram, jowar, chilly, and sweet orange.

**34. Tondur-Agadur association:**

Cracking clay black soils that are moderately well drained and slightly eroded occur in nearly level to very gently sloping colluvial lower sectors. This map unit can be found on nearly level to gently sloping colluvial plains. It covers 709 ha (0.5 percent) of Tondur mandal. Tondur soils cover roughly 70% of the area, while Agadur soils cover 30%.Tondur soils are similar to unit 30 soils.The soils of Agadur are similar to those of Unit 29. The majority of the land is under rainfed cultivation. Under irrigation, important crops grown include sunflower, groundnut, redgram, bengalgram, coriander, jowar, and sweet orange.

**35. Pulivendla-Pernapadu association:**

Calcareous clay soils that are found in level to very gently sloping and moderately well drained but slightly eroded on the colluvic lower plains. This map unit can be found on nearly level to gently sloping colluvial plains. It covers 101 ha (0.08 percent) of the Pulivendla and Vemula mandals. The Pulivendla soils cover roughly 70% of the area, while Pernapadu soils cover 30%. Pulivendla soils are calcareous black soils that are deep and moderately well drained. Their clay surfaces and subsurface soils are very strongly alkaline. The slope varies between 0% and 3%. These soils have been eroded slightly.Nearly level to very gently sloping calcareous clay soils that are moderately well drained slightly eroded on colluvic lower plains.

**36.Goturu-Gondipalleassociation:**

Nearly level to very gently sloping calcareous clay soils that are moderately well-drained slightly eroded on colluvial lower plains.This map unit occurs on nearly level to very gently sloping colluvial plains. It covers an area of ha (1.1) in Vemula, Vempalli, and Tondur mandals. The Gotur soils cover about 70 percent and Gondipalle 30 percent.Goturu soils are relatively shallow, well- drained calcareous clay soils. They've a very strongly alkaline clay surface andsub-soil. Pitch ranges from 0-3 percent. These soils are slightly eroded.Gondipalle soils are analogous to soils of unit 33.

**37. Pernapadu soils:**

Nearly level to very gently sloping, calcareous cracking clay soils that are moderately well-drained slightly eroded on colluvial lower plains. This map unit happens on nearly level to very lightly sloping colluvial plains. It covers an area of 3689 ha (2.8%) in Vempalli, Vemula, Pulivendla, and Tondur mandals. Pernapadu soils are similar to soils of Unit 30. Most of the area is under rainfed cultivation. Important crops grown are coriander, Bengal gram, sunflower, redgram, jowar, chilly, groundnut, and sweet orange under irrigation.

**38. Pernapadu-Tondur association:**

On colluvic lower plains, calcareous clay soils that are well drained and slightly eroded are nearly level to very gently sloping. This map unit can be found on nearly level to gently sloping colluvial plains. It is spread across 1,683 ha (1.3 percent) of Tondur and Pulivendla mandals. Soils in Gondipalle are similar to soils in Unit 33. The majority of the land is under rainfed cultivation. Redgram, groundnut, sunflower, and cotton are important crops grown.

**39. Gondipalle soils:**

On colluvic lower plains, calcareous clay soils that are well drained and slightly eroded are nearly level to very gently sloping. This map unit can be found on nearly level to gently sloping colluvial plains. It is spread across 1,683 ha (1.3 percent) of Tondur and Pulivendla mandals. Soils in Gondipalle are similar to soils in Unit 33. The majority of the land is under rainfed cultivation. Redgram, groundnut, sunflower, and cotton are important crops grown.

**40. Goturu soils:**

On the colluvic lower plains, calcareous clay soils that are relatively well drained and little eroded are nearly flat to very gently sloping.On relatively gently sloping colluvial plains, this map unit can be found. In the Vemula, Pulivendla, and Tondur mandals, it spans 1,707 acres (1.3 percent). The soils of Goturu are comparable to those of Unit 36.The majority of the land is cultivated with rainwater. Under irrigation, important crops include sunflower, coriander, jowar, groundnut, bengalgram, chilly, redgram, and sweet orange.

**41. Agadur-Pernapadu association:**

On the colluvic lower plains, almost flat to very gently sloping, cracking clay soils that are moderately well drained and mildly eroded.On relatively gently sloping colluvial plains, this map unit can be found. In the mandals of Pulivendla, Tondur, Vemula, and Vempalli, it spans 3,613 acres (2.7 percent). The soils of Agadur are comparable to those of Unit 29. The soils of Pernapadu are comparable to those of Unit 30.The majority of these lands are sown with rainfed crops. Under irrigation, important crops include redgram, peanuts, sunflower, cotton, bengal gram, coriander, jowar, and sweet orange.

**42. Bhadrampalle soils:**

On colluvic lower plains, nearly level to gently sloping, cracking calcareous clay soils that are moderately well drained and slightly eroded.This map unit can be found on gently sloping colluvial plains. It has an area of 448 ha (0.3 percent) in the mandals of Pulivendla, Tondur, and Vempalli. Soils in Bhadrampalle are similar to soils in Unit 29. The majority of the land is under rainfed cultivation. Cotton and Bengalgram are important crops grown, and the remainder of the land is fallow.

**43. Pulivendla soils:**

On colluvic lower plains, nearly level to gently sloping, cracking calcareous clay soils that are moderately well drained and slightly eroded.This map unit is found on gently sloping to nearly level colluvial plains. It encompasses 3,540 ha (2.7 percent) of the Vempalli, Vemula, Tondur, and Pulivendla mandals.The soils of Pulivendla are similar to those of Unit 35.The majority of the area is wasteland, with some patches cultivated to sweet orange under irrigation.

## 11. Estimation of soil loss using USLE (Universal soil loss equation)

The annual soil loss was estimated by integrating rainfall erosivity, soil erodibility, topography, cover management, and supporting factors as used in USLE. 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 26). Based on area estimations, the soil erosion risk zones are arranged in ascending order as : high-medum (39142ha, 31.16%) > high (276696ha, 22.05%) > medium (23378ha, 18.6%) > extremely high (16364ha, 13.03%) > low-medium (12025ha, 9.57%) > very high (7007ha, 5.58%).when data arranged as per landform wise, three soil erosion risk zones are delineated viz., high-medum, high and extremely high in hills and ridges . The high – medium soil loss zone covers 32308 ha (25.13% of total area), 15417 ha under high erosion risk zone (11.98%) and off 7087 ha (5.51%) under extremely high erosion risk zone. The mean soil loss 34.97 ± 34.75 t/ha/year to categorize as very high erosion risk zone in hills and ridges due high LS factor and slope gradient > 30 %.

The interhill basin has 20 soil mapping units covering 35.19 % of total area (45255 ha) with soil loss of 115t/ha/year. The mean soil loss is 10.96 t/ha/year to categorize as high erosion risk with a deviation of 23.82 t/ha/year. Out of 20 SMUs, 7 are categorized as medium erosion risk zone with mean soil loss of 3.25 ± 0.55 t/ha/year. The estimated area under medium class is 22497 ha (17.5% of total area). The six SMUs under high-medium class covers 6843ha (5.3%) with mean soil loss of 12.87 ± 12.87 t/ha/year. This class has sum of soil loss of 45.07 t /ha/year. Only three SMUs are categorized under low -medium erosion risk zones with total soil loss of 4.51 t/ha/year in an area of 8817ha (6.86% of total area).The mean soil loss is 1.503 ± 0.27 t/ha/year with variation of 18.26 per cent. The SMU Balapanur (16) is classified as very high erosion risk zone covering 6559 ha (5.1%) and Santhakovur (13) under high-risk covering 548 ha (0.43%). This landscape unit is mostly used for groundnut – banana based cropping systems in the regions wherein crop management factor and soil erodibility factor decides the differential rates of erosional status.

The fifteen SMUs in colluvial- alluvial pediplains cover 28542 ha (22.19%) with total soil loss of 487 t/ha/year and mean of 32.45 ± 37.39 t/ha/yr. The five SMUs under high eroson risk cover 11731 ha (9.12%) with a total oil loss of 84.64 t/ha/yr and mean of 16.92±1.66 t/ha/yr. The four SMUs in colluvial-alluvial pediplains are classified under

extremely eroded zone and covers 9986 ha (7.76%) with the total soil loss of 364t/ha/yr and mean of 91.02 ± 8.23 t/ha/yr. the per cent area under low-medium erosion class is 1.66 (2134ha) and of high-medium erosion class in Pernapadu - Gondipalle (33) unit with an area of 853ha (0.66%). The variation in the results may be attributed to the varying soil factors in the different landscape units. In the study area, as expected, high erosion rate was recorded in the steeper slope area that ranges from 30 to 83% and the steeper slope land use of agricultural lands. Areas with high erosion rates require immediate action of soil conservation practices. The land management strategies to be implemented should match the characteristics of the topography, land use cover, and interest of the local community. Agroforestry, terracing, cut-and-carry system can be integrated to sustainably manage erosion-prone areas of steep hills of Palakonda range.

**Table 26.** Area and extent of soil mapping units in relation to landforms and soil loss

| Land form | Soil mapping unit | area | | Soil loss (t/ha/year) / soil erosion risk |
|---|---|---|---|---|
| | | ha (hectares) | Per cent (%) | |
| 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 | |

## 12.0. Soil erosion risk assessment

CORINE model is a qualitative, simple, easy to apply with GIS and cost - effective approach (Yuksel, *et al.*, 2008; Zhu 2012; Reis, *et al.*, 2016, Tayebi, *et al.*, 2017). Studies regarding soil erosion have received growing interest under different approaches; these have led to the development of several models for estimating erosion of which the USLE is the most widely used models. Other models CORINE has also been used successfully at different scales and areas. Later, this model was employed to determine soil erosion risk Dalaman Basin of west Mediterranean region. Doran and Zeiss (2000) and Golbasi environmental protection area of Turkey on 1:25000scale using geographic information system (GIS) technique (Denis and Kabul, 2005). The temporal soil erosion risk of Istanbul–Elmalı dam watershed was estimated using CORINE model (Aydın and Tecimen, 2010). The application of CORINE (Co Ordination of Information on the Environment model) was used in assessment of soil erosion risk of Ramgad watershed, Nainital and reported that 24.9%, 52.2% and 22.76% of area are under low, moderate and high actual erosion risk (Gupta and Uniyal, 2012). The chosen site for this case study is Pulivendula tehsil having Seshachalam hills associated with erramala ranges formed massive quartzites, interbedded with slates and lavas of Kadapa district, Andhra Pradesh. The study site has dry deciduous forest type with pterocaropus *santalinus* or red sanderslying between the elevation of 800 and 2000 feet. The present research was undertaken in Pulivendula tehsil where soil erosion and seasonal droughts are common and also major concern for agricultural development, yet such studies are scanty. Therefore, the CORINE model was selected to provide erosion risk map for restoring and protecting areas in the study area. In this paper, the soil erosion risk was assessed by combining CORINE model with GIS spatial analysis techniques. The CORINE model parameters such as actual soil erosion risk and potential soil erosion risk were determined using field surveying, laboratory analysis, and IRS-P6 satellite imagery interpretation and topographic map. Hence, evaluation of soil loss rates and identification of erosion prone areas are overlooked to protect the area from further erosion damage.

## 12.1. Soil erodibility

Soil erodibility describes the vulnerability of the soil to detachment and transport caused by raindrops and runoff. It is related to soil texture, structure, organic matter content, permeability, parent material properties and other factors (Kirkby, *et al*., 2000). Many studies have reported that in terms of soil texture, silt, very fine sand, and clay soils tend to be less erodible than sand, sandy loam, and loamy soils (CORINE, 1992). Increasing soil depth can bring about a higher water holding capacity, which may prevent overland flow by absorbing larger amounts of rainfall (CORINE,1992). Increasingly eroded soil profiles will allow less rainfall to be infiltrated and stored, and this process would logically result in increased erosion (Trimble and Crosson, 2000). Stones at the soil surface can have negative as well as positive effects on sediment yield. These effects comprise the shielding of the soil surface from detachment by raindrop splash and runoff or the interception of splashed sediment (Poesen, *et al*., 1994). However, after surface runoff is initiated, existence of stones may cause adverse effects by encouraging rill erosion through water turbulences (Yuksel, *et al*., 2008). In CORINE model, soil erodibility is calculated as function of soil texture, depth, and stoniness. Soil texture is classified into three classes including (1) slightly erodible, (2) moderately erodible, and (3) highly erodible according to the USDA textural classification. Similarly, soil depth is also classified as (1) slightly erodible, (2) moderately erodible, and (3) highly erodible soils, by considering the depth from the soil surface to the base of the soil profile. Stoniness refers to the percentage surface cover of stones (>20 mm) and is classified as (1) fully protected (>10%) and (2) not fully protected soils (<10%). Then the soil erodibility index can be calculated as Eq.1 (CORINE, 1992).

Soil erodibility index = texture class X depth class X stoniness class

For this study, soil investigation was carried out within the study area in August, 2009. A total of 198 topsoil samples were collected, and their locations were recorded using GPS device. Soil mechanical composition was measured following Kettler, *et al*. (2001) and particle size was classified as sand (2.0–0.05 mm), silt (0.05–0.002 mm), and clay (< 0.002 mm). The texture class of each soil sample was determined according to the CORINE model.. Among textural groups, only sandy clay and clay texture covers

66% of area (97872 ha) and the rest of the area is under the textural group of sandy clay loam, clay loam and loamy sand (29.29 %, Fig.20). Regarding depth class, the soils depth < 75 cm cover 66469 ha (45.42 %), 55192 ha under 25 to 75 cm (37.71%) and 19515ha under less than 25cm (13.34 %). Over all, the stony soils less than 10% cover 52.73% of total area whereas 43.74% of area has more than 10% stony cover. These three parameters are considered and rated. The ratings are multiplied to derive soil erodibility index to categorize under three classes such as low, moderate and high. The highly erodible soils are mostly concentrated in north and north western parts covering 11670 ha (7.97% of total area). The low credibility of soils are mostly concentrated in winterkill basins and collusion-alluvial sectors covering 78793ha (53.84 per cent) and off 50714ha (34.65%) under moderate erodible soils in southern parts (Fig.20).

**Hills and ridges**

**Table 27**. Assessment of soil erodibility for hills and ridges

| SMU | soil texture | | soil depth | | stoniness | | Soil erodability | | **area** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **ha** | **%** |
| 1.Rockoutcrops (R) - Kanampalli(Kpl) | scl,cl | 2 | <25 | 3 | >40 | 1 | **6** | **high** | 7953 | 6.18 |
| 2. Rockoutcrops®- - Ganganapalle(Ggp) | sc, c | 1 | <25 | 3 | <15 | 1 | **3** | **moderate** | 7464 | 5.80 |
| 3. Rockoutcrops®-Rachanakuntapalle(Rkp) | scl-cl | 2 | <50 | 2 | >50 | 1 | **4** | **moderate** | 24939 | 19.39 |
| 4. Rockoutcrops®--Lingala(Lgl) | cl, sc | 1 | <50 | 2 | >50 | 1 | **2** | **low** | 6410 | 4.98 |
| 5. Rachanakuntapalle(Rkp) – rockoutcrops® | scl-cl | 2 | <50 | 2 | >50 | 1 | **4** | **moderate** | 1333 | 1.04 |
| 6.Ganganapalle(Ggp)-Rockoutcrops® | sc, c | 1 | <25 | 3 | <15 | 1 | **3** | **moderate** | 677 | 0.53 |
| 7.Rockoutcrops®-Mupendranpalle(Mpl) | sc, c | 1 | <50 | 2 | >50 | 1 | **2** | **low** | 3572 | 2.78 |
| 8.Mupendranpalle(Mpl)- Rockoutcrops® | sc,c | 1 | <50 | 2 | >50 | 1 | **2** | **low** | 2464 | 1.92 |
| | | | | | | | | Total | 54812 | 42.62 |

The soil erodibility was evaluated as per CORINE model and rated as per the scheme. The results of erodibility of hill land soils show that the soils with a textural sequence of scl-cl (SMU-1, 3 &5, Table 27) have high (SMU-1) to moderate erodibility (SMU3&5).

The SMU 2, 6, 7 & 8 have textural class of sc-c with low to moderate erodibility. The highly erodible soils (SMU -1) cover 7953 ha (6.18%), moderately erodible soils (SMU 2, 3, 5& 6) of 34413 ha (26.76%) and low erodible soils of 12446 ha (9.68%). The clay and sandy clay soils have low infiltration rates with high runoff are subjected moderate erosion but soils have thin cover over hills which results in high erosion due to low water holding capacity an higher overland flow (Fosteret 1985). Out of 8 units, 6 soil units have more than 50 % stoniness covering 46671ha (36.29% of total area). This unit covers 85.14% of total area under hills and ridges with stone cover of more than 50%.

**Inter hill basin**

The interhill basin covers 45255ha (35.19% of total area) with five textural groups viz., clay ©, sandy clay (sc), clay loam (cl), sandy clay loam (scl) and sandy loam (sl). Eighty six per cent of interhill basin has clay /sandy clay texture with a code of 1. It approximately accounts to 39151ha (Table 28). There are three depth classes in the model and estimated that thirty seven thousand seven hundred hectares has soil depth more than 75cm in interhill basins that counts eighty three per cent of total area. These soils have less than 10 per cent of stoniness covering 40166 ha (88% of total interhill basin). The interhill basin have low to moderate erodibility clas except SMU 23 and 14 where erodibility is rated as high. These two units cover 3198ha (2.99%)

**Table 28**. Assessment of soil erodibility for interhill basin

| | SMUs | Area ha | Area(%) | texture | code | | Soil depth (cm) | code | | Stoniness (%) | code | Soil erodibility | | class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interhill basin | 9.Tallalapalle(Tlp) | 1829 | 1.42 | sc, c | 1 | | <50 | 2 | | >50 | 1 | **2** | | low |
| | 10.Murarichintala ((Mct) | 1934 | 1.5 | cl,c | 2 | | ,<50 | 2 | | >50 | 1 | **4** | | moderate |
| | 11.Tatireddipalle((Trp) | 788 | 0.61 | scl,cl | 2 | | >150 | 1 | | <10 | 2 | **4** | | moderate |
| | 12.Kottalu(Ktl) | 372 | 0.29 | c | 1 | | <75 | 2 | | <10 | 2 | **4** | | moderate |
| | 13.Santakovur(Skv) | 548 | 0.43 | c | 1 | | <150 | 1 | | <10 | 2 | **2** | | low |
| | 14.Murarichintala ((Mct)-Tallalapalle(Tlp) | 508 | 0.39 | cl,c | 2 | | <75 | 2 | | <10 | 2 | **8** | | high |
| | 15.Cherlapalle(Cpl) | 184 | 0.14 | scl,cl | 2 | | >150 | 1 | | <10 | 2 | **4** | | moderate |
| | 16.Balapanur(Bpr) | 6559 | 5.1 | c | 1 | | <150 | 1 | | <10 | 2 | **2** | | low |
| | 17.Simhadripuram (Spm) | 7583 | 5.9 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 18.Simhadripuram (Spm) -Agraharam((Ahm) | 9125 | 7.1 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 19.Balapanur (Bpr) - Sunkesula(Skl) | 4294 | 3.34 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 20.Vemula(Vml) | 1667 | 1.3 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 21.Velpula(Vpl) | 1326 | 1.03 | c | 1 | | <75 | 2 | | >10 | 1 | **2** | | low |
| | 22.Parnapalle(Prp) | 446 | 0.35 | sc,c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 23.Agraharam(Ahm) | 2690 | 2.09 | sl | 3 | | >75 | 1 | | <10 | 2 | **6** | | high |
| | 24.Sunkesula(Skl) | 2778 | 2.16 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 25.Agraharam(Ahm)-Sunkesula(Skl) | 802 | 0.62 | c | 1 | | <75 | 2 | | <10 | 2 | **4** | | moderate |
| | 26.Agraharam(Ahm)- Simhadripuram(Spm) | 369 | 0.29 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 27.Sunkesula(Skl) - Simhadripuram(Spm) | 741 | 0.58 | c | 1 | | >75 | 1 | | <10 | 2 | **2** | | low |
| | 28.Velpula (Vpl)- Vemula(Vml) | 712 | 0.55 | c | 1 | | <75 | 2 | | <10 | 2 | **4** | | moderate |
| | Total | 45255 | 35.19 | | | | | | | | | | | |

**Colluvio-alluvial sectors**

The colluvio-alluvial sectors cover 28542 ha (22.19% of total area, table 29) covering 15 soil mapping units. The low soil erodibility class covers 21240ha with 16.51 per cent total area under colluvio-alluvial sectors and moderate erodibility of 5.68% (7302ha). Over all, the soil erodibility class is rated as low .

**Table.29**. Assessment of soil erodibility for colluvio-alluvial sectors

| | SMUs | Area (Ha) | Area(%) | texture | code | Soil depth (cm) | code | Stoniness (%) | code | Soil | class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Colluvial - alluvial pediplains | 29. Bharampalle(Bpl)-Agadur(Agd) | 788 | 0.61 | sc,c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 30.Tondur(Tdr)-Pernapadu((Ppd) | 1351 | 1.05 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 31.Tondur(Tdr) | 3568 | 2.77 | c,sc | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 32.Agadur(Agd) | 633 | 0.49 | c,sc | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 33. Pernapadu(Ppd)-Gondipalle(Gpl) | 853 | 0.66 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 34.Tondur(Tdr)-Agadur(Agd) | 709 | 0.55 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 35.Pulivendula(Pvd)-Pernapadu(Ppd) | 101 | 0.08 | c,sc | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 36.Goturu(Gtr)-Gondipalle(Gpl) | 1501 | 1.17 | sc,c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 37.Pernapadu(Ppd) | 3689 | 2.87 | c | 1 | <75 | 2 | <10 | 2 | 4 | moderate |
| | 38.Pernapadu(Ppd)-Tondur(Tdr) | 4358 | 3.39 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 39.Gondipalle(Gpl) | 1683 | 1.31 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 40.Goturu(Gtr) | 1707 | 1.33 | sc,c | 1 | <50 | 3 | <10 | 2 | 6 | high |
| | 41.Agadur(Agd)-Pernapadu(Ppd) | 3613 | 2.81 | c | 1 | <75 | 2 | <10 | 2 | 4 | moderate |
| | 42.Bhadrampalle(Bpl) | 448 | 0.35 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | 43.Pulivendula(Pvd) | 3540 | 2.75 | c | 1 | >75 | 1 | <10 | 2 | 2 | low |
| | Total | 28542 | 22.19 | sc,c | 1 | >75 | 1 | <10 | 2 | 2 | low |

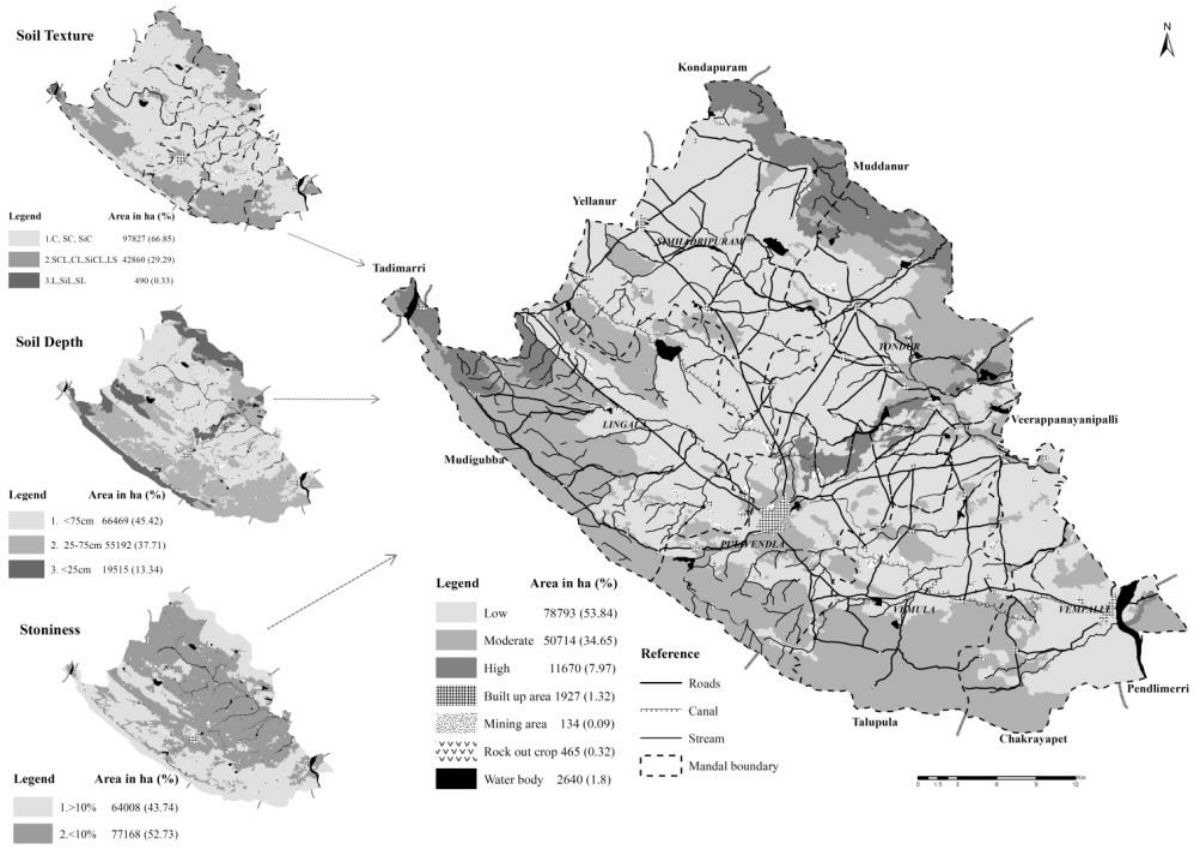



**Fig.20**. Soil erodibility map

The soil erodibility map was derived with the multiplication of rating of soil texture X soil depth X stoniness. The soil erodibility maps shows that 78793ha(53.84% of total area) is rated as low which is mostly concentrated interhill/ colluvio-alluvial sectors of central and south western parts of Pulivendula. The high erodibilty is concentrated in north eastern parts of Pulivendula and cover 7.97% of total area (11670ha).

### 12.2. Erosivity

The Modified Fournier index (MFI) provides a measure of rainfall variability, large values of MFI relating to high variability, low values characterizing sites with an evenly distributed rainfall (CORINE, 1992). The study region is in monsoonal climate area, and the unevenly distributed rainfall throughout the year leads to the relatively high MFI values. Although the MFI gives an acceptable measure of rainfall

variability, it does not take into account the general aridity of the climate. In the present study 109 years of monthly rainfall data from 1901 to 2010 was used to compute MFI and estimated erosivity 1.05*MFI (Hernando and Romana, 2015). The data clearly shows distinct yearly variation of the erosivity index with an intermittent trend of very high to low as presented in table 17/18. The overall mean of MFI is 101.37 ± 48.52mm and coefficient of variation of 47.87 per cent to define erosivity class as moderate. This region experiences 11 events of very high, 38 events of high and 40 events of moderate erositvity (Table 18). The estimated high erosivity index for the study area presages further risk of soil erosion hazards, especially under conditions of increasing rainfall. To strengthen the assessment of erosivity, the BGI was included in it. The Bagnouls – Gaussen Index which gives aridity class (Ac). Both classes are combined to give the erosivity index, which is equal to the product of variability class and aridity class. The BGI value 1 was described as humid according to the CORINE model. The area experience very dry condition where in 2Ti-P1 is > 150 (Fig.21). The overall rating of erosivity is 16 to rate it as high .

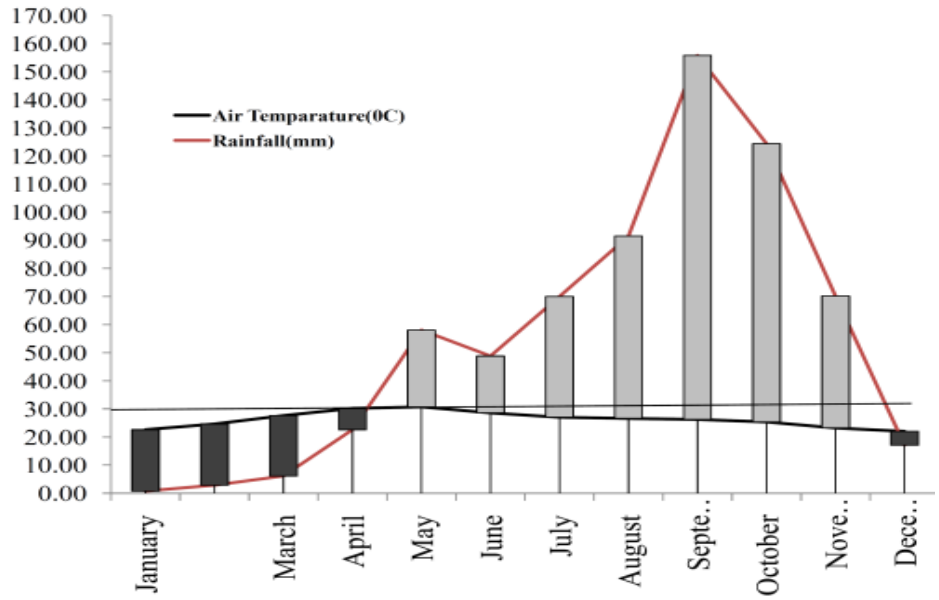



**Fig.21.** BGI diagram showing temperature and rainfall distribution in the study area

**Slope map**

The slope is determined in terms of gradient, shape and length. The slope patterns in Pulivendula area have been grouped under 4 slope classes as defined in CORINE model. The class -1 (<5% slopes) include less than 5% slopes and covers

79832ha (59.89% of total area. They are mostly concentrated in Tondur, and Vempalle mandals and small areas in Simhadripuram, Lingala, Vemula and Pulivendla mandals. The class 2 (5 to 15%) includes 40825ha (30.62%) but spreads in all mandals in North West to south west fringes of Pulivendula tehsil. The class-3 (15 -30%) is mostly confined to Lingala, Simhadripuram and Tondur mandals with moderately steeply to strongly sloping areas. This unit covers 7953ha (5.97%of total area).

