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Assessment of Soil Quality in Dryland Agricultural Landscapes of Pulivendula Tehsil, YSR Kadapa District, Andhra Pradesh

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Abstract

The agro environmental problems such as soil degradation, erosion and deterioration of soil quality coupled with frequent seasonal droughts are major threats for sustained agricultural production in dryland region of Pulivendula tehsil (mapped area of 128609 ha) in Rayalseema plateau of Andhra Pradesh. The spatial information on agroland resources is scanty to assess current status of the soil quality under banana growing areas and its impact on erosion and decline in productivity. The land resource inventory on 1:25000scale was performed using false colour compsite (FCC) images of IRS-P6-LISS-IV data as topobase. Twenty five soil series were classified upto subgroup level in the order of alfisols (5), inceptisols (46%), vertisols (13%) and entisols (4%) and derived soil map with 43 mapping units as soil series association. These soils are lightly 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 (60764 hectares, soil erodability (K) of < 0.15 t ha h ha−1 MJ−1 mm−1) to weakly susceptible to water erosion (29037hectares, K < 0.20). In the present study, the Muencheberg soil quality rating (SQR) method was used and estimated that 42.62 per cent of area under hills and ridges have very poor soil quality and mean soil loss of 38.75t/ha/year (very high) but in interhill basins and colluvio-alluvial complex, have moderate soil quality with mean soil loss of 12.56 t/ha/year (high). The study stated that the systematic soil resource inventory programmes are very important for structuring soil-landscape information and for encouraging high intensive banana growing areas under drip irrigation system in the region.

Keywords: Cuddapah basin; Soil indicators; Soil quality; Soil series; Soil map; Visual assessment.

Introduction

Drylands are areas (40% of earth's terrestrial surface) where an aridity index is less than 0.65 (UNEP 2007) and support over 2 billion people across the globe (Reynolds et al. 2007). The dryland ecosystems stored over 45% of the global terrestrial carbon (Millennium Ecosystem Assessment 2005) and support 50% of the world's livestock with the world hotspots of biodiversity (Myers et al. 2000). Restoring degraded drylands is a global issue and stressing the importance of a quantitative evaluation process by the United Nations Convention to Combat Desertification (UNCCD). Among visual morphological observations of soil characteristics such as depth changes in consistency, matrix/ mottle colour, structure, soil texture and abundance of roots in different restrictive layers were usually recorded in routine soil survey (McDonald et al. 1990; Soil Survey Division Staff, 2017).

MacEwan and Fitzpatrick (1996) were reviewed the pedological work and stated that these soil morphological were used to interpret soil forming processes and therefore soil quality. Several studies were reported Studies to implement restoration strategies in different dry environments from rangelands to shrub and forest stands (Camprubi, et al., 2015; Zucca, et al., 2015), from agricultural ecosystems to mining sites and brownfields (Toktar, et al., 2016). It is important to identify basic soil indicators to monitor and assess the consequences of restoration activities on ecosystem functioning and services using soil pedological information at different scales (Bhaskar, et al., 2014). The various visual soil assessment methods were proposed to quantify soil quality (Shepherd, 2000, Ball, et al., 2007). The soils on agricultural landscapes of Eurasia were assessed by the Muencheberg Soil Quality Rating (Mueller, et al., 2007). This method mainly focused on basic indicators of cropland and grassland productivity related parameters that act as functional coding of soils.

The soil loss estimations may heavily impact on soil organic carbon (SOC) storage as small particles at surface that are easily eroded. In dryland agriculture, erosion can cause the annual loss of less than 5 t/ha of soil under crop production (Pham, et al., 2018) and up to 150–200 t/ha from soil under bare fallow (Douglas, 2008). Soil properties are significantly influenced by spatial factors such as topographic aspect, positions, and climatic conditions. The variations in soil properties and topographic positions are strongly related (Ovalles and Collins, 1986 and Sharma and Bhaskar, 2002). The land use/and cover analysis in Pulivendula tehsil showed that the crop lands occupied 57.9% of total area (887.03 sq. km) whereas 10.79 of area is under Forest (162.49 sq. km) with 27.88 per cent of area under barren (419.87 sq. km, Lakshmi Prasad and Sreenivasulu, 2014). Concerning the impact of different land use types under dryland agricultural ecological systems of Pulivendula are scanty specially on soil erosion in relation to soil quality where intensive agriculture specially banana and groundnut are promising under drip irrigation systems as preferred by local farmers. Therefore the main objective of present study was to determine the current status of soil erosion and its impact on soil quality of different soil mapping units to design soil conservation strategies and also determined soil organic storage capcity of each unit for designing builtup stragies for organic carbon.

Materials and Methods

Study area

Pulivendula lies between14°16'to 14°44' N and 77°56' to 78°31'E (Fig. 1) covering 1,46,235 hectares (ha). The agroclimate is semiarid