**Table 30**. Slope class in Pulivendla

| Class | Mapping Units | Area in ha(%) |
|---|---|---|
| 1 | 16, 22, 30, 31, 32, 34, 37, 38, 41,19, 33 29, 35,9, 10, 11, 12, 13, 14, 15, 17, 18, 20, 21, 23, 24, 25, 26, 27, 28, 36, 39, 40, 42, 43 7, 8 | 79832(59.89) |
| 2 | 4,2, 3, 5,6 | 40825ha(30.62) |
| 3 | 1 | 7,953 (5.97) |

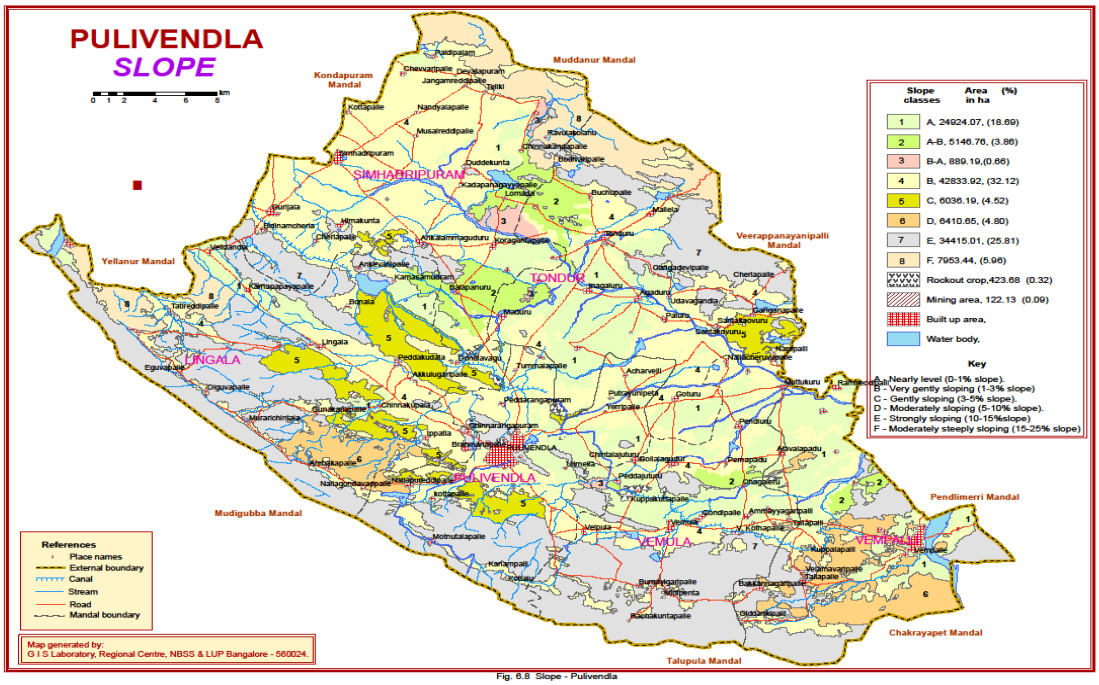



**Fig. 22**. Slope map

## 12.3.Potential erosion risk (PSER)

PSER is defined as the inherent risk of erosion, irrespective of current land use or vegetation cover, and represents the worst possible situation. The estimation of PSER involves overlaying the parameters of soil erodibility, erosivity and slope and then classified as low, moderate and high for determination of CORINE PSER (Fig.23). The results presented in Fig.21 showed that about 62.62% of area was classified under high erosion risk and 33.85% of area under moderate erosion risk level. The study area is actually in high to moderate erosion risk level on the whole indicating mining activities continuously distributed in the southwest of the study area, and sporadically distributed in the north of the study area, where the soil and water conservation practices should be focused on priority. This region has shallow soil depth and steep terrain contribute much to the high PSER. Moderate erosion risk areas mainly located in the northern part of the study area

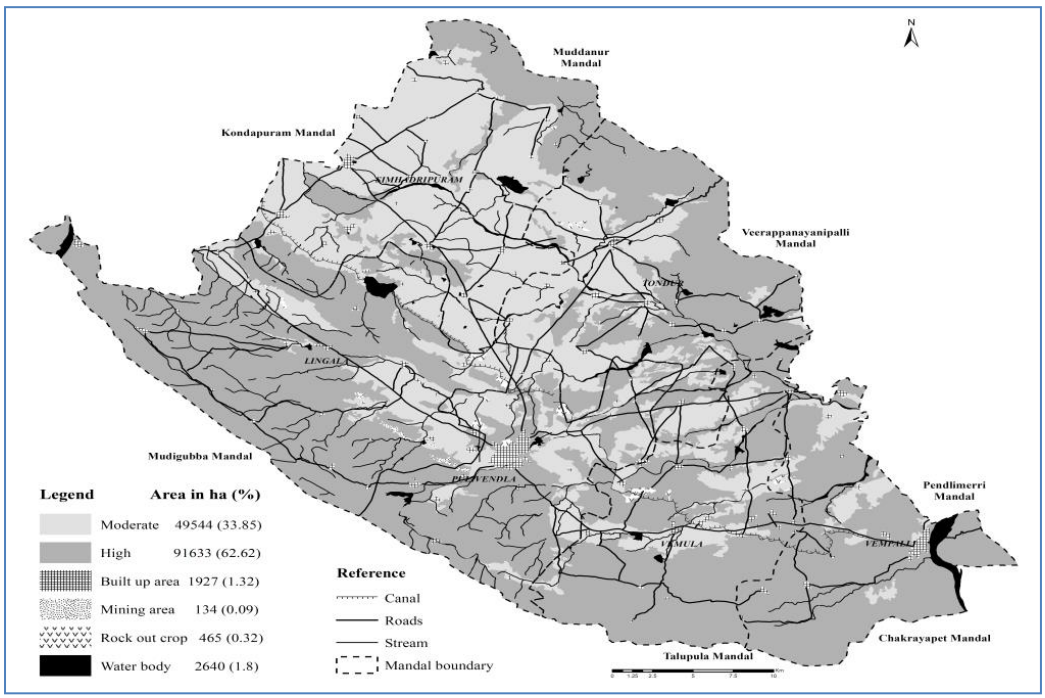



**Fig.23.** Potential soil erosion risk map

### 12.4. Actual erosion risk

Vegetation cover is one of the most important factors in the actual soil erosion risk assessment. The vegetative cover and land use conventions of the study site have been detected by digitized of stand maps within GIS environment. In this context 80 % of the study areas is not fully protected area. The estimated area under high actual erosion risk levels is 66.96 % of total area as against the PSER of 62.62% of area. The high leveled potential erosion risk area decreases when it is evaluated as actual erosion risk assessment perception (Fig.24) which also indicates the effect of vegetation cover. The land use changes significantly influence actual and potential erosion risks at a given time scale (Jordan, *et al*., 2005). The less actual erosion risk result in comparison with the potential erosion risk marks the significant importance of the plant cover (Dengiz and Akgu˙l, 2005). Potential erosion risk value is calculated irrespective of current land use or vegetation cover conditions. Therefore, potential erosion risk is low essentially at the sites that have gentle slope topography. As expected, steep slopes and not fully protected areas should have a high erosion risk as (Kheir, *et al*., 2006) stated that erosion is potentially very high if the eroding rain or the landscape sensitivity is very high, except for the very low landscape sensitivity as it corresponds to flat areas. However, vegetation cover that is major protector against soil erosion especially at sloppy topography has great importance at mountainous water-sheds (Zhou, *et al.,* 2008). The vegetation cover in sloppy topography is not much improved and not fully protected with continued mining and deforestation activities in the region that encouraged high erosion in the region. The main factors that resulted in high erosion risk in the study area included shallow soil depth and steep slope. Besides, most of the study area was covered with sandy loam and loam which are highly erodible soils. On the other hand, only 20% of the area was covered by fully protected vegetation cover i.e. forest. Thus, suitable land use practices should be implemented to reduce erosion and avoid shortening the economic life of the dam. Besides, the results indicated that potential and actual erosion risk mapping by CORINE method is a quite efficient and cost effective approach. Similar kind of observations was reported in soil erosion risk mapping of Goz Watershed in Kahramanmaras Region, Turkey (Reis, *et al*., 2016).

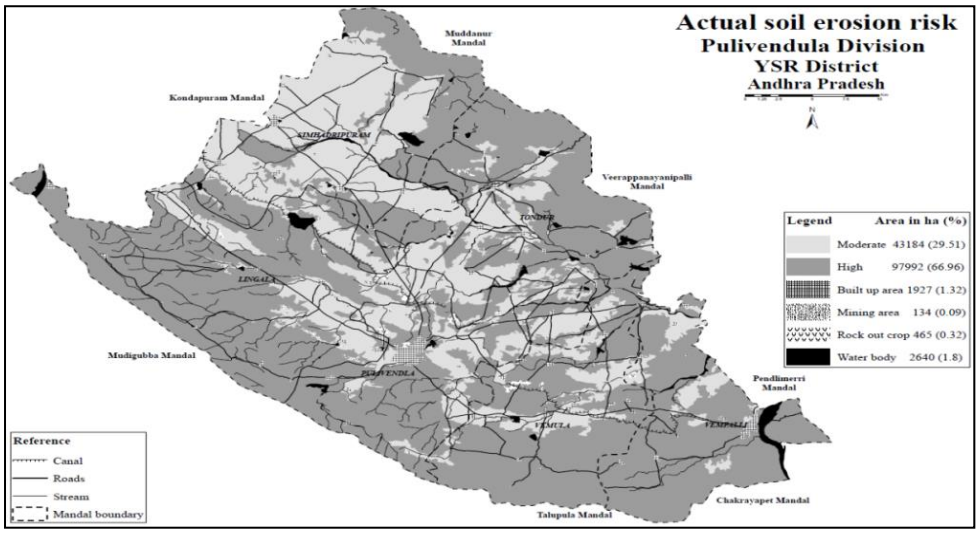



**Fig.24.** Actual soil erosion risk

## 13.0. Morphological evaluation for soil quality

### Pedological indicators at pedon scale

Mac Ewan and Fitzpatrick (1996) made an elaborate discussion on pedological indicators useful for assessing soil quality and act as guide for farmers to monitor changes in soil profiles in response to management practices. They stated that the most useful indicators considering inherent soil quality and soil type in relation to landscape position and its threshold values are given as below:

| Indicators | Observations | Processes /functions |
|---|---|---|
| Surface features | Thin surface crusts , surface seals, smears with cracks, stoniness, pedsatls, rills | Soil structural decline /soil loss |
| | Deposition in valley floors, materials washed on hill slopes | Soil and nutrient loss |
| | Prolonged waterlogging after rain or irrigation | Soil structural decline |
| | Pugging damage, vehicle sinkage | Waterlogging ,soil structure decline |
| | Barren land | Decline in organic carbon, high surface runoff/raindrop impact |
| | Salt efflorescence under dry , bare wetland, death of plant species | Mobilisation and accumulation of salt |
| Roots and pores | Number and depth of roots<br>Root space with visible pores<br>Frequency of visible pores (by horizons) | Porous nature of soil<br>Infiltration, nutrient cycling<br>Drainage and aeration |

| | | |
|---|---|---|
| Horizon boundary | Connectivity of pores between horizons | Root growth, drainage and aeration |
| Soil consistency | Air dry strength of soil –allocation to ordinal class in the range rigid to loose (A surrogate to texture, Organic matter and sodicity) | Root growth, water movement, tillage operation |
| Aggregate stability | Behaviout under pure water –swelling, slaking and dispersion(Emerson test) | Decline structural stability, sealing and crust formation, drainage, aeration, seedling emergence, infiltration |
| EC, pH | 1:2.5 soil water suspension | Salinisation and degree of acidity |
| colour | High value/low chroma , rusty mottling all along root channels and ped surfaces | Degree saturation, aeration, forms of iron |
| Bulk density | Direct measurement or core method , relative compaction, total pore space, air filled porosity at field capacity | Soil aeration, root penetration, drainage |

Considering the above inferences from the literature, the field morphological properties collected during land resource inventory Pulivendula tehsil was used to provide a prototype database that could be readily adapted and made fast local assessment within the frame work of scoring the visual signs of soil health (McGary, 2006).

**13.1. Method -1 of visual scoring (McGary, 2006)**

The information and indicators on the recording sheets were coded to simplify systematic collection, input and analysis of data. We first compiled 10 biophysical indicators enlisted and the analysis of each soil type was performed and outcomes reported in this article. The visual scores of individual farmers for each biophysical indicator were rated individually as 0=poor, 1=moderate and 2= good. These ratings were multiplied with weighing factor to derive visual ranking and then added overall ranking so as to categorize as poor if score is <10, 10 - 25 as moderate and > 25 as good. The forty three mapping units are evaluated in three landforms of Pulivendula tehsil and presented in Table 31. Among 8 soil mapping units, five units have poor quality whereas three units are rated as moderate. Out of twenty soil mapping units, seven are rated as moderate and others as good in interhill basins (Table 32). In colluvio - alluvial sectors, fifteen mapping units are evaluated and rated seven units as moderate while others as good. It is estimated that poor quality soils occupy 35.25% of total area (45338ha) wherein shallow soil series are mostly associated with rock outcrops as dominant feature.

Both interhill basins and colluvio-alluvial sectors, the moderate quality of soils cover 25.25% of total area (32823ha) where as good quality soils accounts to 39.23% (50448ha)

**Table 31.**Landforms wise soil quality rating

| **Landform** | **Soil mapping unit** | **Area** | | **Proportion** | **SQR Method 1** |
|---|---|---|---|---|---|
| | | ha | % | | |
| Hills and ridges | 1. Rock outcrops( R)-Kanampalli (Kpl) | 7953 | 6.18 | 60:40:00 | 10(poor) |
| | 2.Rockoutcrops( R)-Ganganapalle(Ggp) | 7464 | 5.8 | 60:40:00 | 13.2(moderate) |
| | 3.Rockoutcrops(R)-Rachukuntapalle(Rkp) | 24939 | 19.39 | 60:40:00 | 9.2(poor) |
| | 4.Rockoutcrops(R) - Lingala(Lgl) | 6410 | 4.98 | 60:40:00 | 9.8(poor) |
| | 5. Rachakuntapalle(Rkp) - .Rockoutcrops( R) | 1333 | 1.04 | 60:40:00 | 10.6(moderate) |
| | 6.Ganganapalle(Ggp) -Rockoutcrops( R) | 677 | 0.53 | 60:40:00 | 14.8(moderate) |
| | 7.Rockoutcrops( R)-Mupendranpalle(Mpl) | 3572 | 2.78 | 60:40:00 | 10(poor) |
| | 8.Mupendranapalle(Mpl)-.Rockoutcrops( R) | 2464 | 1.92 | 60:40:00 | 8(poor) |
| Interhill basin | 9.Tallalapalle(Tlp) | 1829 | 1.42 | 100 | 13(moderate) |
| | 10.Murarichintala ((Mct) | 1934 | 1.5 | 100 | 30 (good) |
| | 11.Tatireddipalle((Trp) | 788 | 0.61 | 100 | 23(moderate) |
| | 12.Kottalu(Ktl) | 372 | 0.29 | 100 | 23(moderate) |
| | 13.Santakovur(Skv) | 548 | 0.43 | 100 | 13(moderate) |
| | 14.Murarichintala ((Mct)-Tallalapalle(Tlp) | 508 | 0.39 | 60:40:00 | 23.2(moderate) |
| | 15.Cherlapalle(Cpl) | 184 | 0.14 | 100 | 22(moderate) |
| | 16.Balapanur(Bpr) | 6559 | 5.1 | 100 | 34(good) |
| | 17.Simhadripuram (Spm) | 7583 | 5.9 | 100 | 29(good) |
| | 18.Simhadripuram (Spm) - Agraharam((Ahm) | 9125 | 7.1 | 60:40:00 | 29.4(good) |
| | 19.Balapanur (Bpr) - Sunkesula(Skl) | 4294 | 3.34 | 60:40:00 | 32(good) |
| | 20.Vemula(Vml) | 1667 | 1.3 | 100 | 25(good) |
| | 21.Velpula(Vpl) | 1326 | 1.03 | 100 | 27(good) |
| | 22.Parnapalle(Prp) | 446 | 0.35 | 100 | 24(moderate) |
| | 23.Agraharam(Ahm) | 2690 | 2.09 | 100 | 30(good) |
| | 24.Sunkesula(Skl) | 2778 | 2.16 | 100 | 29(good) |
| | 25.Agraharam(Ahm)-Sunkesula(Skl) | 802 | 0.62 | 60:40:00 | 29.6(good) |
| | 26.Agraharam(Ahm)- Simhadripuram(Spm) | 369 | 0.29 | 60:40:00 | 29.6(good) |
| | 27.Sunkesula(Skl) - Simhadripuram(Spm) | 741 | 0.58 | 60:40:00 | 29(good) |
| | 28.Velpula (Vpl)- Vemula(Vml) | 712 | 0.55 | 60:40:00 | 26.2(good) |
| Colluvial - alluvial pediplains | 29. Bharampalle(Bpl)-Agadur(Agd) | 788 | 0.61 | 60:40:00 | 26.8(good) |
| | 30.Tondur(Tdr)-Pernapadu((Ppd) | 1351 | 1.05 | 60:40:00 | 21.8(moderate) |
| | 31.Tondur(Tdr) | 3568 | 2.77 | 100 | 21(moderate) |
| | 32.Agadur(Agd) | 633 | 0.49 | 100 | 25(good) |
| | 33. Pernapadu(Ppd)-Gondipalle(Gpl) | 853 | 0.66 | 60:40:00 | 23(moderate) |
| | 34.Tondur(Tdr)-Agadur(Agd) | 709 | 0.55 | 60:40:00 | 22.6(moderate) |
| | 35.Pulivendula(Pvd)-Pernapadu(Ppd) | 101 | 0.08 | 60:40:00 | 27.2(good) |
| | 36.Goturu(Gtr)-Gondipalle(Gpl) | 1501 | 1.17 | 60:40:00 | 20(moderate) |
| | 37.Pernapadu(Ppd) | 3689 | 2.87 | 100 | 23(moderate) |
| | 38.Pernapadu(Ppd)-Tondur(Tdr) | 4358 | 3.39 | 60:40:00 | 32(good) |
| | 39.Gondipalle(Gpl) | 1683 | 1.31 | 100 | 23(moderate) |
| | 40.Goturu(Gtr) | 1707 | 1.33 | 100 | 18(moderate) |
| | 41.Agadur(Agd)-Pernapadu(Ppd) | 3613 | 2.81 | 60:40:00 | 24.2(moderate) |
| | 42.Bhadrampalle(Bpl) | 448 | 0.35 | 100 | 28(good) |
| | 43.Pulivendula(Pvd) | 3540 | 2.75 | 100 | 30(good) |
| | Total | 128609 | 100 | | |

**Table 32.** Area under each soil quality class in Pulivendula

| Land form | SQR | SMU | Area | |
|---|---|---|---|---|
| | | | % | ha |
| Hills /ridges | poor | 1. Rock outcrops( R)-Kanampalli (Kpl) | 7953 | 6.18 |
| | | 3.Rockoutcrops(R)-Rachukuntapalle(Rkp) | 24939 | 19.39 |
| | | 4.Rockoutcrops(R) - Lingala(Lgl) | 6410 | 4.98 |
| | | 7.Rockoutcrops( R)-Mupendranpalle(Mpl) | 3572 | 2.78 |
| | | 8.Mupendranapalle(Mpl)-.Rockoutcrops( R) | 2464 | 1.92 |
| | | Sum | **45338** | **35.25** |
| | Moderate | 2.Rockoutcrops( R)-Ganganapalle(Ggp) | 7464 | 5.8 |
| | | 5. Rachakuntapalle(Rkp) - .Rockoutcrops( R) | 1333 | 1.04 |
| | | 6.Ganganapalle(Ggp) -Rockoutcrops( R) | 677 | 0.53 |
| Inter hill basin | | 9.Tallalapalle(Tlp) | 1829 | 1.42 |
| | Moderate | 11.Tatireddipalle((Trp) | 788 | 0.61 |
| | | 12.Kottalu(Ktl) | 372 | 0.29 |
| | | 13.Santakovur(Skv) | 548 | 0.43 |
| | | 14.Murarichintala ((Mct)-Tallalapalle(Tlp) | 508 | 0.39 |
| | | 15.Cherlapalle(Cpl) | 184 | 0.14 |
| | | 22.Parnapalle(Prp) | 446 | 0.35 |
| colluvial-alluvial sector | | 30.Tondur(Tdr)-Pernapadu((Ppd) | 1351 | 1.05 |
| | | 31.Tondur(Tdr) | 3568 | 2.77 |
| | | 33. Pernapadu(Ppd)-Gondipalle(Gpl) | 853 | 0.66 |
| | | 34.Tondur(Tdr)-Agadur(Agd) | 709 | 0.55 |
| | | 36.Goturu(Gtr)-Gondipalle(Gpl) | 1501 | 1.17 |
| | | 37.Pernapadu(Ppd) | 3689 | 2.87 |
| | | 39.Gondipalle(Gpl) | 1683 | 1.31 |
| | | 40.Goturu(Gtr) | 1707 | 1.33 |
| | | 41.Agadur(Agd)-Pernapadu(Ppd) | 3613 | 2.81 |
| | | **sum** | **32823** | **25.52** |
| Inter-hill basin | Good | 10.Murarichintala ((Mct) | 1934 | 1.5 |
| | | 16.Balapanur(Bpr) | 6559 | 5.1 |
| | | 17.Simhadripuram (Spm) | 7583 | 5.9 |
| | | 18.Simhadripuram (Spm) - Agraharam((Ahm) | 9125 | 7.1 |
| | | 19.Balapanur (Bpr) - Sunkesula(Skl) | 4294 | 3.34 |
| | | 20.Vemula(Vml) | 1667 | 1.3 |
| | | 21.Velpula(Vpl) | 1326 | 1.03 |
| | | 23.Agraharam(Ahm) | 2690 | 2.09 |
| | | 24.Sunkesula(Skl) | 2778 | 2.16 |
| | | 25.Agraharam(Ahm)-Sunkesula(Skl) | 802 | 0.62 |
| | | 26.Agraharam(Ahm)- Simhadripuram(Spm) | 369 | 0.29 |
| | | 27.Sunkesula(Skl) - Simhadripuram(Spm) | 741 | 0.58 |
| | | 28.Velpula (Vpl)- Vemula(Vml) | 712 | 0.55 |
| colluvial-alluvial sectors | | 29. Bharampalle(Bpl)-Agadur(Agd) | 788 | 0.61 |
| | | 32.Agadur(Agd) | 633 | 0.49 |
| | | 35.Pulivendula(Pvd)-Pernapadu(Ppd) | 101 | 0.08 |
| | | 38.Pernapadu(Ppd)-Tondur(Tdr) | 4358 | 3.39 |
| | | 42.Bhadrampalle(Bpl) | 448 | 0.35 |
| | | 43.Pulivendula(Pvd) | 3540 | 2.75 |
| | | **Sum** | **50448** | **39.23** |

### 13.2. Method 2. The Muencheberg soil quality rating

Out of twenty five soil series, nine series have moderate soil quality rating with maximum above 50 in case of Agraharam, Balapanur, Kottalu whereas the rating in between 40 and 50 in case of Parnapalle, Tondur, Gondipalle, Bhadrampalle, Velupula and Murarichintala series. Overall, the mean SQR is 33.78±1.44 per cent with coefficient of variation of 30.91 per cent. The SQR is positively and significantly related with clay, CEC, soil loss, organic carbon and pH that can explain 61 per cent of variability. This equation is given as given under: SQI = 34.03 - 0.42 (clay, %) + 0.38 (CEC, cmol/kg) – 55.46 (Soil loss, t/ha/yr) – 1.85(OC, g/kg) -3.96 (pH) adjusted $R^2$ = 0.51, $R^2$ =0.61 resdiual error 7.39 on 19 DF and F test value of 6.03 on 5 and 19df.

The soil quality of forty three soil mapping units are evaluated and classified in three categories as very poor, poor and moderate. The soil units under hills and ridges are rated as very poor as soils are shallow to extremely shallow with more than 60 per cent of coarse fragments in A-C horizons and mainly associated with rock outcrops. This quality rating is for farm land hence these soils are not suitable for banana and also have very poor quality. The area under this unit covers 54812ha (42.61 % of total mapped area of 128609ha). The eleven mapping units in colluvio-alluvial sector (22281ha, 17.32%) have poor SQR with mean of 33.25 ± 4.17% and coefficient of variation of 12.56 per cent. The ten soil mapping units in Interhill basin (17338ha, 13.48%) are rated as poor SQR with a mean of 33.53 ± 3.88 per cent and CV of 11.59. Out of twenty five soil series, nine series have moderate soil quality rating with maximum above 50 in case of Agraharam, Balapanur, Kottalu whereas the rating in between 40 and 50 in case of Parnapalle, Tondur, Gondipalle, Bhadrampalle, Velupula and Murarichintala series. Overall, the mean SQR is 33.78 ± 1.44 per cent with coefficient of variation of 30.91 per cent. Further, it is clear from the data that in interhill basin, 15325ha is evaluated as moderately to marginally suitable for banana with low organic carbon and exchangeable K.

In interhill basin, ten soil mapping units have moderate SQR with mean of 45.49±3.54% and CV of 7.29 per cent. This unit covers 27917ha (21.7% of total area) and only 25 537ha is adjudged as suitable for banana. In colluvio-alluvial sector, four soil mapping units have moderate SQR covering 6261 ha.

**Table 33.** Soil mapping unit wise SQR and Soil loss

| Landform | Soil mapping unit | Area | | Soil loss (t/ha/year) / soil erosion risk | | SQI | Quality rating |
|---|---|---|---|---|---|---|---|
| | | ha | (%) | | | | |
| Hills and ridges | 1. Rock outcrops( R)-Kanampalli (Kpl) | 7953 | 6.18 | 25.11 | high | 12.31 | Very poor |
| | 2.Rockoutcrops( R)-Ganganapalle(Ggp) | 7464 | 5.80 | 57.94 | high | 12.31 | Very poor |
| | 3.Rockoutcrops(R)-Rachukuntapalle(Rkp) | 24939 | 19.39 | 9.91 | high-medium | 13.32 | Very poor |
| | 4.Rockoutcrops(R) - Lingala(Lgl) | 6410 | 4.98 | 102.80 | extremely high | 14.74 | Very poor |
| | 5. Rachakuntapalle(Rkp) - .Rockoutcrops( R) | 1333 | 1.04 | 8.93 | high medium | 14.97 | Very poor |
| | 6.Ganganapalle(Ggp) - Rockoutcrops( R) | 677 | 0.53 | 57.94 | extremely high | 13.47 | Very poor |
| | 7.Rockoutcrops( R)-Mupendranpalle(Mpl) | 3572 | 2.78 | 8.6 | high medium | 15.43 | Very poor |
| | 8.Mupendranapalle(Mpl)-.Rockoutcrops( R) | 2464 | 1.92 | 8.56 | high medium | 18.14 | Very poor |
| Interhill basin | 9.Tallalapalle(Tlp) | 1829 | 1.42 | 8.97 | high medium | 25.50 | Poor |
| | 10.Murarichintala ((Mct) | 1934 | 1.50 | 8.90 | high medium | 46.43 | Moderate |
| | 11.Tatireddipalle((Trp) | 788 | 0.61 | 1.33 | low medium | 32.04 | Poor |
| | 12.Kottalu(Ktl) | 372 | 0.29 | 3.46 | Medium | 50.00 | Moderate |
| | 13.Santakovur(Skv) | 548 | 0.43 | 11.84 | High | 29.86 | Poor |
| | 14.Murarichintala ((Mct)-Tallalapalle(Tlp) | 508 | 0.39 | 8.92 | high medium | 38.06 | Poor |
| | 15.Cherlapalle(Cpl) | 184 | 0.14 | 5.27 | high medium | 34.29 | Poor |
| | 16.Balapanur(Bpr) | 6559 | 5.10 | 24.23 | Very high | 50.57 | Moderate |
| | 17.Simhadripuram (Spm) | 7583 | 5.90 | 1.82 | Low medium | 35.36 | Poor |
| | 18.Simhadripuram (Spm) - Agraharam((Ahm) | 9125 | 7.10 | 2.68 | medium | 41.27 | Moderate |
| | 19.Balapanur (Bpr) - Sunkesula(Skl) | 4294 | 3.34 | 3.65 | medium | 43.49 | Moderate |
| | 20.Vemula(Vml) | 1667 | 1.30 | 7.65 | High-medium | 34.50 | Poor |
| | 21.Velpula(Vpl) | 1326 | 1.03 | 4.12 | Medium | 42.00 | Moderate |
| | 22.Parnapalle(Prp) | 446 | 0.35 | 1.36 | Low-medium | 43.54 | Moderate |
| | 23.Agraharam(Ahm) | 2690 | 2.09 | 3.59 | Medium | 50.14 | Moderate |
| | 24.Sunkesula(Skl) | 2778 | 2.16 | 2.97 | Medium | 32.86 | Poor |
| | 25.Agraharam(Ahm)-Sunkesula(Skl) | 802 | 0.62 | 3.61 | Medium | 43.23 | Moderate |
| | 26.Agraharam(Ahm)-Simhadripuram(Spm) | 369 | 0.29 | 2.78 | Medium | 44.23 | Moderate |
| | 27.Sunkesula(Skl) - Simhadripuram(Spm) | 741 | 0.58 | 2.65 | Medium | 33.86 | Poor |
| | 28.Velpula (Vpl)- Vemula(Vml) | 712 | 0.55 | 5.36 | Hogh-medium | 39.00 | Poor |
| Colluvial - alluvial pediplains | 29. Bharampalle(Bpl)-Agadur(Agd) | 788 | 0.61 | 19.34 | High | 33.88 | Poor |
| | 30.Tondur(Tdr)-Pernapadu((Ppd) | 1351 | 1.05 | 85.36 | Extremely high | 41.08 | Moderate |
| | 31.Tondur(Tdr) | 3568 | 2.77 | 102.80 | Extremely high | 44.36 | Moderate |
| | 32.Agadur(Agd) | 633 | 0.49 | 1.86 | Low medium | 40.50 | Moderate |
| | 33. Pernapadu(Ppd)-Gondipalle(Gpl) | 853 | 0.66 | 5.68 | high medium | 31.74 | Poor |
| | 34.Tondur(Tdr)-Agadur(Agd) | 709 | 0.55 | 90.56 | Extremely high | 42.81 | Moderate |
| | 35.Pulivendula(Pvd)-Pernapadu(Ppd) | 101 | 0.08 | 15.32 | High | 34.71 | Poor |
| | 36.Goturu(Gtr)-Gondipalle(Gpl) | 1501 | 1.17 | 2.75 | Low-medium | 29.84 | Poor |
| | 37.Pernapadu(Ppd) | 3689 | 2.87 | 17.31 | High | 36.16 | Poor |
| | 38.Pernapadu(Ppd)-Tondur(Tdr) | 4358 | 3.39 | 85.36 | Extremely high | 39.44 | Poor |
| | 39.Gondipalle(Gpl) | 1683 | 1.31 | 3.10 | Medium | 25.11 | Poor |
| | 40.Goturu(Gtr) | 1707 | 1.33 | 1.33 | Low-medium | 33.00 | Poor |
| | 41.Agadur(Agd)-Pernapadu(Ppd) | 3613 | 2.81 | 15.36 | High | 38.76 | Poor |
| | 42.Bhadrampalle(Bpl) | 448 | 0.35 | 24.23 | Very high | 29.46 | Poor |
| | 43.Pulivendula(Pvd) | 3540 | 2.75 | 17.31 | High | 33.75 | Poor |
| | Total | 128609 | 100 | | | | |

## 13.2.Method

### 3. Soil quality index (SQI) in this methodology involves integration of physical and chemical properties

The SQIs for each soil mapping unit of Pulivendula tehsil are plotted as histograms as per landform wise for comparisons between units of SQI values. The indicators were transformed on the basis of their ability to attain critical level or range was scored as 1 and anyone below critical as 0. Later these were integrated into percentage quality rating (%Q rating) as %Q = Number of indicators that attain critical level / total number of indicators assessed X100.These ratings were further grouped as High (% Q rating > 65), medium (% Q rating 35 to 65) and low (<35% Q rating). The hills and ridges have 8 unit plots with medium quality SQI values but the soils are shallow and associated with rockutcrops. The 22 units in inter hill basin , are rated as medium to high quality One of the advantages of an index for assessing forest soil quality is that the index values tend to follow a normal distribution even though individual soil properties that are used to calculate the index are often non-normally distributed. The observed SQI values are shown for each soil mapping unit in histograms (fig. 25). The interhill basins have large areas of red and black soils and tends to have lower organic carbon and nutrient contents with a risk of soil-related crop productivity decline The variables that were expected to be strongly associated were found to have significantly high correlation coefficients. A strong positive correlation between soil pH and exchangeable Ca is expected because high pH soils tend to be calcareous because of the presence of carbonate minerals high in Ca. Exchange sites on clay minerals tend to have more Ca and Mg than other elements, thus accounting for the strong positive association between exchangeable Ca and Mg (K, Mg, and Ca) and SQI levels. In colluvio-alluvial sectors, 15 units are evaluated as medium level of soil quality with parameters viz., soil pH, Zn and Olsen's P below critical level and remaining units are rated as high.

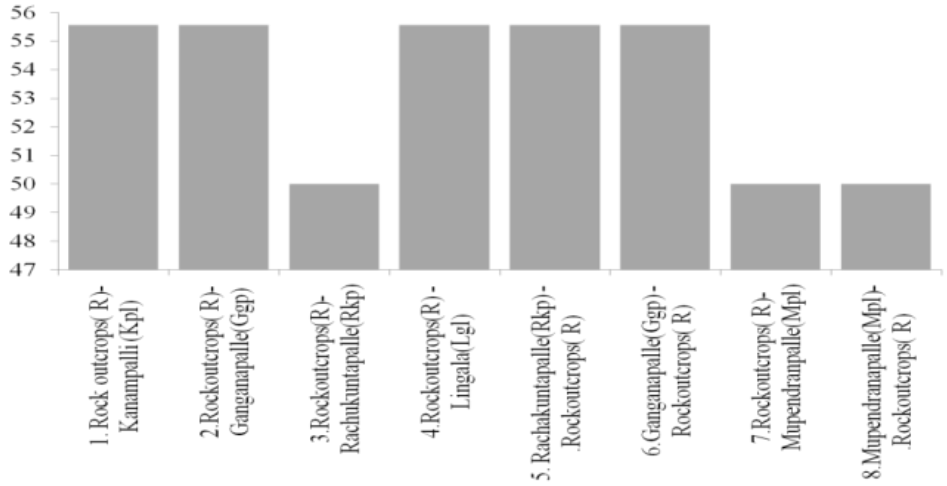
**Table 34.** SQR level of soil mapping units in Pulivendula region

| Land form | SMU | BD(Mg/m3) | Coarse fragment(% | Soil pH | Ca(Mg/kg) | Mg(mg/kg) | K(Mg/kg) | ESP | Mn | Fe | Cu | Zn | Olsen's P(mg/kg) | Available S9mg/kg) | Sum | SQR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hills and ridges | 1. Rock outcrops( R)-Kanampalli (Kpl) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 2.Rockoutcrops( R)- | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |

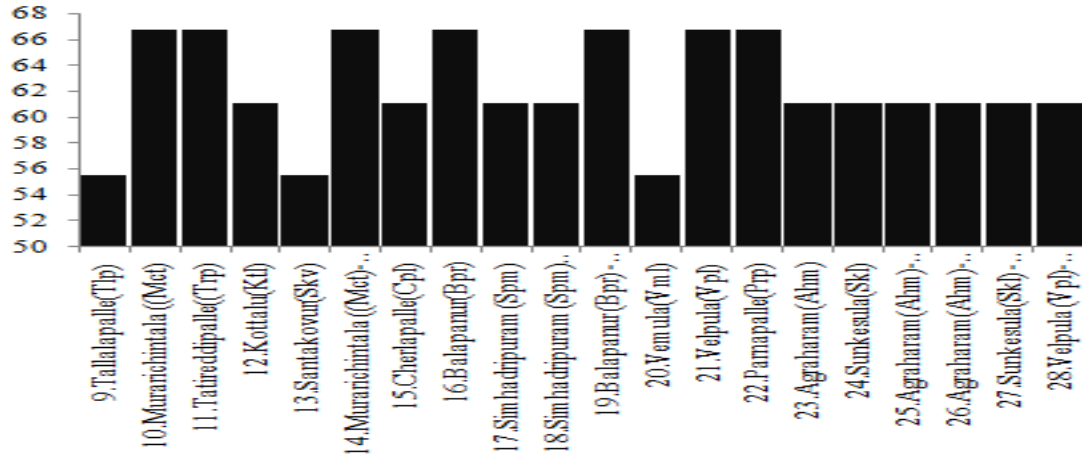
| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ganganapalle(Ggp) | | | | | | | | | | | | | | | |
| | 3.Rockoutcrops(R)-Rachukuntapalle (Rkp) | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 9 | 50.00 |
| | 4.Rockoutcrops(R) - Lingala(Lgl) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 5. Rachakuntapalle(Rkp) - .Rockoutcrops ( R) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 6.Ganganapalle (Ggp)-Rockoutcrops( R) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 7.Rockoutcrops( R)-Mupendranpalle (Mpl) | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 9 | 50.00 |
| | 8.Mupendranapalle( Mpl)-.Rockoutcrops( R) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 9 | 50.00 |
| Interhill basin | 9.Tallalapalle(Tlp) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 | 55.56 |
| | 10.Murarichintala ((Mct) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 11.Tatireddipalle (Trp) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 12.Kottalu(Ktl) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 13.Santakovur(Skv) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 | 55.56 |
| | 14.Murarichintala ((Mct)-Tallalapalle(Tlp) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 15.Cherlapalle(Cpl) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 16.Balapanur(Bpr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 17.Simhadripuram (Spm) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 18.Simhadripuram (Spm) - Agraharam((Ahm) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 19.Balapanur (Bpr) - Sunkesula(Skl) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 20.Vemula(Vml) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 | 55.56 |
| | 21.Velpula(Vpl) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 22.Parnapalle(Prp) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 12 | 66.67 |
| | 23.Agraharam(Ahm) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 24.Sunkesula(Skl) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 25.Agraharam(Ahm) -Sunkesula(Skl) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 26.Agraharam(Ahm) - Simhadripuram (Spm) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 27.Sunkesula(Skl) – Simhadripuram (Spm) | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 28.Velpula (Vpl)-Vemula(Vml) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| Colluvial-alluvial sectors | 29. Bharampalle(Bpl)-Agadur(Agd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 30.Tondur(Tdr)-Pernapadu((Ppd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 31.Tondur(Tdr) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 32.Agadur(Agd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 33. Pernapadu(Ppd)-Gondipalle(Gpl) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 11 | 61.11 |
| | 34.Tondur(Tdr)-Agadur(Agd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 35.Pulivendula(Pvd) -Pernapadu(Ppd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 36.Goturu(Gtr)-Gondipalle(Gpl) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 | 55.56 |
| | 37.Pernapadu(Ppd) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 11 | 61.11 |
| | 38.Pernapadu(Ppd)-Tondur(Tdr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 11 | 61.11 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 39.Gondipalle(Gpl) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 | 55.56 |
| | 40.Goturu(Gtr) | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 10 | 55.56 |
| | 41.Agadur(Agd)-Pernapadu(Ppd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 42.Bhadrampalle(Bpl) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | 43.Pulivendula(Pvd) | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 11 | 61.11 |
| | | | | | | | | | | | | | | | | |

A.Hills and ridges




B.Interhill basins



C.Colluvio-alluvial sectors

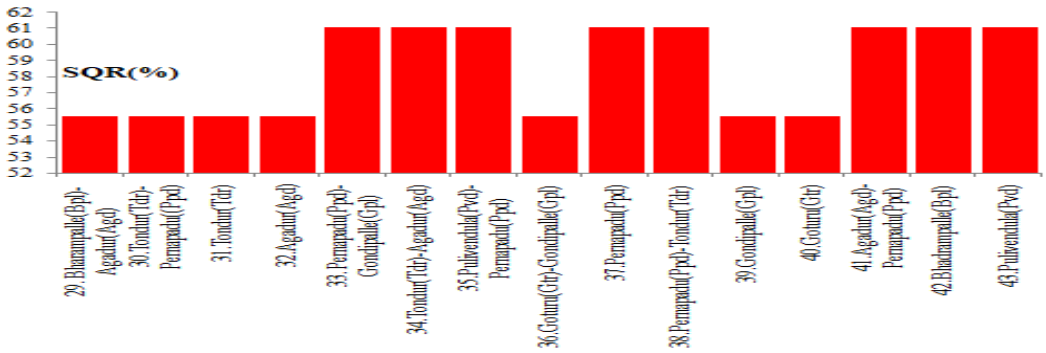



**Fig. 25**.SQR levels of each mapping unit in Pulivendula

## 14.0.Soil- site suitability analysis:

### 14.1.Groundnut (*Arachis hypogeae*)

The suitability evaluation for groundnut shows that only 23 soil mapping units are moderately suitable (Fig.26) with the limitations of rooting depth (r), topography (t) and salt content (z). The moderately suitable soil mapping units cover 56224ha (43 % of total area) consisting of 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 Vempalle (6894 ha, 27.39% of cultivated area) and Vemula (3613ha, 17.29% of cultivated area, Table 35)**.** There is a lot of scope to expand area under groundnut as the arability and irrigability analysis shows 42 per cent (56092ha) 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 / Vempalle mandals in south eastern parts.

**Table 35.** Soil site suitability for Groundnut (*Arachis hypogeae*)

| Suitability subclass | Landform | Soil mapping unit | Area | |
|---|---|---|---|---|
| | | | ha | % |
| S2tz | Interhill basin | Murarichintala (10) | 1934 | 1.5 |
| | | Kottalu(12) | 372 | 0.3 |
| | | Total | 2306 | 1.8 |
| | Gently sloping midlands | Balapanur(16) | 6599 | 4.9 |
| | | Simhadripuram (17) | 7583 | 5.7 |
| | | Simhadripuram-Agraharam(18) | 9125 | 6.8 |
| | | Parnapalli(22) | 446 | 0.3 |
| | | Agraharam(23) | 2690 | 2.0 |
| | | Agraharam - Simhadripuram (26) | 369 | 0.3 |
| | | Total | 26812 | 20.0 |
| | Colluvic-alluvial sector | Agadur(32) | 633 | 0.5 |
| | | Tondur – Agadur(34) | 709 | 0.5 |
| | | Pernapadu(37) | 3689 | 2.8 |
| | | Pernapadu – Tondur(38) | 4358 | 3.3 |
| | | Agadur – Pernapadu(41) | 3613 | 2.7 |
| | | Bhadrampalli(42) | 448 | 0.3 |
| | | Total | 13450 | 10.1 |
| S2zg | Gently sloping midlands | Vemula(20) | 1667 | 1.2 |
| | | Velpula(21) | 1326 | 1.0 |
| | | Velpula – Vemula(28) | 712 | 0.5 |
| | | Total | 3705 | 2.7 |
| S2rtz | Interhill basin | Tatireddipalli(11) | 788 | 0.6 |
| | | Santakovur(13) | 548 | 0.4 |
| | | Total | 1336 | 1.0 |
| | Gently sloping midlands | Balapanur - Sunkesula(19) | 4294 | 3.2 |
| | | Sunkesula(24) | 2778 | 2.1 |
| | | Agraharam – Sunkesula (25) | 802 | 0.6 |
| | | Sunkesula – Simhadripuram(27) | 741 | 0.6 |
| | | Total | 8615 | 6.5 |

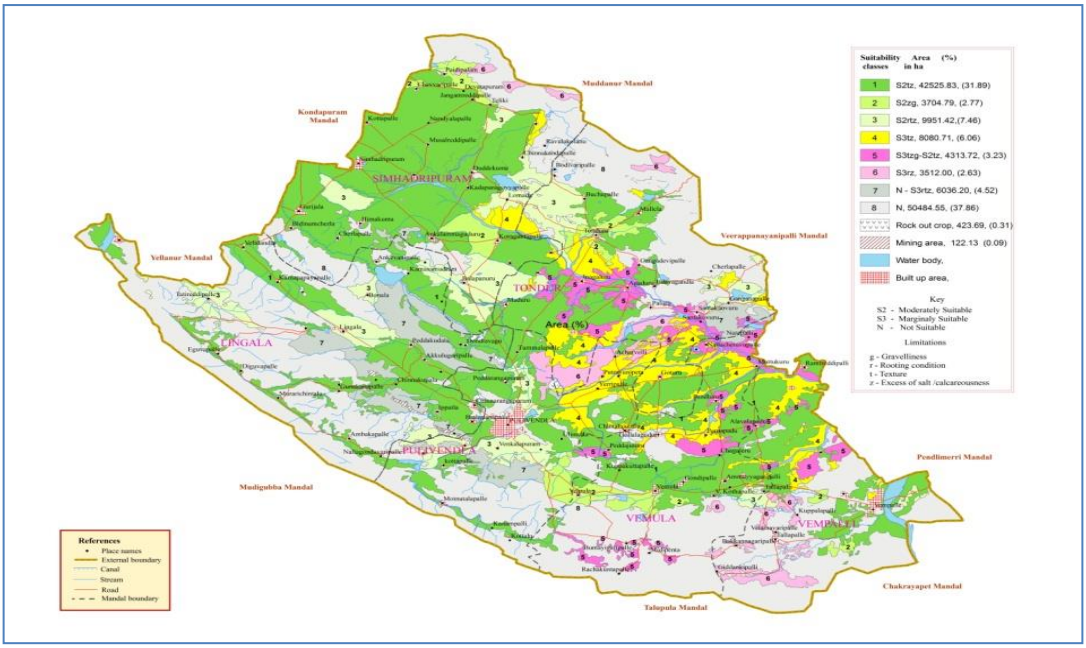



**Fig.26.** Soil-site suitability for groundnut in Pulivendula tehsil

## 14.2.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 90kgha$^{-1}$). The cost of cultivation of groundnut crop varied from a minimum of Rs 14025 (Pulivendula, 43) to Rs 31298(Agadur-32, Fig.25) 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

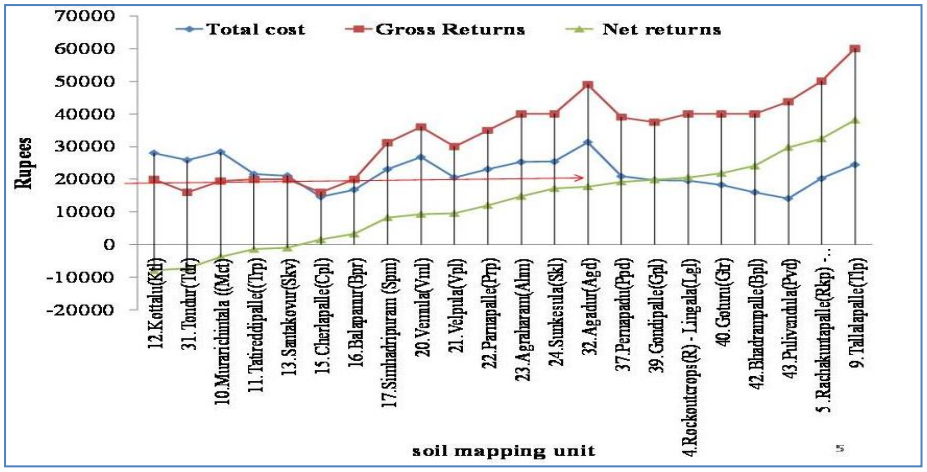



**Fig.27**. Soil mapping unit wise agro economic analysis for groundnut

### 14.3. 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 (56092ha) of arable land with 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 dry land 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 (54812ha, 42.62% of total area), interhill basins (45255ha, 35.19%of total area) and colluvio-alluvial landforms (28542ha, 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±39.32lakh hectares with coefficient of variation of 25.9 per cent and mean productivity of 623.57±294.94 kg/ha over a period of. This area received mean rainfall of 402.4±110.53mm 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 1080kg/ha is recorded under the south west monsoon rainfall of 259mm. 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 $40^0$C based on Prasad *et al* (2003) and monthly rainfall > 40mm and monthly aridity (De Martonne Aridity Index) < 20. The decadal mean and standard deviation for rainfall, mean temperature and De Martonne Aridity Index shows that this area receives mean annual rainfall of 679.59±237.52mm, of which the kharif rainfall contributes 340.69mm (50.28% of total rainfall) with a range mean air temperature of $30.7^0$C to $36.9^0$C 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 60mm but receives >135 mm rainfall during pod development phase (September). It is interesting to point out that mean annual rainfall of 250mm at the time of sowing with a deviation of -100 to + 100mm , 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 (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 varied from 10g/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 ± 46.57g/kg as against the soils on quartzite with mean of 20 ± 10g$kg^{-1}$. 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. 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-Fe is deficient in 57% of soils followed by 51% for DTPA-Zn. The deep black soils with sodic enriched clay is well distributed in north central parts of Pulivendula in 23533ha (18.29% of total area) with benfit cost ratio of 1:1.6 (Fig.25). 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) throughout the season, 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 the region (as evident from crop yield statistics and discussions with local farmers during surveys), there is a need for appraisal of land resources for suitability assessment for groundnut both in terms of physical and economics 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, soil map Fig.19). 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 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 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 is 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 is found that for 64% of cases in June there is no risk of pluvial erosion, in 50 % of cases in September / October (43%) favorable for triggering pluvial linear erosion (Table15).The critical seasonal erosion is in the month of September / October favouring high – medium soil erosion risk in the region in an area of 39142ha (31.16%) but extremely high erosion in Quartzite hills of Pulivendula in an area of 16364ha (13.03% of total area (Table 26 ).

### 14.4. Banana (Musa spps)

The agriculture land suitability evaluation is to predict the potential and limitation of the land for crop production (Pan and Pan, 2012) and also used for alternative kinds of agriculture (He, *et al*., 2011). The process of land suitability classes is based on the assessment of soil-site characteristics along with climate analysis (Sonneveld, *et al*., 2010). The agro climatic assessment of banana shows that climate is marginally suitable with mean annual rainfall of 679.59 ± 237.52 mm and mean air temperature of $30.7^0$C to $36.9^0$C with dry months more than 5 months (March to May). The aridity index is 18.43 indicating semi arid conditions wherein kharif rainfall contributes 340.69 mm (50.28% of total rainfall). However, banana requires 1,000 to1, 500mm (Sailesh Ranjitkar, *et al*., 2016), but grown as cash promising crop in substantially lower seasonality precipitation of Kadapa basin under drip irrigation. The suitable areas required for banana are flat areas and slopes of less than 12 degree.

The suitability of 43 soil mapping units for banana is evaluated using the criteria of Sys, *et al*. (1993). Based on Table 36, SMU 1 to 8 in hills and ridges (54812ha, 42.62% of total area) are not suitable for banana cultivation having strong association with rock outcrops. This unit consists of shallow gravelly soils (Kanampalle, Ganganapalle, Rachanakuntapalle, Mupendranapalle and Lingala series) with limitation of low water holding capacity, poor organic carbon, root restricting layers below 50cm and low available K/Zn. These units are potentially unsuitable but respond well to inputs use and conservation measures to upgrade to S3. The interhill basin covers 45255 ha (35.19% of total area) with 20 soil mapping units (SMUs). Among 20 SMUs, only 8 SMUs (viz., 12,18,21,23,24,25,26, and 28) are moderately suitable but needs careful management of organic carbon and covers 14.13 per cent of area in interhill basin (18174 ha) while 7 SMUs (22688ha,17.65% of area ), viz., 11,13,14,17,19,20 and 27 ) are marginally suitable with limitation of sub soil calcium carbonate, low organic carbon, strong alkalinity, coarse fragments and low available K and DTPA-Zn. The soil depth more than 100cm is ideal for banana cultivation but feeder roots confined to 45cm only (Shanmugavelu, *et al*., 1992). Fifteen soil mapping units (SMU 29 to 43) on colluvio-alluvial plains (28542ha, 22.19%) have very deep, moderately well drained, calcareous, strongly to moderately alkaline black soils with high shrink-swell potentials. Only five SMUs (32, 38, 40, 41 and 43) are marginally suitable for banana with limitations of coarse texture, coarse fragments, calcium carbonate, exchangeable Na/K and drainage

(Table 36). As a whole, it is estimated that 56091ha (38.33 per cent of area) is suitable for banana and spatially distributed from North West to south east all along the canal net work (Fig.28). The results from land evaluation for drip irrigation shows that among 13 units of marginally suitable for banana are evaluated 9 SMUs as highly suitable (34502 ha) whereas 8 SMUs (13882ha) are of moderately suitable. The results from land evaluation for drip irrigation shows that among 13 units of marginally suitable for banana are evaluated 9 SMUs as highly suitable (34502 ha) whereas 8 SMUs (13882ha) of moderately suitable are highly suitable for drip irrigation (Fig.29).

**Table 36.** Area and extent of soil-land form associations with suitability for banana under drip irrigation

| Land form | Soil mapping unit | area | | Banana | | Drip | |
|---|---|---|---|---|---|---|---|
| | | ha (hectares) | Per cent (%) | Rating | Suitability class | Rating | Suitability class |
| Hills and ridges | 1.Rockoutcrops ( R)-Kanampalli(Kpl) | 7953 | 6.18 | 3.34 | N2 | 17.96 | N2 |
| | 2. Rockoutcrops®- -Ganganapalle(Ggp) | 7464 | 5.80 | 9.65 | N2 | 21.60 | N2 |
| | 3. Rockoutcrops®-Rachanakuntapalle(Rkp) | 24939 | 19.39 | 3.72 | N2 | 24.30 | N2 |
| | 4. Rockoutcrops®--Lingala(Lgl) | 6410 | 4.98 | 4.26 | N2 | 25.52 | N2 |
| | 5. Rachanakuntapalle(Rkp) –rockoutcrops® | 1333 | 1.04 | 4.12 | N2 | 53.20 | N2 |
| | 6.Ganganapalle(Ggp)-Rockoutcrops® | 677 | 0.53 | 16.40 | N2 | 33.25 | N2 |
| | 7.Rockoutcrops®-Mupendranpalle(Mpl) | 3572 | 2.78 | 15.60 | N2 | 29.93 | N2 |
| | 8. Mupendranpalle(Mpl)-Rockoutcrops® | 2464 | 1.92 | 11.32 | N2 | 76.95 | S1 |
| Interhill basin | 9.Tallalapalle(Tlp) | 1829 | 1.42 | 14.21 | N2 | 90.25 | S1 |
| | 10.Murarichintla(Mct) | 1934 | 1.50 | 15.83 | N2 | 85.50 | S1 |
| | 11. Tatireddipalle(Trp) | 788 | 0.61 | 49.42 | S3 | 95.00 | S2 |
| | 12. Kottalu(Ktl) | 372 | 0.29 | 69.04 | S2 | 68.40 | S1 |
| | 13. Santhakovur(Skv) | 548 | 0.43 | 41.42 | S3 | 72.20 | S1 |
| | 14. .Murarichintala(Mct)-Tallapalle(TlP) | 508 | 0.39 | 43.73 | S3 | 95.00 | S3 |
| | 15. Cherlapalle(Cpl) | 184 | 0.14 | 19.81 | N1 | 85.50 | S1 |
| | 16. Balapanur(Bpr) | 6559 | 5.10 | 41.18 | S3 | 95.00 | S1 |
| | 17. Simhadripuram(Spm) | 7583 | 5.90 | 43.73 | S3 | 90.25 | S1 |
| | 18. Simhadripuram(Spm)-Agraharam(Ahm) | 9125 | 7.10 | 61.29 | S3 | 67.50 | S1 |
| | 19. Balapanur(Bpr)-Sunkesula(Skl) | 4294 | 3.34 | 52.89 | S3 | 56.53 | S1 |
| | 20. Vemula(Vml) | 1667 | 1.30 | 40.00 | S3 | 85.50 | S2 |
| | 21. Velpula(Vpl) | 1326 | 1.03 | 68.64 | S2 | 85.74 | S1 |
| | 22. Parnapalle(Prp) | 446 | 0.35 | 30.78 | N1 | 90.25 | S2 |
| | 23. Agraharam(Ahm) | 2690 | 2.09 | 76.71 | S2 | 90.25 | S1 |
| | 24. Sunkesula(Skl) | 2778 | 2.16 | 64.60 | S2 | 90.25 | S2 |
| | 25. Agraharam(Ahm)-Sunkesula(Skl) | 802 | 0.62 | 71.87 | S2 | 80.75 | S2 |
| | 26. Agraharam(Ahm)-Simhadripuram(Spm) | 369 | 0.29 | 66.82 | S2 | 17.96 | s1 |
| | 27. Sunkesula(Skl)-Simhadripuram(Spm) | 741 | 0.58 | 58.34 | S3 | 21.60 | S2 |
| | 28. . Velpula(Vpl)- . Vemula(Vml) | 712 | 0.55 | 61.16 | S2 | 24.30 | S2 |
| Colluvial-alluvial | 29. Bhadrampalle(Bpl)- | 788 | 0.61 | 29.84 | N1 | 25.52 | S2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| pediplains | Agadur(Agd) | | | | | | |
| | 30.Tondut(Tdr)-Pernapadu(Ppd) | 1351 | 1.05 | 31.12 | N1 | 53.20 | S1 |
| | 31.Tondur(Tdr) | 3568 | 2.77 | 29.07 | N1 | 33.25 | S1 |
| | 32. Agadur(Agd) | 633 | 0.49 | 48.45 | S3 | 29.93 | S1 |
| | 33.Pernapadu(Ppd)-Gondipalle(Gpl) | 853 | 0.66 | 29.17 | N1 | 76.95 | S2 |
| | 34. Tondur(Tdr)- Agadur(Agd) | 709 | 0.55 | 34.88 | N1 | 90.25 | S1 |
| | 35.Pulivendula(Pvd)-Pernapadu(Ppd) | 101 | 0.08 | 23.27 | N2 | 85.50 | S1 |
| | 36.Goturu(Gtr)-Gondipalle(Gpl) | 1501 | 1.17 | 33.80 | N1 | 95.00 | S1 |
| | 37. Pernapadu(Ppd) | 3689 | 2.87 | 34.20 | N1 | 68.40 | S1 |
| | 38. Pernapadu(Ppd)- Tondur(Tdr) | 4358 | 3.39 | 32.15 | N1 | 72.20 | S1 |
| | 39. Gondipalle(Gpl) | 1683 | 1.31 | 22.72 | N1 | 95.00 | S3 |
| | 40. Goturu(Gtr) | 1707 | 1.33 | 41.18 | S3 | 85.50 | S1 |
| | 41. Agadur(Agd)-Pernapadu(Ppd) | 3613 | 2.81 | 42.75 | S3 | 95.00 | S1 |
| | 42. Bhadrampalle(Bpl)- | 448 | 0.35 | 17.44 | N2 | 90.25 | S1 |
| | 43. Pulivendula(Pvd) | 3540 | 2.75 | 15.99 | N2 | 67.50 | S1 |
| | Total | 128609 | 100 | | | 56.53 | |

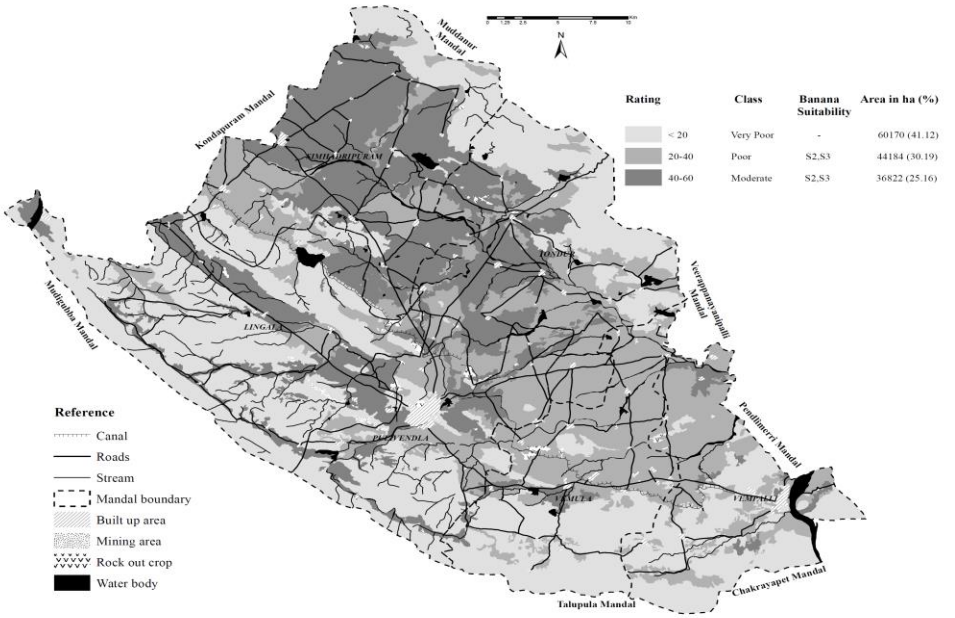



**Fig.28**. Map showing soil quality and suitability for banana in Pulivendula tehsil

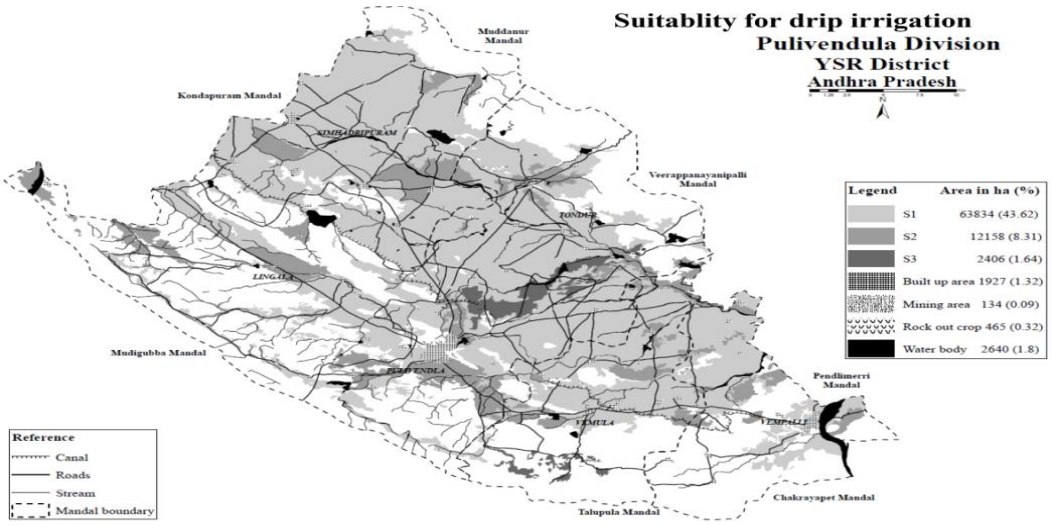



**Fig. 29.** Suitability map for drip irrigation

## Conclusions and Recommendations

Land resources forms the basis for human survival and development since the 20th century, due to the deteriorating ecological environment, increased food demand caused by rapid population growth, the rapid development of urbanization and industrialization, and the unreasonable development and utilization of land resources by human beings, worldwide land degradation has been increasing and worsening. In the present study, Pulivendula tehsil of YSR Kadapa district is selected to identify visual signatures of dry land degradation. The land resource data on 1:25000 scales was used along with field investigations in selected sites and analyzed the regional climatic and crop data in support of objectives of study. The following conclusions are drawn as given under:

The climatic analysis in relation to pedological systems of hot arid ecosubregion (K6E2) of Pulivendula tehsil of Kadapa district is critically examined for rain fed 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 ± 237.52mm, of which the kharif rainfall contributes 340.69mm but deficit of 60mm to that critical rainfall of 400mm (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 De Martonne Aridity Index (Im) below 15 is reported for June to September to define climate as semiarid and index of moisture (Im) lower than 20, then the land in this month needs to be irrigated (Zambakas, 1992). Angot pluvial index was computed using the climate data registered at Kadapa station over 109 years (1901 to 2010). On an yearly basis, the March–October interval marks the season of the year most affected by 5 to 10mm rainfall events , while the upper threshold (20 mm) is confined to August to October with high – intensity of rainfalls having a probability > 50% (Dragota, 2006). It is estimated that the frequency of occurrence of very dry spells is in the order of January, February and March, 98 per cent in April, 67 in May and 64 in June with equally dry spells of 37 in June/July. 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.

These soils are grouped into five depth classes and eight textural classes but dominance of clay soils (>50 per cent) in the region. The mean clay for A horizons is 39.64±14.25% with a range of 12.7% in P18 to 60.2% in P21. These soils are slightly to strong alkalinity (pH 8.5) with mean organic carbon of 7.26 ± 3.13gkg$^{-1}$and mean calcium carbonate of 87.62 ± 46.57g/kg in soils on shale. The high pH (>9.0) in B horizons have strong positive and significant at 1% level correlate with $CaCO_3$(r = 0.52**) and exchangeable sodium (r = 0.39* table value of 0.37 DF of 45). The organic carbon have a mean of 13.58 ± 4.24 gkg$^{-1}$ showing negative correlation with pH (r = - 0.55**, p = 0.01level, table value of 0.48) and exchangeable sodium (r = 0.38*, p =0.05 level, table value of 0.38). The mean CEC is 23.93 ± 7.64 coml.(+)kg$^{-1}$ in soils on quartzite as against the soils on shale with mean CEC of 30.52 ± 13.12 coml.(+)kg$^{-1}$. The data shows that seventy two per cent of soils have high (48%) to very high CEC (24%) and confine to gently sloping areas with high clay content. The one way ANOVA analysis shows that there is a significant difference between the horizons for sand, clay, organic carbon and CEC at p <0.01 where as pH, EC and ESP at p < 0.05 level. The soils identified and mapped in the study area fall under four orders (Alfisols, Entisols, Inceptisols and Vertisols), five suborders (Ustalfs, Orthents, Aquepts, Ustepts and Usterts) seven greatgroups (Paleustalfs, Rhodustalfs, Haplustalfs, Ustorthents, Halaquepts, Haplustepts and Haplusterts), twelve subgroups, eighteen families and twenty five series. Alfisols cover about 6367 ha (4.8 %), Entisols about 5477 ha (4.1 %),

Inceptisols 47342 ha (35.5 %) and Vertisols 31118 ha (23.3 %). Twenty five soil series were identified and prepared soil map of 43 mapping units. The soils on quartzitic hills and ridges have eight mapping units mostly associated with rock outcrops, and covers 54812hectare (42.62% of total area) whereas soils on shale landforms cover 73797ha (57.4% of total area).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 Santakovur series (SVK) with medium susceptible to water erosion ( K = 0.30–0.4). The soil erodibility was evaluated as per CORINE model and rated as per the scheme. The results of erodibility of hill land soils show that the soils with a textural sequence of scl-cl (SMU-1, 3 &5,) have high (SMU-1) to moderate erodibility (SMU3&5). The SMU 2, 6, 7 & 8 have textural class of sc-c with low to moderate erodibility. The highly erodible soils (SMU -1) cover 7953 ha (6.18%), moderately erodible soils (SMU 2, 3, 5& 6) of 34413 ha (26.76%) and low erodible soils of 12446 ha (9.68%). The results of Potential soil erosion risk showed that about 62.62% of area was classified under high erosion risk and 33.85% of area under moderate erosion risk level. In this context 80 % of the study areas is not fully protected area. The estimated area under high actual erosion risk levels is 66.96 % of toil area as against the PSER of 62.62% of area. The high level of potential erosion risk area decreases when it is evaluated as actual erosion risk assessment indicating the effect of vegetation cover on erosion risk. The land use changes significantly influence actual and potential erosion risks at a given time scale in the region.

Using 10 biophysical properties as per (McGary, 2006), the forty three mapping units were evaluated in three landforms of Pulivendula tehsil. Among 8 soil mapping units, five units have poor quality whereas three units are rated as moderate. Out of twenty soil mapping units , seven are rated as moderate and others as good in interhill basins. In colluvio - alluvial sectors, fifteen mapping units are evaluated and rated. Seven units are moderate while others as good. It is estimated that poor quality soils occupy 35.25% of total area (45338ha) wherein shallow soil series are mostly associated with rock outcrops as dominant feature. Both interhill basins and colluvio-alluvial sectors, the moderate quality of soils cover 25.25% of total area (32823ha) where as good quality soils accounts to 39.23% (50448ha). The Muencheberg soil quality rating of forty three soil mapping units are evaluated and classified in three categories as very poor, poor and

moderate. The soil units under hills and ridges are rated as very poor as soils are shallow to extremely shallow with more than 60 per cent of coarse fragments in A-C horizons and mainly associated with rock outcrops. This quality rating is for farm land hence these soils are not suitable for banana and also have very poor quality. The area under this unit covers 54812ha (42.61 % of total mapped area of 128609ha). The eleven mapping units in colluvio-alluvial sector (22281ha, 17.32%) have poor SQR with mean of 33.25±4.17% and coefficient of variation of 12.56 per cent. The ten soil mapping units in Interhill basin (17338ha, 13.48%) are rated as poor SQR with a mean of 33.53±3.88 per cent and CV of 11.59. The measured soil properties were used to derive soil quality. The hills and ridges have 8 unit plots with medium quality SQI values but the soils are shallow and associated with rock outcrops. The 22 units in inter hill basin , are rated as medium to high quality One of the advantages of an index for assessing forest soil quality is that the index values tend to follow a normal distribution even though individual soil properties that are used to calculate the index are often non-normally distributed.

The ‘good growth plan for groundnut demands drought tolerant varieties suitable for three dominant landscape positions such as hills and ridges (54812ha, 42.62% of total area), interhill basins (45255ha, 35.19%of total area) and colluvio - alluvial landforms (28542ha, 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 23533ha (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 have erodability16364ha (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. The results from suitability analysis of banana under drip irrigation show that 56091ha of land in interhill basins and colluvio-alluvial deposits are evaluated as suitable (S2 and S3) for banana cultivation as against the current area of 22000ha. Further the study shows that 34502ha of suitable land for banana is evaluated as highly suitable for drip irrigation system with an extremely high erosion risk area of 16364 ha. The suggested land conservation

directives are construction of bench terraces with rocks and planted with vetiver grass on the edges of the terrace.

Pulivendula tehsil in Kadapa district is a part of drought prone area and often experiences severe groundnut yield loss, thus making ideal to study the effect of climate change in developing and evaluating sustainable land management options to meet local needs and priorities. The present scientific analysis focus on two complementary approaches such as sustainable intensification (land resource data base for identifying suitable mapping units for groundnut cultivation) and climate smart agriculture to mitigate extremes of climate through increasing agricultural productivity of small farm holders and strengthening ecosystems to combat droughts. To tap the possibilities these approaches, mapping and assessment of land resources were made on 1:25000 scale to derive soil map with 45 units as series associations. It is estimated that hills/ridges cover 42.62% of total area with poor soil water conservation structures such check dams, contour rock walls, contour furrows, micro catchments, terraces, water reservoirs and retaining dams and severe loss of vegetative cover on the steep hillsides, are most widespread and contributing to high runoff rate and high erosion risk zones (13.03% of total area). The results from the study led to the conclude that combining crop residue with organic amendment and runoff hedges is the best treatment for steep slope areas, although it is crucial to manage the pigeon-pea (runoff) hedges to achieve higher groundnut yield. The agropedological approach facilitates to capture a greater range of climatic conditions and evaluate the biophysical and socio-economic benefits of the most promising SLM technique — residue mulch combined with pigeon-pea hedges against the traditional baseline practice of groundnut – pigeon pea intercropping. It is strongly advocated in semi-arid regions to have long-term historic rainfall statistics to provide a unique time-series of rainfall scenarios to express the agricultural and soil erosion risk associated with climate variability and the potential of the conservation measures to absorb climatic variability through technological innovations. The landscapes of Pulivendula of Cuddapah basin reveals the rich stories of past with complex geological evolution and also reflections of regional economy, agro ecology and cultural values of farming communities. The terrain include the rugged and spectacular ferruginous quartzite hill Ranges; the basaltic caps of western plains; and the majestic gorges of Gondikota formations of Chitravathi and Penneru river basins with scattered *prosopis* throughout the grazing lands. The objective of soil-landscape assessment is to define the

character and significance of the landscapes of Pulivendula; to understand the changes in soil-landscape properties in the event of future agricultural land use and to design and manage the landscape aesthetic values for future generations.

The general recommendations for hill/ridges to improve the soil health are : (a) The top soils ripping with suitable sub-soiling mixing through disc plough to loosen the soils for good aeration and favour deep rooted crops to be grown. The heap should be used to cultivate with dwarf grasses such as *Doctyloctenium aegyptiuman, Aristida adscensionis* and *Digitaria setigera* to prevent erosion and gully formation.

(c) The surface vegetation should be actively maintained with seeding and weed control operations.

The hills/ridges are mostly suitable for agro-forestry systems as mentioned below for restoration of soil organic carbon and to check soil erosion.

- **Grasses/ legumes**: *Bothriochola intermedia, B. pertusa, Cenchrus setigerus* and *Chrysopogan fulvus* and *Clitoria ternatea, Desmanthus virgatus, Desmodium tortosum* and *Stylosanthes hamata*.
- **Leguminous trees/ shrubs**: *Albizia procera, A. lebbeck, A. amara, Acacia nilotica, A. tortilis, Pongamia pinnata, Sesbania aegyptiaca, Dichostachys corten* and *D. cineraria*.
- **Field crops** : *Cajanus cajan, Pennisetum typhoides, Phaseolus mungo* and *P. aureus*

In Pulivendula region, around 22,043 ha (16.8%) are under strongly sloping to steeply sloping with shallow soils. These areas require soil conservation along with agro forestry practices. The contour and graded bunding and bench terracing are designed for under different slopes as permanent structures, which can be termed as ‘hardware’ treatments.

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## Appendix

**Table 6.1.** Mandal wise descriptive statistics for area and population data of villages

| Mandals | | Total area (ha) | Total population | Number of house holds | Net area sown(ha) | Total irrigated area(ha) | Pe capita land (ha) | Per capita netsown area(ha) | Per capita irrigate land(ha) |
|---|---|---|---|---|---|---|---|---|---|
| 1.Simhadripuram (21villages) | | | | | | | | | |
| mean | | 1397.95 | 1640.95 | 427.20 | 686.76 | 201.54 | 1.46 | 0.49 | 0.17 |
| sd | | 952.24 | 1693.04 | 435.75 | 564.12 | 234.54 | 1.31 | 0.17 | 0.19 |
| Cv(%) | | 68.12 | 103.17 | 102.00 | 82.14 | 116.38 | 89.82 | 35.62 | 116.24 |
| Kurtosis | | 0.41 | 1.91 | 1.71 | 1.24 | 0.77 | 6.33 | 0.10 | 5.85 |
| Skewness | | 1.05 | 1.60 | 1.55 | 1.34 | 1.29 | 2.28 | -0.87 | 2.20 |
| Confidence intervalat 95% level | Lower limit | 980.62 | 980.62 | 980.62 | 980.62 | 980.62 | 0.89 | 0.41 | 0.08 |
| | Upper limit | 1815.28 | 1815.28 | 1815.28 | 1815.28 | 1815.28 | 1.87 | 0.90 | 0.25 |
| K-S test | | 0 .18 | 0.25 | 0.24 | 0.16 | 0.22 | 0.24 | 0.16 | 0 .21 |
| p | | 0.53 | 0.13 | 0.16 | 0.61 | 0.24 | 0.17 | 0.60 | 0.26 |
| total | | 27959.00 | 32819.00 | 8534.00 | 13735.10 | 4030.70 | | | |
| 2.Lingala (18 villages) | | | | | | | | | |
| mean | | 4146.83 | 4339.52 | 1366.48 | 2233.33 | 820.15 | 14.85 | 4.68 | 15.65 |
| sd | | 9645.56 | 10708.82 | 2753.71 | 4687.44 | 1349.02 | 33.11 | 12.51 | 40.69 |
| Cv(%) | | 232.60 | 246.77 | 201.52 | 209.89 | 164.48 | 222.90 | 267.56 | 259.94 |
| Kurtosis | | 7.88 | 8.86 | 7.79 | 7.59 | 4.25 | 6.93 | 7.96 | 7.94 |
| Sk | | 0.50 | 1.02 | 1.04 | 0.84 | 1.50 | 2.61 | 2.42 | 1.16 |
| Confidence interval at 95% level | Lower limit | 1029.00 | 1120.34 | 284.74 | 500.28 | 162.28 | 0.70 | 0.40 | 0.11 |
| | Upper limit | 4146.83 | 4339.52 | 568.70 | 1037.21 | 352.22 | 2.16 | 0.93 | 0.32 |
| KS test | | 0.12 | 0.14 | 0.12 | 0.15 | 0 .12 | 0.38 | 0.35 | 0 .33 |
| p value | | 0.93 | .86843. | 0.93 | 0.72 | 0.92 | 0.007. | 0.02 | 0.02 |
| Total | | 26012.00 | 29945.00 | 7681.00 | 13837.30 | 4630.50 | | | |
| 3.Pulivendula (7villages) | | | | | | | | | |
| mean | | 1401.00 | 1882.57 | 490.86 | 642.86 | 147.19 | 1.49 | 0.67 | 0.08 |
| sd | | 1454.24 | 3091.17 | 778.21 | 687.69 | 268.45 | 1.05 | 0.52 | 0.04 |
| Cv | | 103.80 | 164.20 | 158.54 | 106.97 | 182.39 | 70.52 | 77.35 | 51.00 |
| kurtosis | | 4.62 | 6.55 | 6.48 | 4.05 | 6.91 | 0.07 | 0.48 | 2.03 |
| Skewness | | 2.09 | 2.53 | 2.52 | 1.96 | 2.62 | 0.85 | 0.94 | 1.49 |
| Confidence interval at 95% level | Lower limit | 323.70 | -407.36 | -85.67 | 133.42 | -51.68 | 0.71 | 0.29 | 0.05 |
| | Upper limit | 2478.30 | 4172.50 | 1067.35 | 1152.49 | 346.05 | 2.27 | 1.06 | 0.11 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| KS test | | 0.29 | 0.43 | 0.42 | 0 .27 | 0.47 | 0.19 | 0 .24 | 0.29 |
| p value | | 0.50 | 0 .11 | 0.12 | 0.58 | 0.06 | 0.94 | 0 .74 | 0.49 |
| Total | | 9807.00 | 13178.00 | 3436.00 | 4500.00 | 1030.30 | | | |
| 4.Thondur (17 villages) | | | | | | | | | |
| mean | | 3340.31 | 5226.82 | 1027.85 | 2054.93 | 505.62 | 8.00 | 7.55 | 5.07 |
| sd | | 7044.83 | 9058.89 | 2120.16 | 4109.02 | 1219.20 | 21.98 | 23.15 | 15.25 |
| Cv(%) | | 210.90 | 173.32 | 206.27 | 199.96 | 241.13 | 274.70 | 306.83 | 300.86 |
| Kurtosis | | 9.42 | 6.20 | 8.28 | 8.30 | 12.22 | 9.97 | 10.99 | 10.94 |
| Skewness | | 2.99 | 2.45 | 2.83 | 2.83 | 3.44 | 3.16 | 3.32 | 3.31 |
| Confidence interval at 95% level | Lower limit | 2808.47 | 4781.11 | 921.78 | 1814.17 | 432.46 | 7.77 | 7.42 | 5.03 |
| | Upper limit | 3872.15 | 5672.54 | 1134.55 | 2295.69 | 578.78 | 8.23 | 7.67 | 5.10 |
| KS test | | 0 .19 | 0.16 | 0.18 | 0.14 | 0.24. | 0.13 | 0.16 | 0.18 |
| p value | | 0.45 | 0.70 | 0.58 | 0.81 | 0.22 | 0.85 | 0.68 | 0.53 |
| Total | | 24704.00 | 23964.00 | 6120.00 | 14002.30 | 2259.30 | | | |
| 5.Vemula (12 villages) | | | | | | | | | |
| mean | | 5249.13 | 5431.78 | 1282.48 | 3060.90 | 656.52 | 47.69 | 52.42 | 49.37 |
| sd | | 8225.16 | 7690.78 | 1948.80 | 4641.73 | 753.92 | 100.27 | 112.36 | 110.98 |
| Cv(%) | | 156.70 | 141.59 | 151.96 | 151.65 | 114.84 | 210.27 | 214.35 | 224.81 |
| Kurtosis | | 6.00 | 4.73 | 5.78 | 5.87 | 2.62 | 6.92 | 6.93 | 6.97 |
| Skewness | | 2.37 | 2.04 | 2.31 | 2.34 | 1.63 | 2.63 | 2.63 | 2.64 |
| Confidence interval at 95% level | Lower limit | 4652.04 | 4656.51 | 1078.02 | 2718.13 | 594.62 | 47.47 | 52.27 | 49.35 |
| | Upper limit | 5846.22 | 6207.05 | 1486.94 | 3403.67 | 718.41 | 47.90 | 52.56 | 49.39 |
| KS test | | 0.22 | 0.13 | 0.12 | 0 .21 | 0 .19 | 0.16 | 0.24 | 0.27 |
| p value | | 0.52 | 0.96 | 0.97 | 0.55 | 0.67 | .085 | 0.43 | 0.27 |
| Total | | 21417.00 | 29160.00 | 7477.00 | 12825.50 | 2207.50 | | | |
| 6.Vempalli (11 villages) | | | | | | | | | |
| mean | | 5694.33 | 6661.81 | 1679.16 | 3351.22 | 631.26 | 66.17 | 61.74 | 54.89 |
| sd | | 7074.46 | 9592.79 | 2454.96 | 4218.31 | 713.89 | 71.30 | 72.08 | 73.40 |
| Cv(%) | | 124.24 | 144.00 | 146.20 | 125.87 | 113.09 | 107.76 | 116.74 | 133.72 |
| Kurtosis | | 3.89 | 5.71 | 5.97 | 4.21 | 3.76 | 2.94 | 2.52 | 3.49 |
| Sk | | 1.81 | 2.27 | 2.34 | 1.89 | 1.72 | 1.64 | 1.57 | 1.83 |
| Confidence interval at 95% level | Lower limit | 5136.75 | 576.64 | 236.39 | 3003.70 | 556.44 | 65.89 | 61.60 | 54.87 |
| | Upper limit | 6251.91 | 12746.98 | 3121.93 | 3698.74 | 706.08 | 66.44 | 61.89 | 54.92 |
| KS test | | 0.19 | 0.36 | 0 .41 | 0.29 | 0.27 | 0.17 | 0.14 | 0.20 |
| P value | | 0.72 | 0.07 | 0.03 | 0.24 | 0 .31 | 0.84 | 0.93 | 0 .68 |

**General evaluation some soil physical and chemical properties (Source : London, 1991; Msanya et l.1996)**

1.Organic carbon

| | Very low | low | medium | High | Very high |
|---|---|---|---|---|---|
| Organic carbon (%) | <0.60 | 0.6-1.25 | 1.26-2.50 | 2.51-3.50 | >3.5 |

2.Soil reaction

| | | | |
|---|---|---|---|
| Extremely acid | <4.5 | Neutral | 6.6-7.3 |
| Very strongly acid | 4.50-5.0 | Slightly alkaline | 7.4-7.8 |
| Strongly acid | 5.1-5.5 | Moderately alkaline | 7.9-8.4 |
| Moderately acid | 5.6-6.0 | Strongly alkaline | 8.5-9.0 |
| Slightly acid | 6.1-6.5 | Very strongly alkaline | >9.0 |

3.Cation Exchange capacity

| cmol/kg | Very low | low | medium | High | Very high |
|---|---|---|---|---|---|
| CEC(cmol/kg) | <6.0 | 6-12 | 12.1-25.0 | 25-40 | >40 |

4.Exchangeable calcium

| cmol/kg | Very low | low | medium | High | Very high |
|---|---|---|---|---|---|
| Ca in clay soils rich in 2:1 clay minerals | <2.0 | 2.0-5.0 | 5.1-10.0 | 10.1-20.0 | >20 |
| Ca (loamy soils) | <0.5 | 0.5-2.0 | 2.1-4.0 | 4.1-6.0 | >6.0 |
| Ca(Kaolinitic and sandy soils) | <0.2 | 0.2-0.5 | 0.6-2.5 | 2.6-5.0 | >5.0 |

5.Exchangeable magnesium

| cmol/kg | Very low | low | medium | High | Very high |
|---|---|---|---|---|---|
| Mg in clay soils rich in 2:1 clay minerals | <0.3 | 0.3-1.0 | 1.1-3.0 | 3.1-6.0 | >6.0 |
| Mg(loamy soils) | <0.25 | 0.25-0.75 | 0.75-2.0 | 2.1-4.0 | >4.1 |
| Mg(Kaolinitic and sandy soils) | <0.2 | 0.2-0.5 | 0.5-1.0 | 1.1-2.0 | >2.0 |

6. Exchangeable Potassium

| cmol/kg | Very low | low | medium | High | Very high |
|---|---|---|---|---|---|
| K in clay soils | <0.2 | 0.2-0.4 | 0.41-1.20 | 1.21-2.00 | >2.00 |
| K(loamy soils) | <0.13 | 0.13-0.25 | 0.26-0.80 | 0.81-1.35 | >1.35 |
| K (Kaolinitic and sandy soils) | <0.05 | 0.05-0.10 | 0.11-0.40 | 0.41-0.70 | >0.70 |

7.Exchangeable sodium

| cmol/kg | Very low | low | medium | High | Very high |
|---|---|---|---|---|---|
| Na | <0.10 | 0.10-0.30 | 0.31-0.70 | 0.71-2.00 | >2.00 |

8.Exchangeable sodium per cent

| | nonsodic | Slightly sodic | Moderately sodic | Strongly sodic | Very strongly sodic | Extremely sodic |
|---|---|---|---|---|---|---|
| ESP(%) | <6 | 6-10 | 11-15 | 16-25 | 26-35 | >35 |

**Table 21.1** . Horizonwise descriptive statistics for physical and chemical properties

| Statistical parameters | sand (%) | silt | clay | sand/ silt | silt + clay | silt/sitl+clay | pH | EC($dSm^{-1}$) | OC g/kg-1) | $CaCO_3$ | EX.Ca cmol/kg | EX.Mg | Ex.Na | Ex. K. | CEC | CEC / clay | SIC | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A horizon | | | | | | | | | | | | | | | | | | |
| mean | 42.59 | 17.60 | 39.64 | 4.54 | 57.25 | 0.32 | 8.46 | 0.30 | 8.36 | 74.00 | 50.23 | 8.64 | 1.45 | 0.93 | 29.39 | 0.73 | 8.88 | 4.92 |
| sd | 17.75 | 7.17 | 14.25 | 6.77 | 17.77 | 0.11 | 0.51 | 0.26 | 4.06 | 51.88 | 28.40 | 4.87 | 2.25 | 0.71 | 12.56 | 0.17 | 6.23 | 17.90 |
| cv | 41.68 | 40.76 | 35.95 | 149.20 | 31.03 | 33.85 | 6.00 | 86.52 | 48.59 | 70.11 | 56.53 | 56.37 | 155.45 | 76.09 | 42.72 | 22.81 | 70.11 | 363.84 |
| skewness | 0.68 | -0.70 | -0.48 | 3.30 | -0.65 | -1.01 | -1.09 | 4.10 | 0.71 | 0.13 | 0.30 | -0.12 | 1.83 | 1.05 | -0.17 | -0.18 | 0.13 | -1101.63 |
| Kutosis | -0.48 | -0.02 | -0.83 | 12.06 | -0.51 | 1.52 | 2.25 | 18.51 | -0.10 | -1.47 | -0.94 | -1.50 | 2.39 | 0.47 | -0.49 | -0.61 | -1.47 | -485.86 |
| Bw+Bss horizons | | | | | | | | | | | | | | | | | | |
| mean | 22.14 | 19.61 | 58.06 | 2.94 | 78.10 | 0.25 | 8.76 | 1.05 | 4.80 | 88.94 | 61.51 | 10.47 | 10.79 | 0.68 | 44.19 | 0.76 | 10.41 | 24.42 |
| sd | 11.11 | 6.53 | 9.01 | 7.57 | 10.83 | 0.08 | 0.44 | 1.48 | 2.72 | 44.64 | 20.72 | 4.95 | 12.22 | 0.27 | 11.92 | 0.17 | 5.52 | 102.46 |
| cv | 50.18 | 33.29 | 15.52 | 257.10 | 13.87 | 34.29 | 5.07 | 141.43 | 56.72 | 50.19 | 33.68 | 47.24 | 113.17 | 40.50 | 26.98 | 21.96 | 53.05 | 419.50 |
| skewness | 1.21 | -1.20 | -1.26 | 4.65 | -1.26 | -0.46 | -0.37 | 2.19 | 0.47 | 0.49 | -0.53 | 0.27 | 1.40 | 0.57 | -0.01 | 0.61 | 0.62 | -11300.41 |
| Kutosis | 1.77 | 2.98 | 1.23 | 23.70 | 2.26 | 2.98 | 0.37 | 4.73 | -0.35 | 0.34 | -0.33 | -0.44 | 1.04 | 1.07 | 1.41 | 3.61 | 0.35 | 74.29 |
| Bt horizon | | | | | | | | | | | | | | | | | | |
| mean | 44.92 | 18.36 | 36.72 | 2.79 | 55.08 | 0.33 | 8.41 | 0.18 | 2.50 | 74.29 | 44.91 | 10.99 | 0.43 | 0.34 | 19.29 | 0.52 | 8.91 | 2.21 |
| sd | 10.53 | 6.13 | 7.32 | 1.19 | 10.53 | 0.08 | 0.25 | 0.03 | 1.73 | 63.70 | 27.08 | 8.75 | 0.32 | 0.09 | 6.67 | 0.09 | 7.64 | 4.76 |
| cv | 23.43 | 33.41 | 19.95 | 42.81 | 19.11 | 23.63 | 3.00 | 17.54 | 69.16 | 85.74 | 60.29 | 79.59 | 74.62 | 27.42 | 34.58 | 17.75 | 85.74 | 215.78 |
| skewness | -1.38 | 1.02 | 0.38 | -0.15 | 1.38 | 0.72 | -2.20 | -0.82 | 0.92 | 1.03 | 1.62 | 0.36 | 0.39 | -0.42 | 1.97 | 1.39 | 1.03 | 19.58 |
| Kutosis | 1.30 | 0.24 | -0.40 | -0.20 | 1.30 | 0.59 | 4.64 | -0.66 | 1.28 | 0.67 | 1.98 | -1.87 | -1.34 | -1.26 | 3.50 | 1.93 | 0.67 | -38.30 |

## 1. KANAMPALLI (Kpl) SERIES

The Kanampalli soil series is a member of loamy-skeletal, mixed, isohyperthermic family of Lithic Ustorthents. Typically, Kanampalli soils have dark reddish brown, moderately alkaline gravelly sandy clay loam A horizon overlying hard quartzite. They have developed from quartzite and occur on moderately steeply sloping lands with 15-25 per cent slope at elevation of about 540 m above MSL.

Typifying pedon: Kanampalli series gravelly sandy clay loam-forest

| | | |
|---|---|---|
| A | 0-21cm | Reddish brown (5YR 4/4D) and dark reddish brown (5YR 3/4M); gravelly sandy clay loam; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; 85 per cent stones, boulders and gravels; many fine roots; pH 8.3; clear smooth boundary. |
| R | 21cm | Hard Quartzite rock |

**Type Location**: 14º19’45”N, 78º13’45”E, Kottalu village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 14 to 24 cm. The colour is in hue 7.5YR, 5YR and 2.5YR, value 3 to 4 and chroma 2 to 6. Texture ranges from sandy clay loam to sandy clay. The structure is subangular blocky. The gravel content ranges from 35 to 85 per cent.

**Competing series**: Ganganapalle series which is very shallow non gravelly and it is also Lithic Ustorthents.

**Geographic Setting**: Kanampalli soils are developed from quartzite and occur on moderately steeply sloping lands at an elevation of 540 m above MSL. The climate is semi arid with average annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Ganganapalle and Rachakuntapalle series, which are classified as Lithic Ustorthents and Lithic Haplustepts.

**Drainage and permeability**: Well to somewhat excessively drained with moderately rapid permeability.

**Land Use and Vegetation**: Mostly under scrub forest.

**Natural vegetation:** *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Extensive (2386 ha) in Lingala, Tondur and Simhadripuram mandals of Kadapa district, Andhra Pradesh.

**Series proposed:** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : VIes

ii. Land irrigability subclass : 6st

iii. Productive potential : Low

Pedon: 57J/3/T5/P1 Classification: Loamy-skeletal, Lithic Ustorthents

Location: Kottalu village, Pulivendla taluk, Kadapa Dist Series: Kanampalli

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-21 | A | 72.1 | 4.3 | 23.6 | 2.1 | 6.7 | 20.8 | 32.5 | 10.1 | 85 | scl |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCo_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-21 | 8.3 | 8.0 | 7.9 | 0.14 | 16.3 | 10 | 6.7 | 2.0 | 0.02 | 0.22 | 8.9 | 12.6 | 0.53 | 71 |

## 2. GANGANAPALLE (Ggp) SERIES

The Ganganapalle series is a member of clayey, mixed, isohyperthermic family of Lithic Ustorthents. Soils of this series have red, neutral, sandy clay A horizon overlying hard quartzite. They have developed from quartzite and occur on moderately steeply sloping lands with 15-25 per cent slope at elevation of about 540 m above MSL.

**Typifying pedon**: Ganganapalle series clay - forest

| | | |
|---|---|---|
| A | 0-15cm | Red (2.5YR 4/8 M); clay; moderate medium subangular blocky structure; friable, sticky and plastic; common fine to medium roots; pH 7.1; clear smooth boundary. |
| R | 15cm | Hard Quartzite rock |

**Type Location**: 14$^{o}$ 20’0”N, 78$^{o}$17’15”E, Mallela Village, Tondur Mandal, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 13 to 24 cm. The colour is in hue of 5YR and 2.5YR, value 3 to 4 and chroma 3 to 8. Texture ranges from sandy clay loam to sandy clay. The structure is subangular blocky.

**Competing Series:** Kanampalli series, which is very shallow, gravelly loam texture and it is also Lithic Ustorthents**.**

**Geographic Setting:** Ganganapalle soils are developed from quartzite and occur on moderately steeply sloping lands at an elevation of 540 M above MSL. The climate is semi arid with average annual rainfall of 500 mm.The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated Soils:** Kanampalli and Rachakuntapalle series, which are classified as Lithic Ustorthents and Lithic Haplustepts.

**Drainage and permeability:** Well to somewhat excessively drained, with moderately rapid permeability.

**Use and Vegetation:** *Mostly under scrub forest. Natural vegetation:* Azadirachta indica *(neem),* Terminalia tomentosa *(maddi),* Pongamia pinnata *(Pongamia),* Casia cyamia, Calotrophis *sp.* Prosopis juliflora, *Lantana sp.*

**Distribution and extent:** Extensive (2645 ha) in Lingala, Pulivendla, Tondur, Vemula and Vempalli mandals of Kadapa district, Andhra Pradesh.

**Series proposed**: NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : VIes

ii. Land irrigability subclass : 6st

iii. Productive potential : Low

Pedon: 57J/6/T5/2 Classification: Clayey, Lithic Ustorthents

Location: Mallela village, Pulivendla taluk, Kadapa dist. Series: Ganganapalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-15 | A | 32.1 | 20.5 | 47.4 | 2.2 | 7.5 | 5.9 | 2.0 | 14.6 | 0 | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-15 | 7.1 | 6.5 | 6.0 | 0.23 | 17.7 | 30 | 30.9 | 6.3 | 0.12 | 0.32 | 37.6 | 30.5 | 0.64 | 100* |

* In calcareous soils Base saturation is more than 100 percent.

## 3. LINGALA (Lgl) SERIES

The Lingala series is a member of clayey-skeletal, mixed, isohyperthermic family of Lithic Haplustepts. Soils of this series have dark reddish brown, moderately alkaline, gravelly clay loam A horizons, dark red, slightly alkaline, gravelly clay loam B horizon. They have developed from quartzite rock and occur on moderately sloping lands with 5-10 per cent slope at elevation of about 380 m above MSL.

Typifying pedon: Lingala gravelly clay loam cultivated

| | | |
|---|---|---|
| Ap | 0-18cm | Reddish brown (5YR 4/4D) and dark reddish brown (5YR 3/4M). gravelly clay loam; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; 60 per cent fine and coarse gravel; common very fine to fine roots; pH 8.1; clear smooth boundary. |
| Bw | 18-47 cm | Dark red (2.5 YR 3/6M); gravelly clay loam; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; 50 per cent fine and coarse gravel; few very fine to fine roots; pH 7.8; abrupt smooth boundary |
| R | 47 cm | Hard Quartzite rock |

**Type Location**: 14$^{o}$20’30”N, 78$^{o}$13’45”E, Kottalu village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 32 to 50 cm. The thickness of A horizon is 14 to 20 cm. Its colour is in 5YR and 2.5YR hue, value 3 to 4 and chroma 2 to 4. The texture is sandy clay loam to clay loam with gravel content ranges from 35 to 80 per cent. The thickness of B-horizon is 16 to 31 cm. Its colour is in 5 YR and 2.5YR hue, value3 to 4 and chroma 2 to 4. The texture is clay loam to sandy clay. The gravel content ranges from 45 to 85 per cent.

**Competing Series:** Rachakuntapalle series, which is also shallow soils with gravelly loam texture. It is also a Lithic Haplustepts**.**

**Geographic Setting**: The soils of Lingala series occur on moderately sloping to strongly sloping Quartzite and sandstone landform with 5 to 15 per cent slopes. The

elevation is ranges from 260 to 450 m MSL. The climate is semi arid with average annual rainfall of 500 mm.The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Rachakuntapalle and Kanampalli series, which are classified as Lithic Haplustepts and Lithic Ustorthents.

**Drainage and permeability**: Well to somewhat excessively drained with moderately rapid permeability.

**Use and Vegetation**: Mostly under scrub forest. Few patches are cultivated to redgram, castor, and groundnut.*Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Lingala, Pulivendla, Vemula and Vempalli mandals and covers an area of 1923 hectares.

**Series proposed by** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : VIes

ii. Land irrigability subclass : 6st

iii. Productive Potential : Low

Pedon: 57J/3/T7/P2 Classification: Clayey-skeletal, mixed, Lithic Haplustepts

Location: Kottalu village, Pulivendla taluk, Kadapa Dist Series: Lingala

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-18 | Ap | 44.4 | 23.8 | 31.8 | 4.2 | 7.6 | 8.3 | 13.4 | 10.9 | 60 | gcl |
| 18-47 | Bw | 26.3 | 34.8 | 39.7 | 5.7 | 3.0 | 6.2 | 6.6 | 4.7 | 50 | gcl |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-18 | 8.1 | 7.6 | 7.5 | 0.22 | 11.9 | 20 | 24.6 | 3.6 | 0.04 | 0.14 | 28.4 | 26.6 | 0.84 | 100 |
| 18-47 | 7.8 | 7.1 | 7.0 | 0.18 | 11.0 | 00 | 10.5 | 1.4 | 0.07 | 0.06 | 12.0 | 16.7 | 0.42 | 72 |

## 4. RACHAKUNTAPALLE (Rkp) SERIES

The Rachakuntapalle soil series is a member of loamy-skeletal, mixed, isohyperthermic Lithic Haplustepts. Typically Rachakuntepalle soils have yellowish red, neutral, gravelly sandy clay loam A horizons and yellowish red, slightly alkaline, gravelly sandy clay B horizon with 60-85 per cent gravel. They have developed from quartzite and occur on strongly sloping lands with 10-15 per cent slope at an elevation of about 540 m above MSL.

**Typifying pedon**: Rachakuntapalle gravelly sandy clay loam- forest

| | | |
|---|---|---|
| A | 0-14cm | Yellowish red (5YR 4/6 M); gravelly sand clay loam; weak medium subangular blocky structure; slightly hard, friabl,e slightly sticky and slightly plastic; 60 per cent gravel and stones; common, very fine to fine roots; pH 7.2; clear smooth boundary. |
| Bw | 14-40 cm | Yellowish red (5YR 4/6 M); gravelly clay loam; weak medium subangular blocky structure; friable, sticky and plastic; 85 percent stones and gravel; common, fine roots; pH 7.5; abrupt smooth boundary |
| R | 40 cm | Hard Quartzite rock |

**Type Location**: 14º18’0”N, 78º17’30”E, Rachakuntapalle village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum is 30 to 50 cm. The A horizon is 10 to 22 cm thick. Its colour is in the hue 7.5YR, 5YR and 2.5YR, value 3 to 4 and chroma 2 to 6. The texture is sandy clay loam to sandy clay. The gravel content ranges from 35 to 80 percent. The B horizon is 18-32 cm thick. Its colour is in hue 5YR and 2.5YR, value 3 to 4 and chroma 2 to 6. The texture is sandy clay loam to clay loam and sandy clay. The gravel content ranges from 35 to 85 per cent.

**Competing series**: Lingala series, which is also shallow soils with gravelly clay texture. It is also a Lithic Haplustepts.

**Geographic Settings:** The Soils of Rachakuntapalle series occur on moderately sloping to moderately steeply sloping lands on Quartzite and sandstone landform with 5 to 25 per cent slopes. The elevation is 360-700 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Lingala series, which is also shallow, with gravelly clay texture. It is also a Lithic Haplustepts.

**Drainage and permeability**: Well to somewhat excessively drained with moderately rapid permeability

**Use and Vegetation**: Mostly under scrub forest. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Extensive (8415 ha) in Lingala, Pulivendla, Tondur, Vemula, Vempalli, and Simhadripuram mandals of Kadapa district, Andhra Pradesh..

**Series proposed by** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : VIes

ii. Land irrigability subclass : 6st

iii. Productivity potential : Low

Pedon: 57J/7/T1/1 Classification: Loamy-skeletal, mixed, Lithic Haplustepts

Location: Rachakuntapalle village, Pulivendla Taluk, Kadapa District, AP. Series: Rachakuntapalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments w/w (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-14 | Ap | 57.3 | 18.3 | 24.4 | 12.8 | 12.1 | 7.0 | 12.5 | 12.8 | 60 | gscl |
| 14-40 | Bw | 41.1 | 26.9 | 32.0 | 6.9 | 6.2 | 7.4 | 11.2 | 9.4 | 80 | gcl |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-14 | 7.2 | 6.1 | 5.7 | 0.16 | 8.4 | 0 | 9.5 | 1.9 | 0.04 | 0.47 | 11.9 | 25.7 | 1.05 | 46 |
| 14-40 | 7.5 | 6.4 | 6.0 | 0.13 | 8.6 | 0 | 10.4 | 2.1 | 0.04 | 0.49 | 13.0 | 30.9 | 0.97 | 42 |

## 5. MUPENDRANPALLE (Mpl) SERIES

The Mupendranpalle soil series is a member of clayey-skeletal, calcareous, mixed, isohyperthermic Lithic Haplustepts. Typically soils of Mupendranpalle have dark reddish brown, moderately strong alkaline, gravelly sandy clay loam A horizons and strongly alkaline, gravelly sandy clay B horizon with 70 per cent gravel. They have developed from Shales and occur on very gently sloping lands with 1-3 per cent slope at an elevation of about 320 m above MSL.

Typifying pedon: Mupendrapalle gravelly sandy clay loam cultivated

| | | |
|---|---|---|
| Ap | 0-20cm | Dark reddish brown (5YR 3/4D, 5YR 3/3M) gravelly clay; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; 30 per cent fine and coarse gravel; common, very fine and medium roots; few fine lime nodules; slightly effervescent; pH 8.4; clear smooth boundary. |
| Bw | 20-40 cm | Dark reddish brown (5YR 3/3 M); gravelly clay; weak medium subangular blocky structure; friable sticky and plastic; 70 percent coarse gravel and stone; common very fine roots; common very fine lime nodules; slightly effervescent; pH 8.5; abrupt smooth boundary |
| R | 40 cm | Hard shale rock |

**Type Location**: 14º 21’45”N, 78º15’15”E, Mupendranpalle village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 35 to 50 cm. The thickness of A horizon ranges from 15 to 20 cm. Its colour is in 5YR and 2.5YR hue, value 3 to 4 and chroma 2 to 4. The texture is sandy clay loam to sandy clay. The gravel ranges from 10 to 50 per cent. The B horizon is 19 to 34 cm thick. Its colour is in 5YR and 2.5YR hue, value 3 and chroma 2 to 4. The texture is sandy clay to clay. The gravel content varies from 35 to 70 per cent.

**Competing series**: Lingala series, which is shallow, noncalcareous gravelly clay soils and classified under Lithic Haplustepts

**Geographic settings:** Soils of Mupendranpalle series occur on very gently sloping lands with 1-3 per cent slopes on shales at an elevation of about 320 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Rachakuntapalle series, which is shallow and classified under Lithic Haplustepts

**Drainage and permeability**: Well drained with moderately rapid permeability

**Use and Vegetation**: Mostly under scrub forest. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Lingala, Pulivendla, and Simhadripuram mandals of Kadapa district, Andhra Pradesh and covers an area of 2371hectares.

**Series proposed by** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability class : IVes

ii. Land irrigability class : 4st

iii. Productivity potential : Low

Pedon: 57J/7/T7/3 Classification: Clayey-skeletal, calcareous, Lithic Haplustepts

Location: Mupendranpalle village, Pulivendla Taluk, Kadapa District, AP. Series: Mupendranpalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 29.5 | 29.0 | 41.5 | 3.3 | 4.1 | 5.3 | 11.0 | 5.8 | 30 | c |
| 20-40 | Bw | 22.7 | 31.4 | 45.9 | 1.7 | 2.7 | 5.4 | 6.4 | 6.4 | 70 | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-20 | 8.4 | 7.8 | 7.6 | 0.38 | 10.7 | 40 | 48.3 | 15.4 | 0.22 | 1.00 | 64.9 | 29.1 | 0.70 | 100 |
| 20-40 | 8.5 | 7.8 | 7.6 | 0.23 | 8.5 | 30 | 44.6 | 13.7 | 0.40 | 0.42 | 59.1 | 31.1 | 0.68 | 100 |

## 6. TALLALAPALLE (Tlp). SERIES

The Tallalapalle series is a member of clayey-skeletal, calcareous, mixed, isohyperthermic Lithic Haplustepts. Tallalapalle soils have dark reddish brown, strongly alkaline, gravelly sandy clay loam A horizon and dark reddish brown, moderately alkaline, gravelly sandy clay B horizon with 65 per cent gravel and stones. They have developed from shales and occur on very gently sloping inter hill basin with 1-3 per cent slope at an elevation of about 300 m above MSL.

Typifying pedon: Tallalapalle gravelly sandy clay loam cultivated

| | | |
|---|---|---|
| Ap | 0-19cm | Yellowish red (5YR 4/6D) and dark reddish brown (5YR 3/4M); gravelly clay loam; weak medium subangular blocky structure; slightlyhard friable slightly sticky and slightly plastic; 30 per cent gravel and stones; many very fine roots; slightly effervescent; pH 8.5; clear smooth boundary. |
| Bw | 19-40 cm | Dark reddish brown (5YR 3/3 M); gravelly clay; weak medium subangular blocky structure; friable sticky and plastic; 65 percent gravel and stones; common very fine roots; strongly effervescent; abrupt smooth boundary |
| R | 40 cm | Shale |

**Type Location**: 14º 20’30”N, 78º 23’15”E, Tallalapalle Village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 35 to 50 cm. The A horizon is 12 to 19 cm thick. Its colour is in 5YR hue, value 3 and chroma 4. The texture is clay loam. The gravel content varies from 45 to 60 per cent. The B horizon is 20 to 34 cm thick. Its colour is 5YR hue, value 3 and chroma 3 to 4. The texture is sandy clay to clay. The gravel content varies from 60 to 80 per cent.

**Competing series**: No competing series

**Geographic settings:** Soils of Tallalapalle series occur on very gently sloping interhill basin on shales with 1-3 per cent slopes. The elevation is about 300 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Rachakuntapalle and Sunkesula series. Rachakuntapalle series are shallow Lithic Haplustepts whereas Sunkesula series are moderately shallow Vertic Haplustepts.

**Drainage and permeability**: Well-drained with moderately rapid permeability

**Use and Vegetation**: Cultivated to Lemon plantations, bengalgram and redgram. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Tondur, Vemula Simhadripuram and Vempalli mandals of Kadapa district, Andhra Pradesh and covers an area of 1,829 hectares.

**Series proposed by** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : IVs
ii. Land irrigability subclass : 4s
iii. Productivity potential : Low

Pedon: 57J/7/T8/3 Classification: clayey-skeletal, calcareous, mixed, Lithic Haplustepts.

Location: Tallalapalle Village, Pulivendla Taluk, Kadapa District, AP Series: Tallalapalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-19 | Ap | 40.9 | 19.6 | 39.5 | 8.1 | 7.9 | 7.1 | 9.8 | 8.1 | 30 | cl |
| 19-40 | Bw | 24.7 | 20.2 | 55.1 | 4.7 | 3.1 | 5.5 | 6.0 | 5.5 | 65 | gc |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-19 | 8.5 | 7.9 | 7.6 | 0.19 | 9.7 | 70 | 56.5 | 8.7 | 0.32 | 1.33 | 66.9 | 28.3 | 0.72 | 100 |
| 19-40 | 8.4 | 7.8 | 7.5 | 0.15 | 6.6 | 60 | 53.6 | 8.1 | 0.17 | 0.92 | 62.8 | 30.7 | 0.56 | 100 |

## 7. SANTAKOVUR (Skv). SERIES

The Santakovur series is a member of clayey-skeletal, calcareous, isohyperthermic Typic Haplustepts. Santakovur soils have dark reddish brown, moderately alkaline, sandy clay loam A horizons and very strongly alkaline, sandy clay and gravelly sandy clay loam B horizon. They have developed from shales and occur on very gently sloping interhill basin with 1-3 per cent slope at an elevation of about 200 m above MSL.

**Typifying pedon**: Santakovur sandy clay loam cultivated

| | | |
|---|---|---|
| Ap | 0-17cm | Reddish brown (5YR 4/4D) to dark reddish brown (5YR 3/4M); gravelly clay loam; weak medium subangular blocky structure; friable, slightly sticky and slightly plastic; 15 per cent gravels; many very fine to fine roots; common many lime nodules; strongly effervescent; pH 8.3; clear smooth boundary. |
| Bw1 | 17-42 cm | Dark reddish brown (5YR 3/3 M); clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; 10 per cent fine gravels; common many roots; many medium lime nodules; strongly effervescent; pH9.3; clear smooth boundary |
| Bw2 | 42-62cm | Dark reddish brown (5YR 3/3M); gravelly clay loam; weak medium subangular blocky structure; friable, slightly sticky slightly plastic; 65 per cent stones; few fine roots; medium many lime nodules; strongly effervescent; pH 9.4; abrupt smooth boundary. |

**Type Location**: 14$^{o}$ 30’30” N, 78$^{o}$ 21’15”E, Santakovur village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 60 to 63 cm. The A horizon is 15 to 17 cm thick. Its colour is in hue 5YR, value 3 to 4 and chroma 4. The texture is sandy clay loam to sandy clay. The gravel content ranges from 10 to 15 per cent. The thickness of B horizon is 45 to 47 cm. Its colour is in 5YR hue, value 3 and chroma 3 to 4. The texture is sandy clay. The gravel content varies from 10 to 60 per cent. The B horizon is strongly effervescent with dil Hcl.

**Competing series**: No competing series.

**Geographic settings:** Soils of Santakovur series occur on very gently sloping inter hill basin on weathered shales with 1-3 per cent slope at an elevation of 200m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Goturu and Cherlapalle series. The Goturu soils are moderately shallow, Typic Haplustepts whereas Cherlapalle series are deep, Vertic Haplustepts.

**Drainage and permeability**: Welldrained with moderately rapid permeability

**Use and Vegetation**: Cultivated to acid lime, Castor and Sunflower. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Tondur mandal of Kadapa district, Andhra Pradesh and covers an area of 548 hectares.

**Series proposed :** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : IIIs

ii. Land irrigability subclass : 3s

iii. Productive potential : Medium

Pedon: 57J/6/T9/3 Classification: clayey-skeletal, calcareous, Typic Haplustepts

Location: Santakovuru village, Pulivendla Taluk, Kadapa District, AP. Series: Santakovuru,

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-17 | Ap | 48.8 | 18.7 | 32.5 | 8.0 | 8.6 | 6.5 | 8.3 | 7.8 | 15 | gcl |
| 17-42 | Bw1 | 44.8 | 18.4 | 36.8 | 10.9 | 8.0 | 4.0 | 8.3 | 6.6 | 10 | cl |
| 42-62 | Bw2 | 42.0 | 19.2 | 38.8 | 8.2 | 6.3 | 7.1 | 5.9 | 7.9 | 65 | cl |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-17 | 8.3 | 7.9 | 7.6 | 0.29 | 9.2 | 150 | 52.9 | 11.7 | 0.60 | 1.04 | 66.2 | 21.7 | 0.67 | 100 |
| 17-42 | 9.3 | 8.1 | 7.7 | 0.30 | 5.5 | 200 | 74.5 | 10.7 | 2.58 | 0.34 | 88.1 | 26.4 | 0.72 | 100 |
| 42-62 | 9.4 | 8.2 | 7.7 | 0.31 | 5.1 | 200 | 81.9 | 9.7 | 2.21 | 0.38 | 94.2 | 30.9 | 0.79 | 100 |

## 8. TATIREDDIPALLE (Trp). SERIES

The Tatireddipalle series is a member of veryfine, smectic, isohyperthermic Vertic Haplustepts. Tatireddipalle soils have very dark greyish brown, moderately alkaline, clay A horizon and B horizon. They have developed from shales and occur on very gently sloping inter hill basin with 1-3 per cent slope at an elevation of about 360 m above MSL.

Typifying pedon: Tatireddipalle clay- cultivated

| | | |
|---|---|---|
| Ap | 0-15cm | Very dark grayish brown (10YR 3/2M); clay; moderate coarse subangular blocky structure; hard, firm, very sticky and very plastic; coarse few roots; few fine lime nodules; slightly effervescent; pH 8.3; clear smooth boundary. |
| Bw1 | 15-33 cm | Very dark grayish brown (10YR 3/2 M); clay; moderate coarse subangular blocky structure with pressure faces ; firm, very sticky and very plastic; common fine roots; few fine lime nodules, slightly effervescent; pH 8.4; gradual smooth boundary |
| Bw2 | 33-55 cm | Very dark grayish brown (10YR 3/2M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; few fine roots; few fine lime nodules; slightly effervescent; pH 8.3, gradual smooth boundary. |
| R | 55 cm | Hard shale rock |

**Type Location**: 14$^{o}$ 31’45”N, 78$^{o}$ 2’15”E, Tatireddipalle village, Pulivendla Taluk, Kadapa District, Andhra Pradesh

**Range in Characteristics**: The thickness of the solum ranges from 55 to 65 cm. The A horizon is 15 to 18 cm thick. Its colour is in hue 10YR, value 3 and chroma 2. Its texture is clay. The gravel content ranges from 5 to 10 per cent. The thickness of B horizon is 40 to 47 cm. Its colour is in hue 10YR, value 3 and chroma 2. The texture is clay. The soil is highly effervescent with dil. HCl. Pressure faces are present in the subsoil.

**Competing series**: No competing series

**Geographic settings:** Soils of Tatireddipalle series occur on very gently sloping interhill basin on weathered shales with 1-3 per cent slopes at an elevation of 360 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Murarichintala series which is very deep, Typic Paleustalfs.

**Drainage and permeability**: Moderately welldrained with slow permeability

**Use and Vegetation**: Cultivated to redgram, banana and coriander. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Lingala mandal of Kadapa district, Andhra Pradesh and covers an area of 788 hectares.

**Series proposed:** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : IIIs

ii. Land irrigability subclass : 3s

iii. Production potential : Medium

Pedon: 57J/2/T25/5 Classification:Very fine, smectic, isohyperthermic Vertic Haplustepts.
Location: Tatireddipalle village, Pulivendla Taluk, Kadapa District, AP Series: Tatireddipalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-15 | Ap | 14.9 | 27.8 | 57.3 | 1.4 | 2.3 | 3.0 | 4.5 | 3.7 | 5 | c |
| 15-33 | Bw1 | 11.5 | 23.9 | 64.6 | 1.1 | 1.4 | 1.6 | 4.0 | 3.4 | 10 | c |
| 33-55 | Bw2 | 9.9 | 24.3 | 65.8 | 1.1 | 1.2 | 1.7 | 2.2 | 3.6 | 5 | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-15 | 8.3 | 7.7 | 7.2 | 0.22 | 11.2 | 40 | 43.4 | 12.6 | 0.14 | 1.83 | 58.0 | 54.5 | 0.95 | 100 |
| 15-33 | 8.4 | 7.7 | 7.1 | 0.19 | 10.5 | 40 | 42.8 | 15.1 | 0.17 | 0.68 | 58.8 | 58.8 | 0.91 | 100 |
| 33-55 | 8.3 | 7.6 | 7.1 | 0.13 | 8.9 | 40 | 46.2 | 16.2 | 0.21 | 0.61 | 63.2 | 58.8 | 0.89 | 100 |

## 9. CHERLAPALLE (Cpl) SERIES

The Cherlapalle series is a member of very fine, smectitic, calcareous, isohyperthermic Vertic Halaquepts. Cherlapalle soils have dark brown, strongly alkaline, clay A horizons and dark yellowish brown to dark brown, strongly alkaline, clay B horizon. They have developed from weathered shales and occur on very gently sloping interhill basin with 1 to 3 per cent slope at an elevation of about 220 m above MSL.

Typifying pedon: Cherlapalle clay – cultivated.

| | | |
|---|---|---|
| Ap | 0-20 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure; very hard, firm, sticky and plastic; very fine many roots; common fine pores; common very fine lime nodules; violently effervescent; pH 9.1; clear smooth boundary. |
| Bw1 | 20-40 cm | Dark grayish brown (10YR 3/4M); clay; moderate medium subangular blocky structure with pressure faces; firm, sticky and plastic; common very fine roots; common very fine lime nodules; strongly effervescent; pH 8.8; clear smooth boundary. |
| Bw2 | 45-72 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure with pressure faces ; firm, very sticky and very plastic; common fine roots; common fine lime nodules; strongly effervescent; pH 8.5; gradual smooth boundary. |
| Bw3 | 72-105 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure with pressure faces ; firm, very sticky and very plastic; few fine roots; common fine lime nodules; slightly effervescent; pH 8.7. |
| Cr | 105cm | Weathered shales |

**Type location:** 14$^{o}$32’0” N, 78$^{o}$ 21’45” E, Cherlapalle village, Pulivendla Taluk, Kadapa district, Andhra Pradesh

**Range in characteristics:** The thickness of solum ranges from 105 to 135 cm. The A horizon is 18 to 20 cm thick. Its colour is in the hue 10YR, value and chroma 3. The texture is sandy clay to clay. The gravel content ranges from 10 to 15 per cent. The thickness of B horizon ranges is 85 to 117 cm. Its colour is in hue 10YR, value 3 and

chroma 2 to 4. The texture is clay. The soil is strongly to violently effervescent with dil Hcl. Well-developed pressure faces are present in the subsoil.

**Competing series:** No competing series.

**Geographic setting:** Soils of Cherlapalle series occur on very gently sloping interhill basin on weathered shales with 1 to 3 per cent slopes at an elevation of 220 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Santakovur soils, which are moderately, shallow, Typic Haplustepts.

**Drainage and permeability:** Moderately well drained with slow permeability.

**Land Use and vegetation:** Cultivated to Bengalgram, redgram, groundnut and coriander. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Tondur mandal and covers an area of 184 hectares.

**Series proposed :** NBSS & LUP, Regional Centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass :IIIs
ii. Land irrigability subclass: 3s
iii. Productive Potential : Medium

Pedon: 57J/6/T7/2 Classification: Very fine, smectitic, calcareous, Vertic Halaquepts

Location: Cherlapalle village, Pulivendla Taluk, Kadapa district, AP. Series: Cherlapalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 32.5 | 21.2 | 46.3 | 5.9 | 4.7 | 9.2 | 7.4 | 5.3 | - | c |
| 20-45 | Bw1 | 22.6 | 20.0 | 57.4 | 5.0 | 3.8 | 3.0 | 5.7 | 5.1 | - | c |
| 45-72 | Bw2 | 14.9 | 20.2 | 64.9 | 3.6 | 2.2 | 1.7 | 3.5 | 3.9 | - | c |
| 72-105 | Bw3 | 10.5 | 19.0 | 70.5 | 9.0 | 0.2 | 0.4 | 0.4 | 0.5 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ . | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$--------→ | | | | | | | % | % |
| 0-20 | 9.1 | 8.1 | 7.7 | 0.34 | 6.2 | 110 | 56.6 | 9.2 | 7.85 | 0.76 | 74.4 | 33.2 | 0.72 | 100 | 23.64 |
| 20-45 | 8.8 | 8.4 | 7.6 | 1.95 | 4.7 | 80 | 37.1 | 6.7 | 29.76 | 0.75 | 74.3 | 37.9 | 0.66 | 100 | 78.52 |
| 45-72 | 8.5 | 8.3 | 7.6 | 2.97 | 4.0 | 60 | 31.2 | 8.3 | 34.60 | 0.93 | 75.0 | 41.9 | 0.65 | 100 | 82.52 |
| 72-105 | 8.7 | 8.4 | 7.6 | turbid | 3.6 | 70 | 38.7 | 9.4 | 31.77 | 1.04 | 80.9 | 43.0 | 0.61 | 100 | 73.88 |

## 10. KOTTALU (Ktl) SERIES

The Kottalu series is a member of fine-loamy, mixed, isohyperthermic, Typic Rhodustalfs. Kottalu soils have dark reddish brown, strongly alkaline, sandy loam A horizons and dark red to dark reddish brown, strongly alkaline, sandy clay loam to sandy clay Bhorizon. They have developed from shales and occur on very gently sloping interhill basin with 1 to 3 per cent slope at an elevation of about 360 m above MSL.

Typifying pedon: Kottalu sandy loam – cultivated

| | | |
|---|---|---|
| Ap | 0-18 cm | Reddish brown (5YR 4/4 D) and dark reddish brown (5YR 3/4M); sandy loam; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine roots; few lime nodules; violently effervescent; pH 8.6; clear smooth boundary. |
| Bt1 | 18-45 cm | Dark red (2.5YR 3/6 M); sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick continuous clay cutans; few fine roots; few, fine lime nodules; strongly effervescent; pH 8.5; gradual smooth boundary. |
| Bt2 | 45-76 cm | Dark red (2.5YR 3/6 M); sandy clay; moderate medium; subangular blocky structure; friable, sticky and plastic; moderately thick continuous clay cutans; few fine roots; few fine lime nodules; strongly effervescent; pH 8.5; gradual smooth boundary. |
| Bt3 | 76-108 cm | Dark reddish brown (2.5YR 3/4 M); sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick continuous clay cutans; few fine lime nodules; strongly effervescent; pH 8.5; gradual smooth boundary. |
| Bt4 | 108-142 cm | Red (2.5YR 4/6M); sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick continuous clay cutans; common fine lime nodules; strongly effervescent; pH 8.6. |
| R | 142 cm | Hard shale rock |

**Type location:** 14$^{o}$ 20’15”N, 78$^{o}$13’15”E, Kottalu village, Pulivendla taluk, Kadapa district, Andhra Pradesh

**Range in characteristics:** The thickness of solum is 125 to 150 cm. The A horizon is 18 to 21 cm thick. Its colour is in the hue 5YR and 2.5YR, value 3 and chroma 3 to 4. The texture is sandy loam to sandy clay loam. The thickness of B horizon is 104 to 132 cm. Its colour is in 2.5YR and 5 YR hue, value 3 to 4 and chroma 3 to 6. The texture is sandy clay loam to clay. The soil is strongly to violently effervescent with dil Hcl. Moderately thick continuous clay cutans are present in the soil.

**Competing series:** No competing series.

**Geographic setting:** Soils of Kottalu series occurs on very gently sloping interhill basin on hard shales with 1 to 3 per cent slopes at an elevation of 360 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Murarichintala and Tatireddipalli series. Murarichintala series are very deep and classified as Typic Paleustalfs. Tatireddipalli series are moderately shallow, Vertic Haplustepts.

**Drainage and permeability:** Well drained with moderately rapid permeability.

**Land use and vegetation:** Cultivated to groundnut, redgram, onion, bengalgram, and castor. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla and Vemula mandals of Kadapa district, Andhra Pradesh and covers an area of 372 hectares.

**Series proposed :** NBSS & LUP, R.C., Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIIs
ii. Land irrigability subclass : 3s
Iii Productivity potential : Medium

Pedon: 57J/3/T6/2 Classification: Fine-loamy, mixed, calcareous, Typic Rhodustalfs.

Location: Kottalu village, Pulivendla taluk, Kadapa district, AP. Series: Kottalu

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-18 | Ap | 74.9 | 10.3 | 14.8 | 9.2 | 11.0 | 15.4 | 30.4 | 8.9 | - | sl |
| 18-45 | Bt1 | 51.4 | 13.2 | 35.4 | 2.6 | 5.9 | 9.4 | 26.3 | 7.1 | - | sc |
| 45-76 | Bt2 | 50.9 | 13.7 | 35.4 | 3.2 | 6.2 | 11.8 | 21.9 | 7.7 | 5 | sc |
| 76-108 | Bt3 | 54.4 | 15.2 | 30.4 | 5.0 | 7.7 | 10.0 | 24.3 | 7.4 | 10 | scl |
| 108-142 | Bt4 | 54.2 | 15.1 | 30.7 | 6.8 | 7.4 | 13.2 | 17.7 | 9.1 | 10 | scl |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | $dSm^{-1}$ | $g\ kg^{-1}$ | $g\ kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-18 | 8.6 | 7.9 | 7.6 | 0.16 | 3.6 | 20 | 21.7 | 1.7 | 0.15 | 0.26 | 23.8 | 7.6 | 0.51 | 100 |
| 18-45 | 8.6 | 7.9 | 7.6 | 0.15 | 2.0 | 30 | 30.1 | 2.8 | 0.22 | 0.23 | 33.4 | 15.8 | 0.45 | 100 |
| 45-76 | 8.5 | 7.9 | 7.6 | 0.17 | 1.4 | 30 | 28.3 | 4.8 | 0.21 | 0.21 | 33.5 | 16.8 | 0.48 | 100 |
| 76-108 | 8.5 | 8.0 | 7.7 | 0.19 | 1.1 | 70 | 41.7 | 7.1 | 0.25 | 0.21 | 49.3 | 17.3 | 0.57 | 100 |
| 108-142 | 8.6 | 8.0 | 7.7 | 0.20 | 0.1 | 80 | 36.6 | 6.7 | 0.24 | 0.20 | 43.7 | 15.7 | 0.51 | 100 |

## 11. MURARICHINTALA (Mct) SERIES

The Murarichintala series is a member of fine-loamy, mixed, isohyperthermic Typic Paleustalfs. Typically, Murarichintala soils have reddish brown to dark reddish brown sandy loam A horizons and dark red to dark reddish brown, strongly alkaline, sandy clay loam to clay B horizons.

Typifying pedon: Murarichintala sandy loam-cultivated

| | | |
|---|---|---|
| Ap | 0-20 cm | Reddish brown (2.5YR 4/4D) and dark reddish brown (2.5YR 3/4M); sandy loam; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; common fine roots; strongly alkaline (pH 8.6); clear smooth boundary. |
| Bt1 | 20-60 cm | Dark reddish brown (2.5YR 3/4M); sandy clay loam; weak medium subangular blocky structure; friable, slightly sticky and slightly plastic; moderately thick continuous clay cutans; common fine roots; few fine lime nodules; strongly alkaline (pH 8.6); gradual smooth boundary. |
| Bt2 | 62-98 cm | Dark red (2.5R 3/6M); sandy clay loam; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; moderately thick continuous clay cutans; few coarse roots; few fine lime nodules; strongly alkaline (pH 8.5); gradual smooth boundary. |
| Bt3 | 98-135 cm | Dark reddish brown (5 YR 3/4 M) clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick continuous clay cutans; few fine roots; few fine lime nodules; moderately alkaline (pH 8.0); gradual smooth boundary. |
| Bt4 | 135-155 + cm | Dark reddish brown (5YR 3/4M); clay; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick continuous clay cutans; few fine roots; few fine calcium carbonate nodules; slightly alkaline (pH 7.7). |

**Type location:** 14º27’00” N, 78º4’00”E, village Murarichintala, tehsil Pulivendla, district Kadapa, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is more than 150 cm. A horizon is 14 to 23 cms thick. Its colour is in the hue of 2.5YR and 5YR, value 3 to 4 and chroma 4 to 6. The texture is dominantly sandy loam. The B horizon is 127 to 143 cm thick. Its colour is in 2.5YR and 5YR hue, value 3 to 4 and chroma 4 to 6. Its texture is sandy clay loam to clay with thin patchy to moderately thick continuous clay cutans.

**Competing series:** Kottalu series, which is deep, calcareous Typic Rhodustalfs.

**Geographic setting:** Murarichintala soils are developed from shales and occur on very gently to gently sloping inter hill basin at an elevation of 250 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils**: These are Kottalu series, a Typic Rhodustalfs

**Drainage and permeability:** Well drained with moderately rapid permeability.

**Land use and vegetation:** Cultivated to banana, sorghum, groundnut and redgram.

Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (Maddi), *Pongamia pinnata* (pongamia), *Calotrophis* sp. *Prosophis juliflora*, Lantana sp.

**Distribution and extent: Extensive (2290 ha) in Lingala, Pulivendla and Vemula mandals of Kadapa district, Andhra Pradesh.**

**Series proposed :** National Bureau of Soil Survey and Land Use Planning, Regional Centre, Hebbal, Bangalore, 2009.

**Interpretation:** The Murarichintala soils are strongly alkaline reddish brown soils associated with sandy loam surface texture with sandy clay loam to clay dark red B horizons. These soils occur on gently sloping interhill basins. These soils can support

variety of crops and horticultural crops in rainfed and/or under irrigated conditions but are prone to salinity/sodicity if continuously irrigated.

**Interpretative grouping**

i. Land capability subclass : IIs

ii. Land irrigability subclass : 2sd

iii. Productivity potential : Medium

Pedon: 57J/3/T15/3 Classification: fine-loamy, mixed, Typic Paleustalfs

Location: Murarichintala village, Pulivendla taluk, Kadapa district, AP. Series: Murarichintala

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 71.1 | 14.2 | 14.7 | 2.1 | 6.2 | 17.2 | 32.0 | 13.7 | - | sl |
| 20-62 | Bt1 | 45.5 | 27.6 | 26.9 | 1.4 | 5.2 | 7.8 | 18.5 | 12.7 | - | scl |
| 62-98 | Bt2 | 55.4 | 19.1 | 25.5 | 3.6 | 6.9 | 14.4 | 14.9 | 15.6 | - | scl |
| 98-135 | Bt3 | 42.7 | 21.9 | 35.4 | 0.6 | 2.2 | 5.6 | 19.4 | 14.9 | - | cl |
| 135-155 | Bt4 | 19.9 | 31.6 | 48.5 | 0.1 | 0.5 | 4.7 | 7.2 | 7.4 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-20 | 8.6 | 8.0 | 7.8 | 0.25 | 4.7 | 10 | 12.5 | 1.8 | 0.01 | 0.58 | 14.9 | 7.2 | 0.49 | 100 |
| 20-62 | 8.6 | 7.9 | 7.7 | 0.21 | 3.8 | 10 | 23.4 | 2.4 | 0.04 | 0.36 | 26.2 | 15.5 | 0.58 | 100 |
| 62-98 | 8.5 | 7.8 | 7.6 | 0.16 | 3.5 | 20 | 22.6 | 2.2 | 0.05 | 0.38 | 25.2 | 12.6 | 0.49 | 100 |
| 98-135 | 8.0 | 7.7 | 7.5 | 0.12 | 3.3 | 10 | 19.5 | 2.5 | 0.08 | 0.41 | 22.5 | 17.9 | 0.51 | 100 |
| 135-155 | 7.7 | 7.3 | 7.0 | 0.15 | 3.1 | 10 | 26.3 | 3.0 | 0.40 | 0.46 | 30.2 | 23.2 | 0.48 | 100 |

## 12. VEMULA (Vml) SERIES

The Vemula series is a member of the clayey-skeletal, mixed, isohyperthermic family of Calcic Haplustalfs. Typically Vemula soils have dark reddish brown, strongly alkaline, clay A horizons; dark reddish brown, strongly alkaline, gravelly clay B horizons underlain by hard quartzite rock.

**Typifying pedon:** Vemula clay-cultivated

| | | |
|---|---|---|
| Ap | 0-20 cm | Dark reddish brown (5 YR 3/3M); clay; moderate medium subangular blocky structure; friable, sticky and plastic; many very fine to fine roots; coarse fragments (v/v) 10 per cent; few fine lime nodules; violently effervescent, strongly alkaline (pH 8.6); clear smooth boundary. |
| Bt1 | 20-41cm | Dark reddish brown (5YR 3/3M); gravelly clay; moderate medium subangular blocky structure; friable, sticky and plastic; common very fine to fine roots; coarse fragments (v/v) 20 per cent; common fine to medium lime nodules; violently effervescent; strongly alkaline (pH 8.5); gradual, smooth boundary. |
| Bt2 | 41-72 cm | Dark reddish brown (5YR 3/3M); gravelly clay; weak medium subangular blocky structure; friable, sticky and plastic; few very fine roots; coarse fragments (v/v) 70 per cent; common fine to medium lime nodules; violently effervescent; strongly alkaline (pH 8.5); clear smooth boundary. |
| R | 72+ cm | Hard quartzite rock. |

**Type location:** 14º22’0” N, 78º17’0” E, village Vemula, tehsil Pulivendala, district Kadapa, Andhra Pradesh.

**Range characteristics:** The thickness of solum ranges from 56 to 75 cm. The thickness of A horizon ranges from 13 to 20 cm. The colour is in the hue of 5YR and 7.5YR, value 3 and chroma 3 to 4. The texture is clay loam to clay. The thickness of B horizon is 37 to 59 cm. Its colour is in 5YR and 7.5YR hue, value 3 and chroma 3 to 4. The texture is gravelly clay with gravel content ranges from 20 to 75 per cent.

**Competing series:** No competing series.

**Geographic setting:** Vemula soils are developed from quartzite and occur on very gently sloping uplands (1 to 3%) at an elevation of 260 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** These are Velpula (Typic Haplustalfs), Sunkesula (Vertic Haplustepts), Balapanur (Sodic Haplusterts) and Simhadripuram (Typic Haplusterts).

**Drainage and permeability:** Well drained with slow permeability.

**Land use and vegetation:** Cutivated to sunflower, bengalgram, sorghum, coriander and groundnut. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (Maddi), *Pongamia pinnata* (pongamia), *Calotrophis* sp. *Prosophis juliflora, Lantana* sp.

**Distribution and extent:** Extensive (1952 ha) in Pulivendla, Vempalli, Tondur and Vemula mandals of Kadapa district, Andhra Pradesh.

**Series proposed :** National Bureau of Soil Survey and Land Use Planning, Regional Centre, Hebbal, Bangalore, 2009.

**Interpretation:** These strongly alkaline dark brown gravelly clay soils are moderately deep and occur on gently sloping uplands with 1-3% slopes.

**Interpretative grouping**

i. Land capability subclass : IIIs
ii. Land irrigability subclass : 3s
iii. Productive potential : Medium

Pedon: 57J/7/T9/2 Classification: clayey-skeletal mixed, Calcic Haplustalfs

Location: Vemula village Pulivendala Taluk, Kadapa District, Series: Vemula

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 32.8 | 24.9 | 42.3 | 4.4 | 4.7 | 6.4 | 9.0 | 8.4 | 10 | c |
| 20-41 | Bt1 | 34.3 | 16.3 | 49.4 | 6.4 | 6.1 | 5.5 | 9.6 | 6.6 | 20 | c |
| 41-72 | Bt2 | 28.2 | 25.7 | 46.1 | 7.7 | 4.6 | 5.4 | 4.3 | 6.2 | 70 | gc |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-20 | 8.6 | 8.0 | 7.6 | 0.20 | 7.0 | 160 | 96.1 | 14.0 | 0.54 | 0.57 | 111.2 | 30.1 | 0.71 | 100 |
| 20-41 | 8.5 | 8.0 | 7.6 | 0.20 | 6.7 | 170 | 108.0 | 23.6 | 0.67 | 0.39 | 132.7 | 37.1 | 0.75 | 100 |
| 41-72 | 8.5 | 8.0 | 7.6 | 0.19 | 3.9 | 220 | 99.1 | 19.8 | 0.70 | 0.30 | 119.9 | 30.4 | 0.66 | 100 |

## 13 SUNKESULA (Skl) SERIES

The Sunkesula series is a member of very fine, smectitic, calcareous, Vertic Haplustepts. Sunkesula soils have brown, moderately alkaline, sandy clay loam A horizons and dark yellowish brown to dark brown, moderately alkaline, clay B horizon. They have developed from shales and occur on very gently sloping middle sector with 1 to 3 per cent slope at an elevation of 320 m above MSL.

Typifying pedon: Sunkesula sandy clay loam-cultivated.

| | | |
|---|---|---|
| Ap | 0-20 cm | Brown (10 YR 4/3 D and M); sandy clay loam; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; few fine roots; few fine lime nodules; strongly effervescent; pH 8.4; clear smooth boundary. |
| Bw1 | 20-38 cm | Dark brown (10 YR 3/3 M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; few fine roots; few fine lime nodules; strongly effervescent; pH 8.3; gradual smooth boundary. |
| Bw2 | 38-70 cm | Dark yellowish brown (10YR 3/4M); clay; moderate medium subangular blocky structure with well developed pressure faces; firm, very sticky and very plastic; few very fine roots; few fine lime nodules; strongly effervescent; pH 8.0; gradual smooth boundary. |
| R | 70 cm | Hard shale rock. |

**Type location:** 14º24’30”N, 78º10’40”E, Sunkesula village, Pulivendla taluk, Kadapa district, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is 56 to 75 cm. The thickness of A horizon is ranges from 8 to 20 cm. Its colour is in the hue 10YR, value 3 to 4 and chroma 2 to 4. The texture is sandy clay loam to clay. The thickness of B horizon is 41 to 63 cm. Its colour is in 10YR hue, value 3 to 4 and chroma 2 to 4. The texture is clay. The soil is strongly to violently effervescent with dilute HCl.

**Competing series:** Tondur series, which is very deep and it is a Vertic Haplustepts.

**Geographic Settings:** Soils of Sunkesula series occurs on very gently sloping middle sector on shales with 1 to 3 per cent slope at an elevation of 320 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Associated soil series are Simhadripuram, Agraharam. Simhadripurm soils are moderately deep, whereas Agraharam soils are deep. Both are Typic/Sodic Haplusterts.

**Drainage and permeability:** Moderately well drained with slow permeability.

**Land use and vegetation:** Cultivated to sweet orange, groundnut, banana, redgram, coriander, sunflower and sorghum. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Extensive (4832 ha) in Lingala, Pulivendla, Tondur, Vemula, Vempalli, and Simhadripuram mandals of Kadapa district, Andhra Pradesh.

**Series proposed by:** NBSS & LUP, Regional Cenre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : IIIs
ii. Land irrigability subclass : 3s
iii. Productivity Potential : Medium

Pedon: 57J/3/R27 Classification: Very fine, smectitic, calcareous, Vertic Haplustepts.

Location: Sunkesula village, Pulivendla taluk, Kadapa district, AP. Series: Sunkesula

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 50.1 | 15.4 | 34.5 | 6.8 | 6.2 | 14.7 | 13.1 | 9.2 | - | scl |
| 20-38 | Bw1 | 21.8 | 19.3 | 58.9 | 3.4 | 2.3 | 5.7 | 5.6 | 4.8 | 5 | c |
| 38-70 | Bw2 | 15.5 | 19.2 | 65.3 | 2.6 | 2.7 | 2.2 | 4.3 | 3.8 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-20 | 8.4 | 8.0 | 7.7 | 0.30 | 11.1 | 40 | 33.0 | 13.9 | 0.45 | 2.68 | 50.0 | 28.0 | 0.81 | 100 |
| 20-38 | 8.3 | 7.9 | 7.5 | 0.33 | 8.8 | 40 | 44.7 | 18.4 | 1.16 | 1.01 | 65.3 | 49.8 | 0.85 | 100 |
| 38-70 | 8.0 | 7.7 | 7.2 | 0.55 | 8.1 | 50 | 48.0 | 17.5 | 1.29 | 0.53 | 67.3 | 51.9 | 0.80 | 100 |

## 14. SIMHADRIPURAM (Spm) SERIES

The Simhadripuram series is a member of the very fine, smectitic, isohyperthermic Sodic Haplusterts. Typically Simhadripuram soils have very dark grayish brown, strongly alkaline clay A horizons and dark brown, strongly alkaline, B horizons over hard shale rock.

Typifying pedon: Simhadripuram clay – cultivated.

| | | |
|---|---|---|
| Ap | 0-20 cm | Dark grayish brown (10YR 4/2 D) and very dark grayish brown (10YR 3/2 M); clay; moderate medium to coarse subangular blocky structure; hard, firm, very sticky and very plastic, common fine roots; few fine lime nodules; strongly effervescent; strongly alkaline (pH 8.4); clear smooth boundary. |
| Bw | 20-42 cm | Dark brown (10YR 3/3 M); clay; moderate coarse subangular blocky structure with pressure faces; firm, very sticky and very plastic; common fine roots; few fine lime nodules; strongly effervescent; strongly alkaline (pH 8.9); gradual smooth boundary. |
| Bss1 | 42-65 cm | Dark brown (10YR 3/3 M); clay; moderate coarse angular blocky structure with slickensides; firm, very sticky and very plastic; few fine roots; few fine lime nodules; strongly effervescent; strongly alkaline (pH 8.8); gradual smooth boundary. |
| Bss2 | 65-92 cm | Dark brown (10YR 3/3M); clay; moderate coarse subangular blocky structure with slickensides; firm, very sticky and very plastic; few fine roots; few fine lime nodules; strongly effervescent; strongly alkaline (pH 9.0); clear smooth boundary. |
| R | 92+ cm | Hard shale rock |

**Type location:** 14$^{o}$26’15” N, 78$^{o}$11’45”E, village Chinnarangapuram, tehsil Pulivendla, district Kadapa, Andhra Pradesh.

**Range in characteristics:** The thickness of solum ranges from 80 to 100 cm. The thickness of A horizon is 15 to 21 cm. Its colour is in the hue 10YR, value 3 and chroma 2 to 4. The texture is sandy clay to clay. The thickness of B horizon is 59 to 82 cm. Its colour is in 10YR hue, value 3 to 4 and chroma 2 to 4. The texture is dominantly clay.

**Competing Series:** Balapanur series, which is very deep and also Sodic Haplusterts.

**Geographic setting:** Simhadripuram soils are formed on midlands of shales and occurs on nearly level to very gently sloping plains at an elevation is 270 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Agraharam (Sodic Haplusterts), Balapanur (Sodic Haplusterts) and Sunkesula (Vertic Haplustepts).

**Drainage and permeability:** Moderately well drained, with slow permeability.

**Land use and vegetation:** Cultivated to bengalgram, redgram, coriander, sweet orange plantations, sorghum, sunflower. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (Maddi), *Pongamia pinnata* (pongamia), *Calotrophis* sp. *Prosophis juliflora, Lantana* sp.

**Distribution and extent:** Extensive (14,377 ha) in Pulivendla, Tondur and Simhadripuram mandals of Kadapa district, Andhra Pradesh.

**Series proposed :** National Bureau of Soil Survey and Land Use Planning, Regional Centre, Hebbal, Bangalore, 2009.

**Interpretation:** Simhadripuram soils are moderately deep with high water and nutrient retention capacity. These soils conserve most of initial rains through bypass flow. On saturation, they are susceptible to sheet erosion even on gentle slopes. They can support climatically adapted crops. These soils have ESP more than 15 per cent within 100 cm.

**Interpretative grouping**

i. Land capability subclass: III s
ii. Land irrigability subclass: 3s
iii. Productivity potential : Medium

Pedon: 57J/3/T11/3 Classification: Veryfine, cal. Sodic Haplusterts

Location: Chinnarangapuram village, Pulivendla taluk, Kadapa dist. Series: Simhadripuram

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 23.2 | 21.5 | 55.3 | 6.1 | 5.9 | 3.5 | 1.5 | 6.2 | 5 | c |
| 20-42 | Bw1 | 19.3 | 21.4 | 59.3 | 1.1 | 1.3 | 0.8 | 1.4 | 14.7 | 5 | c |
| 42-65 | 2Bss2 | 20.5 | 19.5 | 60.0 | 2.9 | 3.8 | 5.8 | 3.9 | 4.1 | 5 | c |
| 65-92 | 2Bss3 | 13.7 | 24.5 | 61.8 | 3.4 | 3.4 | 2.1 | 2.4 | 2.4 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation | ESP % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | | |
| 0-20 | 8.4 | 8.0 | 7.4 | 0.25 | 8.4 | 140 | 104.3 | 12.7 | 2.76 | 0.79 | 120.6 | 42.7 | 0.77 | 100 | 6.46 |
| 20-42 | 8.9 | 8.1 | 7.5 | 0.36 | 6.0 | 130 | 88.1 | 18.4 | 5.25 | 0.60 | 112.4 | 48.4 | 0.82 | 100 | 10.85 |
| 42-65 | 8.8 | 8.2 | 7.5 | 0.46 | 6.5 | 140 | 85.9 | 14.4 | 8.45 | 0.63 | 109.4 | 47.4 | 0.79 | 100 | 17.83 |
| 65-92 | 9.0 | 8.1 | 7.3 | 0.58 | 6.2 | 120 | 79.0 | 16.0 | 9.46 | 0.69 | 105.2 | 52.1 | 0.84 | 100 | 18.16 |

## 15. VELPULA (Vpl) SERIES

The Velpula series is a member of fine, mixed, isohyperthermic, Typic Haplustalfs. Velpula soils have dark reddish brown, moderately alkaline, sandy clay loam A horizons and dark reddish brown to dark red, moderately alkaline, sandy clay B horizon. They have developed from weathered shales and occur on very gently sloping mid sector with 1-3 per cent slope at an elevation of about 260 m above MSL.

Typifying pedon: Velpula sandy clay loam-cultivated

.

| | | |
|---|---|---|
| Ap | 0-20 cm | Yellowish red (5YR 4/6D) and dark reddish brown (5YR 3/4M); sandy clay loam; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine roots; strongly effervescent; pH 8.3; gradual smooth boundary. |
| Bt1 | 20-43 cm | Dark reddish brown (5YR 3/4 M); sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; thick patchy clay cutans; common very fine roots; common fine to medium lime nodules; strongly effervescent; pH 8.4; clear smooth boundary. |
| Bt2 | 43-68 cm | Dark reddish brown (5YR 3/4M); sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick patchy clay cutans; common fine roots; many fine to medium lime nodules; strongly effervescent; pH 8.4; gradual smooth boundary. |
| Bt3 | 68-100 cm | Dark reddish brown (2.5YR 3/4M); sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick patchy clay cutans; few fine roots; many medium to coarse lime nodules; violently effervescent; pH 8.4; gradual smooth boundary. |
| Bt4 | 100-138 cm | Dark red (2.5YR 3/6M); sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick clay cutans; few fine roots; many medium to coarse lime nodules; violently effervescent; pH 8.5. |
| Crk | 138cm | Weathered shales with Caco3 |

**Type location:** 14º22'0"N, 78º17'0"E, Velpula village, Pulivendla Taluk, Kadapa District of Andhra Pradesh.

**Range in characteristics:** The thickness of solum ranges from 124 to 148 cm. The A horizon is 12-21cm thick. Its colour is in the hue 5YR and 7.5YR, value and chroma 3 to 4. The texture is sandy clay loam to sandy clay. The thickness of B horizon is 104 to 131 cm. Its colour is in 5YR and 2.5YR hue, value 3 to 4 and chroma 2 to 6. The texture is sandy clay loam to clay. The soil is strongly to violently effervescent with dilute Hcl.

**Competing series:** No competing series.

**Geographic Setting:** Soils of Velpula series occurs on very gently sloping mid sector on weathered shales with 1-3 per cent slopes at an elevation of 260 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Santakovur soil, moderately shallow, skeletal, calcareous and classified under Typic Haplustepts.

**Drainage and permeability:** Well drained with moderately rapid permeability.

**Land use and vegetation:** Cultivated to groundnut, sunflower, and sweet orange plantations. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula and Vempalli mandals of Kadapa district, Andhra Pradesh and covers an area of 1753 hectares.

**Series proposed:** NBSS & LUP, R.C., Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIs
ii. Land irrigbaility subclass : 2s
iii. Productive potential : Medium

Pedon: 57J/7/T5/4 Classification: Fine, Typic Haplustafs

Location: Velpula village, Pulivendla taluk, Kadapa dist. Series: Velpula

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 60.7 | 13.5 | 25.8 | 3.3 | 6.3 | 18.9 | 22.1 | 10.1 | 10 | scl |
| 20-43 | Bt1 | 46.4 | 15.5 | 38.1 | 3.7 | 4.0 | 16.7 | 16.0 | 6.1 | - | sc |
| 43-68 | Bt2 | 46.9 | 16.9 | 36.2 | 3.4 | 7.5 | 12.7 | 16.6 | 6.7 | - | sc |
| 68-100 | Bt3 | 51.3 | 10.2 | 38.5 | 5.4 | 5.1 | 17.7 | 18.0 | 5.2 | - | sc |
| 100-138 | Bt4 | 47.4 | 15.0 | 37.6 | 3.6 | 7.5 | 6.4 | 24.0 | 5.9 | - | sc |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-20 | 8.3 | 7.9 | 7.9 | 0.14 | 3.3 | 50 | 34.8 | 9.5 | 0.30 | 0.57 | 45.2 | 13.0 | 0.50 | 100 |
| 20-43 | 8.4 | 8.0 | 7.9 | 0.12 | 2.8 | 100 | 51.9 | 17.4 | 0.49 | 0.36 | 70.2 | 17.6 | 0.46 | 100 |
| 43-68 | 8.4 | 8.0 | 7.9 | 0.20 | 1.6 | 120 | 50.4 | 17.1 | 0.87 | 0.36 | 68.7 | 18.1 | 0.50 | 100 |
| 68-100 | 8.4 | 8.1 | 8.0 | 0.20 | 0.7 | 80 | 47.7 | 21.7 | 0.96 | 0.46 | 70.8 | 15.3 | 0.40 | 100 |
| 100-138 | 8.5 | 8.1 | 7.9 | 0.20 | 1.0 | 90 | 43.2 | 22.8 | 0.78 | 0.42 | 67.2 | 16.8 | 0.45 | 100 |

## 16. AGRAHARAM (Ahm) SERIES

The Agraharam series is a member of very fine, smectitic, calcareous, Sodic Haplusterts. Agraharam soils have dark brown, strongly alkaline, clay A horizons and dark brown to very dark grayish brown, strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping middle sector with 1 to 3 per cent slope at an elevation of 260 m.

Typifying pedon: Agraharam clay – cultivated.

| | | |
|---|---|---|
| Ap | 0-16 cm | Dark brown (10YR 3/3 M); clay; moderate coarse subangular blocky structure; hard, firm, very sticky and very plastic; many fine roots; few fine lime nodules; strongly effervescent; pH 8.8; clear smooth boundary. |
| Bw | 16-36 cm | Very dark grayish brown (10YR 3/2 M); clay; moderate coarse subangular blocky structure with pressure faces; firm, very sticky and very plastic; many fine roots; few fine lime nodules; strongly effervescent; pH 8.8; gradual smooth boundary. |
| Bss1 | 36-71 cm | Very dark grayish brown (10YR 3/2 M); clay; moderate medium subangular blocky structure with slickensides ; firm, very sticky and very plastic; many fine roots; few fine lime nodules; strongly effervescent; pH 8.9; gradual smooth boundary. |
| Bss2 | 71-103 cm | Very dark grayish brown (10YR 3/2 M); clay; moderate medium subangular blocky structure with slickensides; firm, very sticky and very plastic; few fine roots; few fine lime nodules; strongly effervescent; pH 8.8; gradual smooth boundary. |
| Bss3 | 103-120 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure with slickensides; firm, very strong and very plastic; few fine roots; few fine lime nodules; pH 8.8; gradual smooth boundary. |
| Cr | 120cm. | Weathered parent material with CaCO3 |

**Type location:** 14º35’30”N, 78º9’15”E, Agraharam village, Pulivendla Taluk, Kadapa district, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is 120 to 130 cm. The A horizon is 13 to 19 cm thick. Its colour is in the hue 10YR, value 3 and chroma 2 to 3. The texture is clay. The thickness of B horizon is 101 to 117 cm. Its colour is in hue of 10YR with value 3 to 5 and chroma 3 to 4. The texture is clay.

**Competing series:** Balapanur series, which is very deep. It is also a Sodic Haplusterts.

**Geographic setting:** Soils of Agraharam series occurs on very gently sloping middle sector on shales with 1 to 3 per cent slope at an elevation of 240 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Sunkesula, Simhadripuram and Balapanur series are associated soils. Sunkesula soils are moderately shallow and Vertic Haplustepts. Simhadripuram soils are moderately deep, whereas Balapanur soils are very deep and classified as Sodic Haplusterts.

**Drainage and permeability:** Moderately well drained with slow permeability.

**Land Use and vegetation:** Cultivated to sweet orange, sunflower, redgram, bengalgram, jowar and coriander. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Extensive (6166 ha) in Lingala, Pulivendla, Tondur and Simhadripuram mandals of Kadapa district, Andhra Pradesh.

**Series proposed:** NBSS & LUP, Regional Centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIs
ii. Land irrigability subclass : 2s
iii. Productivity potential : Medium

Pedon: 57J/2/T19/1 Classification: Veryfine, cal. Sodic Haplusterts

Location: Agraharam village, Pulivendla taluk, Kadapa dist Series: Agraharam

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-16 | Ap | 23.6 | 18.2 | 58.2 | 6.9 | 6.5 | 2.6 | 4.3 | 3.2 | - | c |
| 16-36 | Bw1 | 12.3 | 22.3 | 65.4 | 2.8 | 2.1 | 1.4 | 0.9 | 5.0 | - | c |
| 36-71 | Bw2 | 16.1 | 22.3 | 61.6 | 3.2 | 2.4 | 3.1 | 3.2 | 4.2 | - | c |
| 71-103 | Bw3 | 14.5 | 21.0 | 64.5 | 3.5 | 2.9 | 1.7 | 2.9 | 3.5 | - | c |
| 103-120 | Bw4 | 24.6 | 23.1 | 52.3 | 5.9 | 6.0 | 3.5 | 5.4 | 3.8 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % | % |
| 0-16 | 8.8 | 8.3 | 7.4 | 0.21 | 9.3 | 110 | 88.0 | 11.0 | 0.98 | 1.90 | 101.9 | 44.2 | 0.76 | >100 | 2.22 |
| 16-36 | 8.8 | 8.1 | 7.3 | 0.25 | 5.4 | 80 | 83.2 | 9.5 | 3.10 | 0.91 | 96.7 | 48.2 | 0.74 | >100 | 6.43 |
| 36-71 | 8.9 | 8.0 | 7.3 | 0.32 | 4.8 | 90 | 72.1 | 7.8 | 5.39 | 0.84 | 86.1 | 47.6 | 0.77 | >100 | 11.32 |
| 71-103 | 8.8 | 9.0 | 7.3 | 0.39 | 4.4 | 80 | 80.0 | 13.2 | 9.43 | 0.84 | 10.3.5 | 42.5 | 0.66 | >100 | 22.19 |
| 103-120 | 8.8 | 8.0 | 7.4 | 0.40 | 4.2 | 50 | 58.7 | 7.7 | 4.76 | 0.66 | 71.8 | 37.1 | 0.71 | >100 | 12.83 |

## 17. BALAPANUR (Bpr) SERIES

The Balapanur series is a member of very fine, smectitic, isohyperthermic, Sodic Haplusterts. Typically, Balapanur soils have dark brown, strongly alkaline, clay A horizons, and dark brown, strongly alkaline, clay B horizons.

Typifying pedon: Balapanur clay-cultivated.

| | | |
|---|---|---|
| Ap | 0-14 cm | Dark brown (10YR 3/3 D and M); clay; strong medium to coarse subangular blocky structure; hard, firm, sticky and plastic; few fine roots; few fine lime nodules; strongly effervescent; strongly alkaline (pH 8.8); clear smooth boundary. |
| Bw | 14-50 cm | Dark brown (10YR 3/3M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; few fine roots; few fine lime nodules; strongly effervescent; strongly alkaline (pH 8.6); gradual smooth boundary. |
| BSS1 | 50-98 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure; firm, very sticky and very plastic; presence of slickensides; few fine roots; few fine lime nodules; slightly effervescent; strongly alkaline (pH 8.5); gradual smooth boundary. |
| BSS2 | 98-118 cm | Dark brown (10YR 3/3M); clay; moderate medium, subangular blocky structure; firm, very sticky and very plastic; presence of slickensides; few fine roots; few fine lime nodules; slightly effervescent; strongly alkaline (pH 8.5); gradual smooth boundary. |
| BSS3 | 118-150+ cm | Brown (10YR 4/3M); clay; moderate medium subangular blocky structure; firm, very sticky and very plastic; presence of pressure faces; few fine lime nodules; strongly effervescent; moderately alkaline (pH 8.3). |

**Type location:** 14º32’0”N, 78º 12’ 00” E, village Balapanur; tehsil Pulivendla, district Kadapa, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is more than 150 cm. The thickness of A horizon ranges from 13 to 25 cm. Its colour is in the hue 10Y, value 3 to 4 and chroma 2 to 4. The texture is sandy clay to clay. The thickness of B horizon is more than 135 cm. Its colour is in hue 10YR, value from 3 to 4 and chroma 2 to 4. The texture is dominantly clay. The soil is slightly to violently effervescent with dilute Hcl.

**Geographic setting:** Balapanur soils are formed from shales and occur on very gently sloping midlands at an elevation of 220 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Simhadripuram (Typic Haplusterts) and Sunkesula Vertic Haplustepts.

**Drainage and permeability:** Moderately well drained with slow permeability.

**Land use and vegetation:** Cultivated to **s**weet orange, cotton, castor, redgram, sunflower, bengalgram. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (Maddi), *Pongamia pinnata* (pongamia), *Calotrophis* sp. *Prosophis juliflora, Lantana* sp.

**Distribution and extent:** Extensive (9575 ha) in Tondur and Simhadripuram mandals Kadapa district, Andhra Pradesh.

**Series proposed by:** National Bureau of Soil Survey and Land Use Planning, Regional Centre, Hebbal, Bangalore, 2009.

**Interpretation:** These soils are deep, well drained, dark brown sodic soils with strong alkalinity and clay per cent more than 60 per cent. These soils have high exchangeable potassium and low organic carbon of 5.7 g $kg^{-1}$ in surface layers.

**Interpretative grouping**

i. Land capability subclass : IIs
ii. Land irrigability subclass : 2s
iii. Productivity potential : Medium

Pedon: 57J/2/T2/P2 Classification: Very fine, cal, Sodic Haplusterts

Location: Balapanur village, Pulivendla taluk, Kadapa dist Series: Balapanur (Bpr)

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total % | | | Sand Fractions % | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-14 | Ap | 23.0 | 24.0 | 53.0 | 7.3 | 4.7 | 2.4 | 4.9 | 3.7 | - | c |
| 14-50 | Bw1 | 20.3 | 22.8 | 56.9 | 7.8 | 3.3 | 2.3 | 2.9 | 4.0 | - | c |
| 50-98 | 2Bss1 | 10.6 | 24.4 | 65.0 | 3.1 | 1.3 | 0.9 | 2.6 | 2.7 | - | c |
| 98-118 | 2Bss2 | 5.3 | 26.5 | 68.2 | 1.5 | 0.7 | 0.9 | 1.2 | 1.1 | - | c |
| 118-150 | 2Bss3 | 6.4 | 25.1 | 68.5 | 1.1 | 1.1 | 0.8 | 1.5 | 2.0 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←--------cmol $kg^{-1}$----------→ | | | | | | | % | |
| 0-14 | 8.8 | 8.0 | 7.5 | 0.41 | 5.7 | 100 | 47.1 | 12.3 | 4.13 | 2.43 | 66.0 | 37.4 | 0.71 | >100 | 11.04 |
| 14-50 | 8.6 | 8.0 | 7.4 | 0.58 | 2.9 | 90 | 43.8 | 12.1 | 7.27 | 1.51 | 64.7 | 36.8 | 0.65 | >100 | 19.75 |
| 50-98 | 8.5 | 7.8 | 7.1 | 0.56 | 2.9 | 70 | 55.8 | 9.5 | 5.71 | 1.10 | 72.1 | 48.7 | 0.75 | >100 | 11.72 |
| 98-118 | 8.2 | 7.8 | 7.2 | 1.05 | 2.8 | 60 | 49.8 | 9.5 | 5.61 | 1.18 | 66.1 | 46.8 | 0.69 | >100 | 11.98 |
| 118-150 | 8.3 | 7.8 | 7.2 | 1.19 | 1.8 | 40 | 57.4 | 9.3 | 5.16 | 1.23 | 73.1 | 46.5 | 0.68 | >100 | 11.10 |

## 18. PARNAPALLE (Prp) SERIES

The Parnapalle series is a member of coarse-loamy, mixed, isohyperthermic, Typic Ustorthents. Parnapalle soils have dark greyish brown, strongly alkaline, sandy loam A horizon and dark grayish brown to dark yellowish brown, strongly alkaline, sandy loam C horizon. They have developed from alluvium and occur on nearly level to very gently sloping lands with 0 to 3 per cent slope at an elevation of 280 M above MSL.

Typifyng pedon: Parnapalle sandy loam-cultivated.

| | | |
|---|---|---|
| Ap | 0-21 cm | Grayish brown (10YR 5/2 D) and dark grayish brown (10YR 4/2M); sandy loam; weak fine subangular blocky structure; slightly hard, friable, non sticky and non plastic; many fine roots; pH 8.7; clear smooth boundary. |
| C1 | 21-43 cm | Dark grayish brown (10YR 4/2M); sandy loam; weak fine, subangular blocky structure; very friable, non sticky and non plastic; few fine roots; pH 8.9; clear smooth boundary. |
| C2 | 43-75 cm | Dark yellowish brown (10YR 4/4M); sandy loam; weak fine subangular blocky structure; very friable, non sticky and non plastic; few fine roots; pH 8.7; gradual smooth boundary. |
| C3 | 75-109 cm | Dark brown (7.5YR 3/4 M); sandy loam; weak fine subangular blocky structure; very friable, non sticky and non plastic; pH 8.6; gradual smooth boundary |
| C4 | 109-150 cm | Dark brown (7.5YR 3/4M); sandy loam; weak fine subangular blocky structure; very friable, non sticky and non plastic; pH 8.7. |

**Type Location:** 14°34’45” N, 77°57’30”, Parnapalle village, Pulivendla Taluk, Kadapa district, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is more than 150 cms. The A horizon is 21 to 23 cm thick. Its colour is in the hue 10YR, value 3 to 4 and chroma 2 to 3. The texture is sandy loam. The thickness of C horizon is more than 150 cm. Its colour is in 10YR and 7.5YR hues, value 3 to 4 and chroma 2 to 4. The texture is dominantly sandy loam.

**Competing series:** No competing series

**Geographic setting:** Soils of Parnapalle series occurs on nearly level to very gently sloping lands on alluvium with 0 to 3 per cent slope at an elevation of 280 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Associated soils are Kanampalle soils of hills and ridges which are very shallow, loamy-skeletal, Lithic Ustorthents.

**Drainage and permeability:** Well drained with moderately rapid permeability.

**Land and vegetation:** Cultivated to Paddy. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring Lingala Mandal and extent of area is 446 ha.

**Series proposed by:** NBSS & LUP, Regional Centre, Hebbal, Banglaore.

**<u>Interpretation:</u>**

i. Land capabilitysub class : IIIs
ii. Land irrigability subclass : 3s

ii. Productivity potential : Low

Pedon: 57F/14/T6/2 Classification: Coarse-loamy, Typic Ustorthents

Location: Parnapalle village, Pulivendla taluk, Kadapa dist Series:Parnapalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-21 | Ap | 78.4 | 8.9 | 12.7 | 3.8 | 11.9 | 19.9 | 33.8 | 9.0 | - | sl |
| 21-43 | C1 | 79.2 | 8.9 | 11.9 | 4.3 | 103. | 17.1 | 29.3 | 18.2 | - | sl |
| 43-75 | C2 | 77.1 | 11.2 | 11.7 | 3.3 | 5.3 | 20.6 | 30.0 | 17.9 | - | sl |
| 75-109 | C3 | 74.6 | 6.8 | 18.6 | 1.8 | 7.6 | 7.1 | 27.3 | 30.8 | - | sl |
| 109-150 | C4 | 82.3 | 4.6 | 13.1 | 9.0 | 20.5 | 14.4 | 21.6 | 16.7 | - | sl |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-21 | 8.7 | 7.8 | 7.7 | 0.31 | 5.0 | 20 | 27.2 | 3.3 | 0.51 | 0.20 | 31.2 | 10.3 | 0.81 | 100 |
| 21-43 | 8.9 | 8.0 | 7.8 | 0.22 | 1.1 | 20 | 25.5 | 3.6 | 0.43 | 0.22 | 29.8 | 6.6 | 0.55 | 100 |
| 43-75 | 8.7 | 7.9 | 7.7 | 0.18 | 0.9 | 10 | 9.3 | 2.2 | 0.34 | 0.19 | 12.0 | 7.1 | 0.61 | 100 |
| 75-109 | 8.6 | 7.8 | 7.4 | 0.26 | 1.0 | 10 | 12.9 | 2.9 | 0.37 | 0.21 | 16.4 | 8.5 | 0.46 | 100 |
| 109-150 | 8.7 | 7.8 | 7.4 | 0.23 | 0.1 | 00 | 7.1 | 2.0 | 0.32 | 0.12 | 9.5 | 5.7 | 0.44 | 100 |

## 19. GONDIPALLE (Gpl) SERIES

The Gondipalle seris is a member of clayey, mixed, isohyperthermic Lithic Haplustepts. Gondipalle soils have dark brown, strongly alkaline, gravelly clay A and B horizons. They have developed from shales and occur on nearly level to very gently sloping colluvial lower sector with 0-3 per cent slope at an elevation of 220 m above MSL

Typifying pedon: Gondipalle gravelly clay – cultivated.

| | | |
|---|---|---|
| Ap | 0-22 cm | Dark brown (10YR 3/3M); gravelly clay; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; 15 per cent gravel; common fine to medium lime nodules; common fine and medium roots; strongly effervescent; pH 8.5; clear smooth boundary. |
| Bw | 22-44 cm | Dark brown (10YR 3/3 M); gravelly clay; moderate medium subangular blocky structure; firm, sticky and plastic; 20 per cent gravel; many fine to medium lime nodules; many fine and medium roots; violently effervescent; pH 9.0; abrupt smooth boundary. |
| R | 44 cm | Hard shale rock |

**Type location:** 14$^{o}$23’45”N, 78$^{o}$16’15”E, Gondipalle village, Pulivendla taluk, Kadapa district, Andhra pradesh.

**Range in characteristics:** The thickess of solum is 37 to 45cms. The thickness of A horizon ranges from 15 to 23 cms. Its colour is in the hue 10YR and 7.5YR, value 3 to 4 and chroma 3 to 6. The texture is sandy clay loam to clay with 15 per cent gravel. The thickness of B horizon is 18 to 33 cm. Its colour is in 10YR and 7.5YR hue, value and chroma 3 to 4. The texture is sandy clay to clay with 15 to 20 per cent gravel. . The soil is violently effervescent with dilute Hcl.

**Competing series:** No competing series.

**Geographic setting:** Soils of Gondipalle series occurs on nearly level to very gently sloping colluvial lower sector on shales with 0 to 3 per cent slope at an elevation of

220 above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Tondur and Gotur series are associated soils. Tondur soils are very deep, calcareous, Vertic Haplustepts. The Gotur soils are moderately shallow, calcareous Typic Haplustepts.

**Drainage and permeability:** Well drained with slow permeability.

**Land use and vegetation:** Cultivated to redgram, groundnut, sunflower and cotton. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula and Vempalli mandals and covers an area of 2474 hectares.

**Series proposed :** NBSS & LUP, Regional Centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IVs
ii. Land irrigability subclass : 4s
iii. Productivity potential : low

Pedon: 57J/7/T16/3 Classification: Clayey, cal. Lithic Haplustepts

Location: Gondipalle village, Pulivendla taluk, Kadapa dist Series: Gondipalle

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-22 | Ap | 29.5 | 19.4 | 51.1 | 6.1 | 6.4 | 5.3 | 7.0 | 4.7 | 15 | gc |
| 22-44 | Bw | 29.4 | 17.6 | 53.0 | 5.4 | 5.8 | 5.4 | 8.9 | 3.9 | 20 | gc |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | CaCO3 Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | $dSm^{-1}$ | $g\ kg^{-1}$ | $g\ kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-22 | 8.5 | 7.9 | 7.5 | 0.21 | 14.7 | 150 | 64.1 | 15.9 | 0.31 | 1.45 | 81.8 | 35.8 | 0.70 | 100 |
| 22-44 | 9.0 | 8.2 | 7.6 | 0.35 | 10.3 | 170 | 61.9 | 15.3 | 6.01 | 0.76 | 84.0 | 33.1 | 0.62 | 100 |

## 20 GOTURU (Gtr) SERIES

The Goturu series is a member of fine, mixed, isohyperthermic Typic Haplustepts. Goturu soils have dark yellowish brown, very strongly alkaline, clay A horizon and dark brown to dark yellowish brown, very strong to strongly alkaline, clay B horizon. They have developed from weathered shales and occur on nearly level to very gently sloping colluvic lower sector with 0 to 3 per cent slope at an elevation of 200 m above MSL.

Typifying pedon: Gotur clay-cultivated

| | | |
|---|---|---|
| Ap | 0-21 cm | Dark yellowish brown (10YR 3/4M); clay; moderate medium subangular blocky structure; hard, firm, sticky and plastic; 10 per cent fine gravel; common very fine roots; few fine lime nodules; strongly effervescent; pH 9.1; clear smooth boundary. |
| Bw1 | 21-48 cm | Dark yellowish brown (10YR 3/4M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; common fine roots; common medium lime nodules; strongly effervescent; pH 9.1; gradual smooth boundary |
| Bw2 | 48-70 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; few fine roots; common medium lime nodules; violently effervescent; pH 9.0; clear wavy boundary. |
| Cr | 70 cm | Weathered shales with $CaCo_3$ |

**Type location:** 12º25’0” N, 78º21’45” E, Goturu village, Pulivendla Taluk, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is 65 to 70 cms. The thickness of A horizon is ranges form 19 to 23 cms. Its colour is in the hue of 10YR and 7.5YR with value 3 to 5 and chroma 3 to 4. The texture is sandy clay to clay. The thickness of B horizon ranges from 46 to 51 cm. Its colour is in 10YR and 7.5YR with value 3 to 5 and chroma 3 to 4. The texture is clay. The gravel content varies from 0 to 15 per cent. The soil is strongly to violently effervescent with dilute Hcl.

**Competing series:** No competing series.

**Geographic setting:** Soils of Goturu series occur on nearly level to very gently sloping colluvic lower sector on weathered shales with 0 to 3 per cent slope at an elevation of 200 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geogrpahically associated soils:** Pernapadu and Agadur series are associated soils. Pernapadu series are deep and Agadur series are very deep soils and both are classified under Vertic Haplustepts.

**Drainage and permeability:** Well drained with moderately slow permeability.

**Land use and vegetation:** Cultivated to sunflower, sweet orange, coriander, jowar, groundnut, bengalgram, chillies and redgram. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula, Simhadripuram and Vempalli mandals of Kadapa district, Andhra Pradesh and covers an area of 2757 hectares.

**Series proposed :** NBSS & LUP, Regional centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIIs
ii. Land irrigability subclass : 3s

iii. Productivity potential : Medium

Pedon: 57J/7/T15/3 Classification: Fine, cal. Typic Haplustepts

Location: Goturu village, Pulivendla taluk, Kadapa dist Series: Goturu (Gtr)

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-21 | Ap | 42.0 | 13.9 | 40.0 | 8.5 | 9.9 | 8.9 | 9.2 | 5.4 | 10 | c |
| 21-48 | Bw1 | 20.3 | 16.0 | 58.7 | 2.8 | 2.6 | 5.0 | 4.8 | 5.1 | - | c |
| 48-70 | Bw3 | 19.5 | 16.5 | 59.1 | 3.3 | 3.7 | 3.7 | 4.6 | 4.2 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-21 | 9.1 | 8.2 | 7.5 | 0.47 | 8.4 | 90 | 73.9 | 8.7 | 5.82 | 1.45 | 89.9 | 36.9 | 0.92 | 100 |
| 21-48 | 9.1 | 8.1 | 7.3 | 0.52 | 6.4 | 50 | 71.6 | 4.5 | 12.63 | 0.44 | 89.2 | 51.9 | 0.88 | 100 |
| 48-70 | 9.0 | 8.2 | 7.3 | 0.64 | 5.4 | 70 | 67.4 | 6.3 | 12.63 | 0.58 | 86.9 | 81.9 | 1.39 | 100 |

## 21 PULIVENDLA (Pvd) SERIES

The Pulivendla series is a member of fine, mixed, isohyperthermic Aeric Halaquepts. Pulivendla soils have, dark brown clay surface horizon followed by dark brown clay subsoil. They have developed from weathered shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at an elevation of 220 m above MSL.

Typifying pedon: Pulivendla clay-uncultivated

| | | |
|---|---|---|
| A | 0-19 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure; slightly hard, firm, sticky and plastic; few very fine roots; common fine lime nodules; violently effervescent; pH 9.3; abrupt smooth boundary. |
| Bw1 | 19-44 cm | Dark brown (7.5 YR 3/4M); clay; moderate medium subangular blocky structure; firm, very sticky and very plastic; common very fine roots; common medium lime nodules; violently effervescent; pH9.1; gradual smooth boundary. |
| Bw2 | 44-76 cm | Dark brown (7.5YR 3/4M); clay; moderate medium subangular blocky structure; firm, very sticky and very plastic; common fine roots; many medium lime nodules; violently effervescent; pH 9.5; clear smooth boundary. |
| Bw3 | 76-110 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure; firm, very sticky and very plastic; many medium lime nodules; violently effervescent; pH 9.1; gradual smooth boundary. |
| Bw4 | 110-135 cm | Dark brown (10YR 3/3M); sandy clay; moderate medium subangular blocky structure; friable, sticky and slightly plastic; many medium lime nodules; violently effervescent; pH 9.5 |
| Cr | 135cm | Weathered shales with $CaCo_3$ |

**Type location:** 14°25”0” N, 78°18”45”E, Gollalaguduru village, Pulivendla Taluk, Andhra Pradesh.

**Range in characteristics:** The thickness of solum ranges from 120 to 148 cm. The thickness of A horizon ranges from 19 to 23 cm. Its colour is in 10YR and 7.5YR hue, value 3 and chroma 3 to 4. Its texture is sandy clay to clay. The thickness of B horizon ranges from 99 to 125 cm. Its colour is in 10YR and 7.5YR hue, value 3 and chroma 3 to 4. Its texture is sandy clay to clay. These soils are strongly effervescent with dil Hcl.

**Competing series:** No competing series.

**Geographic settings:** Soils of Pulivendla series occurs on very gently sloping colluvic lower sector on shales with 1-3 per cent slope at an elevation of 220 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Associated soil series are Agadur and Pernapadu. Agadur soils are very deep and very fine, Pernapadu soils are deep and both are Vertic Haplustepts.

**Drainage and permeability:** Moderately welldrained with slow permeability.

**Land Use and vegetation:** Mostly under wasteland with some patches is cultivated to sweet orange. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula and Vempalli mandals of Kadapa district, Andhra Pradesh and covers an area of 3611 hectares.

**Series proposed :** NBSS & LUP, Regional Centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass : IVs
ii. Land irrigability subclass : 4s
iii. Productivity potential : Low

Pedon: 57J/7/R9 Classification: Fine, cal. Aeric Halaquepts

Location: Gollalagudur village, Pulivendla taluk, Kadapa dist Series: Pulivendla

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-19 | A | 38.6 | 1.2 | 60.2 | 13.3 | 7.9 | 7.0 | 5.5 | 5.0 | 10 | c |
| 19-44 | Bw1 | 38.6 | 3.6 | 57.8 | 10.0 | 8.3 | 7.1 | 7.3 | 5.9 | 10 | c |
| 44-76 | Bw2 | 34.8 | 1.6 | 63.6 | 2.5 | 4.8 | 10.3 | 10.4 | 6.8 | - | c |
| 76-110 | Bw3 | 41.4 | 2.4 | 56.2 | 4.2 | 9.7 | 8.8 | 13.3 | 5.5 | - | c |
| 110-135 | Bw4 | 59.6 | 1.3 | 39.1 | 8.0 | 10.4 | 13.4 | 21.8 | 6.0 | - | sc |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Satr. | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % | % |
| 0-19 | 9.3 | 8.5 | 8.2 | 1.47 | 2.6 | 110 | 59.9 | 12.7 | 16.43 | 1.41 | 90.4 | 24.2 | 0.40 | 100 | 67.89 |
| 19-44 | 9.1 | 8.8 | 8.4 | 6.73 | 2.5 | 90 | 48.6 | 1.2 | 42.93 | 0.79 | 102.5 | 23.2 | 0.40 | 100 | 185.04 |
| 44-76 | 9.5 | 9.1 | 8.4 | turbid | 1.0 | 70 | 44.6 | 6.8 | 37.65 | 0.74 | 89.8 | 32.6 | 0.51 | 100 | 115.49 |
| 76-110 | 9.1 | 8.9 | 8.5 | turbid | 0.8 | 90 | 41.5 | 6.5 | 44.71 | 0.61 | 93.3 | 26.7 | 0.48 | 100 | 167.45 |
| 110-135 | 9.5 | 8.9 | 8.6 | turbid | 0.1 | 70 | 31.3 | 5.2 | 24.38 | 0.45 | 61.3 | 18.8 | 0.48 | 100 | 129.68 |

## 22. PERNAPADU (Ppd) SERIES

The Pernapadu series is a member of fine, smectitic, isohyperthermic Vertic Haplustepts. Pernapadu soils have dark yellowish brown, moderately alkaline, clay A horizon and dark yellowish brown, moderate to strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at elevation of 210 m above MSL.

Typifying pedon: Pernapadu clay-cultivated

| | | |
|---|---|---|
| Ap | 0-22 cm | Dark yellowish brown (10YR 3/4M); clay; moderate medium subangular blocky structure; hard firm sticky and plastic; few fine roots; few fine lime nodules; strongly effervescent; pH 8.4; clear smooth boundary. |
| Bw1 | 22-54 cm | Dark brown (10YR 3/4M); clay; moderate medium subangular blocky structure with pressure faces; firm very sticky and very plastic; few fine lime nodules; violently effervescent; pH 8.4; clear smooth boundary. |
| Bw2 | 54-80 cm | Dark yellowish brown (10YR 3/4M); clay; moderate medium subangular blocky structure with pressure faces; firm very sticky and very plastic; few fine roots; common many lime nodules; violently effervescent; pH 8.4; gradual smooth boundary. |
| Bw3 | 80-103 cm | Dark yellowish brown (10YR 3/4M); clay; moderate medium subangular blocky structure with pressure faces; firm very sticky and very plastic; many medium lime nodules; pH 8.5; violently effervescent; clear wavy boundary. |
| Cr | 103 cm | Weathered shales: |

**Type location:** 14º26’0”N, 78º18’30” E, Gollalaguduru village; Pulivendla Taluk, Kadapa district, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is 103 to 148 cm. The thickness of A horizon is 15 to 25 cm. Its colour is in the hue 10YR and 7.5YR, value and chroma 3 to 4. The texture is sandy clay loam to clay. The thickness of B horizon varies from 79 to 130 cm. Its colour is in 10YR and 7.5YR hue, value 3 to 4 and chroma 2 to 4. The texture is clay. The soil is strongly to violently effervescent with dilute Hcl.

**Competing series:** No competing series.

**Geographic settings:** Soils of Pernapadu series occurs on very gently sloping colluvic lower sector on shales with 1-3 per cent slope at an elevation of 210 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Associated soil series are Gondipalle, Pulivendla, Tondur and Agadur series. Gondipalle series are shallow, Lithic Haplustepts. Pulivendla series are deep and classified as Aeric Halaquepts. Agadur and Tondur series are very deep, Agadur is very fine and Tondur series is fine textured. Both are classified under Vertic Haplustepts.

**Drainage and permeability:** Moderately welldrained with slow permeability.

**Land use and vegetation:** Cultivated to coriander, bengalgram, sunflower, redgram, loose orange, jowar, chillies and groundnut. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula, Simhadripuram and Vempalli mandals and covers an area of 7686 hectares.

**Series proposed by:** NBSS & LUP, Regional Centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIs
ii. Land irrigability subclass : 2s
iii. Productivity potential : Medium

Pedon: 57J/7/R18 Classification: Fine, cal. Vertic Haplustepts

Location: Gollalagudur village, Pulivendla taluk, Kadapa dist Series: Pernapadu

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-22 | Ap | 33.4 | 19.3 | 47.3 | 3.7 | 5.1 | 5.7 | 3.0 | 12.1 | - | c |
| 22-54 | Bw1 | 31.6 | 15.0 | 53.4 | 3.7 | 2.9 | 7.6 | 6.5 | 5.1 | - | c |
| 54-80 | Bw2 | 23.0 | 21.2 | 55.8 | 2.4 | 4.8 | 4.9 | 6.1 | 4.0 | - | c |
| 80-103 | Bw3 | 22.4 | 18.8 | 58.8 | 2.9 | 3.6 | 3.4 | 6.4 | 3.5 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-22 | 8.4 | 8.0 | 7.4 | 0.19 | 6.3 | 130 | 86.4 | 3.7 | 0.15 | 0.97 | 91.2 | 45.0 | 0.95 | 100 |
| 22-54 | 8.4 | 7.7 | 7.3 | 0.18 | 6.3 | 140 | 86.7 | 4.5 | 0.24 | 0.46 | 91.9 | 48.5 | 0.91 | 100 |
| 54-80 | 8.4 | 7.7 | 7.1 | 0.20 | 6.8 | 140 | 85.1 | 5.3 | 0.35 | 0.50 | 91.3 | 50.6 | 0.91 | 100 |
| 80-103 | 8.5 | 7.7 | 7.2 | 0.15 | 6.3 | 150 | 95.8 | 5.0 | 0.76 | 0.52 | 102.1 | 52.7 | 0.90 | 100 |

## 23 AGADUR (Agd) SERIES

The Agadur series is a member of very fine, smectitic, isohyperthermic Vertic Haplustepts. Agadur soils have dark brown, moderately alkaline, clay A horizon and dark brown to very dark grayish brown, strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at an elevation of 200 m above MSL.

Typifying pedon: Agadur clay-cultivated

| | | |
|---|---|---|
| Ap | 0-19 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common very fine to fine roots; few very fine lime nodules; slightly effervescent; pH 8.3; clear smooth boundary. |
| Bw1 | 19-49 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; common very fine roots; few fine lime nodules; slightly effervescent; pH 8.6; clear smooth boundary. |
| Bw2 | 49-91 cm | Very dark grayish brown (10YR 3/2M); clay; moderate medium subangular blocky structure with pressure faces; firm very sticky and very plastic; common fine roots; few fine roots; slightly effervescent; pH 8.8; clear smooth boundary. |
| Bw3 | 91-125 cm | Dark brown (10YR 3/3M);clay; moderate medium subangular blocky structure with pressure faces; firm very sticky and very plastic; few fine roots; few fine lime nodules; slightly effervescent; pH 8.9; gradual smooth boundary. |
| Bw4 | 125-145 cm | Dark brown (10YR 3/2 M); clay; moderate medium subangular blocky structure with pressure faces; firm very sticky and very plastic; few fine roots; few fine lime nodules; slightly effervescent; pH 8.8. |

**Type location:** 14º32”15” N, 78º18”45”E, Udavagandla village, Pulivendla Taluk, Kadapa District, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is more than 150 cm. The thickness of A horizon is 11 to 23 cm. Its colour is in 10YR hu, value and chroma of 3 to 4. The texture is sandy clay to clay. The thickness of B horizon is 124 to 139 cm. Its colour is in 10YR hue, value 3 to 4 and chroma 2 to 3. The texture is clay. The soil is slightly effervescent with dil Hcl.

**Competing series:** Tondur series which is also a very deep, Vertic Haplustepts but strongly calcareous.

**Geographic settings:** Soils of Agadur series occurs on very gently sloping colluvic lower sector on shales with 1-3 per cent slope at an elevation of 200 M above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Associated soil series are Bhadranpalle and Tondur. Bhadrampalle series are very deep, fine, Sodic Haplusterts whereas Tondur series are very fine, Vertic Haplustepts. Both are calcareous soils.

**Drainage and permeability:** Moderately welldrained with slow permeability.

**Land use and vegetation:** Cultivated to redgram, bengalgram, sunflower, Coriander, jowar, and sweet orange. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula, Simhadripuram and Vempalli mandals of Kadapa district, Andhra Pradesh and covers an area of 3608 hectares.

**Series proposed by:** NBSS & LUP, Regional Centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIs
ii. Land irrigability subclass : 2s
iii. Productivity potential : Medium

Pedon: 57J/6/T6/2 Classification: Veryfine, cal. Vertic Hapustepts

Location: Udavagandla Village, Pulivendla taluk, Kadapa dist Series: Agadur

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-19 | Ap | 32.6 | 19.8 | 47.6 | 7.4 | 8.0 | 4.3 | 8.3 | 4.6 | - | c |
| 19-49 | Bw1 | 16.8 | 23.4 | 59.8 | 2.6 | 2.8 | 1.8 | 3.5 | 6.1 | - | c |
| 49-91 | Bw2 | 15.1 | 22.0 | 62.9 | 2.7 | 2.9 | 0.9 | 4.1 | 4.5 | - | c |
| 91-125 | Bw3 | 14.0 | 21.8 | 64.2 | 2.3 | 2.3 | 2.1 | 2.5 | 4.7 | - | c |
| 125-145 | Bw4 | 14.2 | 22.9 | 62.9 | 2.7 | 2.7 | 1.4 | 3.6 | 3.8 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-19 | 8.3 | 7.8 | 7.3 | 0.19 | 5.4 | 100 | 75.3 | 7.1 | 0.2 | 1.01 | 83.6 | 42.6 | 0.89 | 100 |
| 19-49 | 8.6 | 7.9 | 7.2 | 0.17 | 4.2 | 80 | 77.9 | 9.4 | 1.29 | 0.62 | 89.2 | 53.1 | 0.89 | 100 |
| 49-91 | 8.8 | 7.9 | 7.2 | 0.211 | 4.2 | 80 | 78.0 | 10.0 | 2.86 | 0.56 | 91.4 | 57.0 | 0.91 | 100 |
| 91-125 | 8.9 | 8.0 | 7.2 | 0.27 | 4.0 | 70 | 74.7 | 12.4 | 3.33 | 0.60 | 91.0 | 59.1 | 0.92 | 100 |
| 125-145 | 8.8 | 8.0 | 7.2 | 0.28 | 3.9 | 70 | 77.0 | 12.3 | 3.50 | 0.67 | 93.5 | 49.7 | 0.79 | 100 |

## 24. TONDUR (Tdr) SERIES

The Tondur series is a member of very fine, smectitic, isohyperthermic Vertic Haplustepts. Tondur soils have dark brown, very strongly alkaline, clay A horizon and very dark grayish brown, very strongly alkaline, clay B horizon. They have developed from shales and occur on very gently sloping colluvic lower sector with 1 to 3 per cent slope at an elevation of 210 m above MSL.

Typifying pedon: Tondur clay-cultivated

| | | |
|---|---|---|
| Ap | 0-20 cm | Dark brown (10YR 3/3 M); clay; moderate medium subangular blocky structure; hard firm sticky and plastic; many very fine and fine roots; slightly effervescent, pH 9.1; clear smooth boundary. |
| Bw1 | 20-47 cm | Very dark grayish brown (10YR 3/2 M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; common very fine roots; few very fine lime nodules; slightly effervescent; pH 9.4; clear smooth boundary. |
| Bw2 | 47-74 cm | Very dark grayish brown (10YR 3/2M); clay; moderate medium subangular blocky structure with pressure faces ; firm, very sticky and very plastic; common very fine roots; few fine lime nodules; strongly effervescent; pH 9.5; gradual smooth boundary. |
| Bw3 | 74-105 cm | Very dark grayish brown (10YR 3/2M); clay; moderate medium subangular blocky structure with pressure faces; firm very sticky very plastic; few fine roots; fine few lime nodules; strongly effervescent; pH 9.4; gradual smooth boundary. |
| Bw4 | 105-152 cm | Dark brown (10YR 3/3M); clay; moderate medium subangular blocky structure with pressure faces; firm, very sticky and very plastic; few fine roots; common fine lime nodules; strongly effervescent; pH 9.3 |

**Type location:** 14º22'0" N, 78º27'0"E, Vempalli village, Pulivendla Taluk, Kadapa district; Andhra Pradesh.

**Range in characteristics:** The thickness of solum is more than 150 cm. The thickness of A horizon is 17 to 23 cm. Its colour is in 7.5YR and 10YR hue, value 3 to 4 and chroma 2 to 4. The texture is sandy clay to clay. The thickness of B horizon is 128 to 136 cm. Its colour is in 7.5YR and 10YR hue, value 3 to 4 and chroma 2 to 4. Its texture is clay. The soil is slight to strongly effervescent with dilute Hcl.

**Competing series:** Agadur series which is in very deep, Vertic Haplustepts but slightly effervescent.

**Geographic settings:** Soils of Tondur series occurs on very gently sloping colluvic lower sector on shales with 1-3 per cent slope at an elevation of 210 M above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geographically associated soils:** Associated soil series are Pernapadu and Agadur. Pernapadu soils are deep, fine textured whereas Agadur soils are very deep, very fine. Both are Vertic Haplustepts.

**Drainage and permeability:** Moderately welldrained with slow permeability.

**Land use and vegetation:** Cultivated to groundnut, sunflower, redgram, sweet orange. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia*, *Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and Extent:** Extensive (6361 ha) in Pulivendla, Tondur, Vemula and Vempalli mandals of Kadapa district, Andhra Pradesh.

**Series proposed by:** NBSS & LUP, Regional Centre, Hebbal, Bangalore.

**Interpretation:**

i. Land capability subclass : IIs

ii. Land irrigability subclass : 2s

iv. Productivity potential : Medium

Pedon: 57J/7/T10-1 Classification: Veryfine, cal. Vertic Haplustepts

Location: Vempalli village, Pulivendla taluk, Kadapa dist Series: Tondur

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-1.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-20 | Ap | 29.8 | 22.3 | 47.9 | 6.9 | 7.0 | 5.1 | 6.4 | 4.4 | - | c |
| 20-47 | Bw1 | 23.6 | 15.8 | 60.6 | 5.7 | 5.8 | 3.2 | 5.8 | 3.2 | - | c |
| 47-74 | Bw2 | 18.9 | 19.0 | 62.1 | 3.8 | 3.7 | 3.4 | 3.6 | 4.4 | - | c |
| 74-105 | Bw3 | 18.0 | 17.5 | 64.5 | 3.8 | 3.8 | 2.1 | 5.3 | 3.0 | - | c |
| 105-152 | Bw4 | 9.2 | 20.8 | 70.0 | 1.6 | 1.5 | 2.0 | 1.9 | 2.1 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$----------→ | | | | | | | % |
| 0-20 | 9.1 | 8.1 | 7.3 | turbid | 5.8 | 100 | 88.2 | 14.7 | 1.93 | 0.42 | 105.3 | 41.9 | 0.87 | 100 |
| 20-47 | 9.4 | 8.2 | 7.4 | turbid | 4.3 | 110 | 83.2 | 9.5 | 6.50 | 0.24 | 99.4 | 47.4 | 0.78 | 100 |
| 47-74 | 9.5 | 8.4 | 7.4 | turbid | 3.6 | 120 | 72.3 | 7.9 | 9.64 | 0.28 | 90.1 | 48.2 | 0.78 | 100 |
| 74-105 | 9.4 | 8.5 | 7.4 | turbid | 2.5 | 100 | 80.2 | 13.2 | 11.49 | 0.30 | 105.2 | 49.4 | 0.77 | 100 |
| 105-152 | 9.3 | 8.6 | 7.5 | turbid | 1.1 | 120 | 58.8 | 7.7 | 13.88 | 0.67 | 81.1 | 50.3 | 0.72 | 100 |

## 25. BHADRAMPALLE (Bpl) SERIES

The Bhadrampalle series is a member of fine, smectitic, isohyperthermic, Sodic Haplusterts. Bhadrampalle soils have dark brown, strongly alkaline, sandy clay A horizon and very dark grayish brown to dark yellowish brown, strongly alkaline, clay B horizons. They have developed from shales and occur on nearly level to very gently sloping lands with 0-3 per cent slope at an elevation of 220 m above MSL.

Typifying pedon: Bhadrampalle sandy clay-cultivated.

| | | |
|---|---|---|
| Ap | 0-12 cm | Dark brown (10YR 3/3 M); sandy clay; moderate medium subangular blocky structure; hard, firm, sticky and plastic; many fine roots; few fine lime noduels; strongly effervescent; pH 8.7; clear smooth boundary. |
| Bw | 12-36 cm | Very dark grayish brown (10YR 3/2 m); clay; moderate coarse subangular blocky structure with pressure faces; firm, very sticky and very plastic; few fine roots; few fine lime nodules; strongly effervescent; pH 8.9; gradual smooth boundary. |
| Bss1 | 36-63 cm | Very dark grayish brown (10YR 3/2 M); clay; moderate coarse angular blocky structure with slickensides; firm, very sticky and very plastic; fine few roots; common few lime nodules; strongly effervescent; pH 8.6; gradual smooth boundary. |
| Bss2 | 63-85 cm | Very dark grayish brown (10YR 3/2M); clay; moderate coarse angular blocky structure with intersecting slickensides ; firm, very sticky and very plastic; few fine roots; common fine lime nodules; strongly effervescent; pH 8.76; gradual smooth boundary. |
| Bss3 | 85-107 cm | Dark yellowish brown (10YR 3/4M);clay; moderate coarse angular blocky structure with intersecting slickensides; firm, very sticky and very plastic; few fine roots; common fine lime nodules; strongly effervescent; pH 8.6; gradual smooth boundary |
| Bss4 | 107-150 cm | Dark yellowish brown (10YR 3.4 M); clay; moderate coarse angular blocky structure with intersecting slickensides; firm, very sticky and very plastic; few fine roots; common fine lime nodules; violently effervescent; pH 9.0 |

**Type location:** 14º34'15"N, 78º14'30"E, Bhadrampalle village, Pulivendla taluk, Kadapa district, Andhra Pradesh.

**Range in characteristics:** The thickness of solum is more than 150 cm. The thickness of A horizon is 12 to 22cm. Its colour is in 7.5YR and 10YR hue, value and chroma 3 to 4. The texture is sandy clay loam to clay. The thickness of B horizon is 128 to 138 cm. Its colour is in 7.5YR and 10YR hue, value 3 to 4 and chroma 2 to 4. Its texture is dominantly clay. The soil is slightly to violently effervescent with dilute Hcl.

**Competing series:** There is no competing series

**Geographic setting:** Soils of Bhadrampalle series are occurs on nearly level to very gently sloping colluvic lower sector on shales with 0 to 3 per cent slope at an elevation of 220 m above MSL. The climate is semi arid with mean annual air temperature of 29.3°C and mean annual rainfall of 500 mm. The estimated MAST is 28.3°C, MSST 29.6°C and MWST 24.7°C. The difference between MSST and MWST is 4.9°C. The moisture regime is ustic.

**Geogrpahically associated soils:** Geographically associated soils are Pulivendla and Tondur series. Soils of Pulivendla series are deep, calcareous Aeric Halaquepts. Tondur soils are very deep Vertic Haplustepts.

**Drainage and permeability:** Moderatley well drained with slow permeability.

**Land use and vegetation:** Cultivated to cotton and purely under fallow. Natural vegetation: *Azadirachta indica* (neem), *Terminalia tomentosa* (maddi), *Pongamia pinnata* (Pongamia), *Casia cyamia, Calotrophis* sp. *Prosopis juliflora*, Lantana sp.

**Distribution and extent:** Occurring in Pulivendla, Tondur, Vemula and Simhadripuram mandalsof Kadapa district, Andhra Pradesh and covers an area of 1000 hectares.

**Series proposed by:** NBSS&LUP, Regional centre, Hebbal, Bangalore

**Interpretation:**

i. Land capability subclass: III s

ii. Land irrigability subclass: 3s

iii. Productivity potential : Medium

Pedon: 57J/2/T30/1 Classification: Fine, cal, Sodic Haplusterts

Location: Bhadrampalle Series: Bhadrampalle (Bpl)

| Depth (cm) | Horizon | Size class and particle diameter (mm) | | | | | | | | Coarse fragments v/v (%) | Textural Class (USDA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | | | Sand | | | | | | |
| | | Sand (2.0-0.05) | Silt (0.05-0.002) | Clay (<0.002) | Very coarse (2.0-.0) | Coarse (1.0-0.5) | Medium (0.5-0.25) | Fine (0.25-0.1) | Very.fine (0.1-0.05) | | |
| 0-12 | Ap | 45.0 | 5.9 | 49.1 | 4.0 | 2.5 | 5.9 | 12.8 | 19.9 | - | sc |
| 12-36 | Bw | 31.6 | 20.8 | 47.6 | 2.5 | 4.2 | 3.6 | 11.0 | 10.3 | - | c |
| 36-63 | Bss1 | 26.4 | 18.5 | 55.1 | 4.2 | 4.9 | 2.9 | 9.0 | 5.4 | - | c |
| 63-85 | Bss2 | 25.0 | 18.9 | 56.1 | 3.5 | 4.3 | 4.0 | 6.3 | 6.8 | - | c |
| 85-107 | Bss3 | 20.7 | 18.2 | 61.1 | 1.9 | 2.9 | 2.8 | 6.9 | 6.2 | - | c |
| 107-150 | Bss4 | 14.4 | 18.2 | 67.4 | 1.7 | 1.3 | 2.3 | 4.7 | 4.5 | - | c |

| Depth | pH (1: 2.5) | | | EC (1: 2.5) | O.C. | $CaCO_3$ Eq. | Extractable Bases | | | | | CEC | CEC/ clay | Base Saturation | ESP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Ca | Mg | Na | K | Sum | | | | |
| (cm) | water | $CaCl_2$ | M KCl | d $Sm^{-1}$ | g $kg^{-1}$ | g $kg^{-1}$ | ←----------cmol $kg^{-1}$-------→ | | | | | | | % | % |
| 0-12 | 8.7 | 7.9 | 7.8 | 0.33 | 4.1 | 100 | 45.7 | 6.7 | 2.4 | 0.6 | 55.4 | 27.3 | 0.56 | 100 | 8.79 |
| 12-36 | 8.9 | 8.3 | 7.9 | 0.67 | 3.3 | 90 | 44.5 | 9.7 | 10.8 | 0.6 | 65.6 | 40.1 | 0.84 | 100 | 26.93 |
| 36-63 | 8.6 | 8.3 | 7.9 | 3.79 | 2.4 | 130 | 74.8 | 16.6 | 19.8 | 0.7 | 111.9 | 45.9 | 0.83 | 100 | 47.14 |
| 63-85 | 8.6 | 8.3 | 7.9 | 3.77 | 1.6 | 140 | 75.5 | 17.2 | 21.8 | 0.7 | 115.2 | 46.4 | 0.83 | 100 | 46.98 |
| 85-107 | 8.6 | 8.3 | 7.9 | 3.60 | 1.7 | 110 | 86.1 | 18.4 | 23.8 | 0.8 | 129.1 | 48.9 | 0.80 | 100 | 48.67 |
| 107-150 | 9.0 | 8.4 | 7.5 | 3.70 | 1.0 | 100 | 55.6 | 22.4 | 22.3 | 0.9 | 101.1 | 50.6 | 0.75 | 100 | 44.07 |

**Glossary**

Alluvium = An unconsolidated, stratified deposit laid down by running water

Angot rainfall index= initially aimed at. determining the characteristic types of monthly. and annual variation of precipitation based on. regional and local comparisons. It emphasizes the climatic features of each month of the year, which means the subunit values define the dry months, while the values higher than one refer to the wet months.

Argillic horizon : A sub-surface B soil **horizon** that is identified by the illuvial (see illuviation) accumulation of silicate clays. The amount of clay necessary is defined in comparison with the quantity in the overlying eluvial (see eluviation) **horizon**, but is at least 20 per cent more.

Biophysical indicators= these are tools that can be used to define resource (e.g., soil, water, vegetation) status. These indicators cannot directly measure sustainability, rather they can be used to compare present resource status with defined limits which fit the current prescription for sustainable practices having acceptable socio-economic outcomes

cation exchange capacity = is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants.

Colluvium = An unconsolidated mass of rock debris and weathered material that has accumulated at the base of a cliff or slope and deposited by surface wash and various mass movement processes

Demography = is the statistical study of populations, especially human beings.

Drip irrigation : In its simplest form, it is an irrigation method using a system of perforated plastic pipes along the ground at the base of a row of plants (= trickle irrigation). In its more advanced form, it is a micro-irrigation system in which water flow is very low, generally less than 8 litres/h and without pressure, i.e. drop by drop. The water emerging infiltrates directly into the soil where it wets a volume of soil called bulb.

Dryland = Drylands are characterized by a scarcity of water, which affects both natural and managed ecosystems and constrains the production of livestock as well as crops, wood, forage and other plants and affects the delivery of environmental services.

Dykes = is a sheet of rock that formed in a fracture in a pre-existing rock body. Dikes can be either magmatic or sedimentary in origin. Magmatic dikes form when magma intrudes intocrack then cry- stallizes as a sheet intrusion, either cutting across layers of rock or through an unlayered mass of rock.

erosivity = is the term used to describe the potential of raindrop impact, runoff from snowmelt, or water applied with an irrigation system rainstorm to detach and erode soil

Exchangeable cations: refer to the positively charged ions which are loosely attached to the edge of clay particles or organic matter in the soil. The cations include Calcium, Magnesium, Potassium, Sodium, Hydrogen and Aluminium.

foliation =. Individual layers, called folia, are visible because of differences in crystal or grain size, or because of entrained sediment

Growing degree days = are a heuristic tool in phenology. GDD are a measure of heat accumulation used by horticulturists, gardeners, and farmers to predict plant and animal development rates such as the date that a flower will bloom, an insect will emerge from dormancy, or a crop will reach maturity.

Land degradation: is the reduction or loss of the biological or economic productivity and complexity of rain—fed cropland, irrigated cropland, or range, pasture, forest or woodlands resulting from natural processes, land uses or other human activities and habitation patterns such as land contamination, soil erosion and the destruction of the vegetation cover.

Land evaluation= 'is defined as the **assessment** of **land** performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of **land** forms, soils, vegetation, climate and other aspects of **land** in order to identify and make a comparison of promising kinds of **land** use in ...

Land utilization = is a detailed description, at an appropriate level of detail, of the land use (later lecture). It includes all the characteristics of the production system and social context which influence suitability, including: (1) products (maybe the broad sense), (2) inputs (off- and on-farm), (3) production calendar, (4) markets and other external influence

Landform = is a feature on the Earth's surface that is part of the terrain.

Lineament : A large-scale linear feature on the land surface, such as a trough or ridge, that is the product of the structural geology of a region

lithic contact = is used to denote a weathered rock **contact** within a profile

Net sown area = this represents the total **area sown** with crops and orchards

Pedon = is a 3-dimensional sample of a body of soil that is 1 $m^2$ at the surface and extends to the bottom of the soil. Pedon descriptions are used to classify soil, to divide pedons into units for analysis, and to define map units for a soil survey.

Per capita:- is a Latin term that translates to "by head." **Per capita** means the average **per** person and is often used in place of "**per** person" in statistical observances.

Precipitation concentration index: defined by Oliver [44], is also a powerful indicator for temporal **precipitation** distribution. Similar to CI, PCI is generally used for evaluating seasonal **precipitation** changes to investigate the heterogeneity of monthly **rainfall** data.

quartzite = is a hard, non-foliated metamorphic rock which was originally pure quartz sandstone. Sandstone is converted into **quartzite** through heating and pressure usually related to tectonic compression within orogenic belts.

shale= is a fine-grained, clastic sedimentary rock, formed from mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. ***Shale*** is characterized by its tendency to split into thin layers (laminae) less than one centimeter in thickness.

*sill* = is a tabular sheet intrusion that has intruded between older layers of sedimentary rock, beds of volcanic lava or tuff, or even along the direction of foliation in metamorphic rock. The term sill is synonymous with concordant intrusive sheet. This means that the sill does not cut across preexisting rocks, in contrast to dikes, discordant intrusive sheets which do cut across older rocks.

Skewness coefficient = This method is most frequently used for measuring skewness. The formula for measuring coefficient of skewness is given by Sk = $mean - mode\ /SD$ The value of this coefficient would be zero in a symmetrical distribution. If mean is greater than mode, coefficient of skewness would be positive otherwise negative.

slicken side = is a smoothly polished surface caused by frictional movement between rocks along the two sides of a fault. ... In pedology, the study of **soils** in their natural environments, a **slickenside** is a surface of the cracks produced in **soils** containing a high proportion of swelling clays.

Soil classification = is a dynamic subject, from the structure of the system itself, to the definitions of classes, and finally in the application in the field. concerns the grouping of soils with a similar range of properties (chemical, physical and biological) into units that can be geo-referenced and mapped.

soil erodibility= is the inherent yielding or nonresistance of soils and rocks to erosion. A high erodability implies that the same amount of work exerted by the erosion processes leads to a larger removal of material. Because the mechanics behind erosion depend upon the competence and coherence of the material, erodability is treated in different ways depending on the type of surface that eroded.

soil loss = is the displacement of the upper layer of ***soil***; it is a form of ***soil degradation***. ... The ***loss*** of ***soil*** from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. ***Soil erosion*** could also cause sinkholes.

soil map= is a geographical representation showing diversity of ***soil types*** and/or ***soil*** properties (***soil*** pH, textures, organic matter, depths of horizons etc.) in the area of interest. ...

Soil series = a group of soils with similar profiles developed from similar parent materials under comparable climatic and vegetational conditions

Soil survey =The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are classified according to the kind and intensity of field examination. (ii) The program of the National Cooperative Soil Survey that includes developing and implementing standards for describing, classifying, mapping, writing, and publishing information about soils of a specific area.

soil texture = The soil as a physical body is described by the size and arrangement of its particles, determining the porosity. Soil particles are divided into three major size fractions: a) sand, b) silt and c) clay. Soils are classified, according to United States Department of Agriculture (USDA) classification system, by their textural class i.e. the percent composition of sand, silt and clay. Soils with high sand content are called “light soils” or “sandy soils” and soils with high clay content are called “heavy soils”. The soil properties such as water holding capacity and intake rate mostly depend on the texture.

spheriodial weathering = is a form of chemical **weathering** that affects jointed bedrock and results in the formation of concentric or **spherical** layers of highly decayed rock within **weathered** bedrock that is known as saprolite.

ternary diagram = is a barycentric ***plot*** on three variables which sum to a constant. It graphically depicts the ratios of the three variables as positions in an equilateral triangle.

Visual signs = It is connected to something through some form of relation (**visual** similarity, history, etc). It often depicts a real world object and is often metaphorical.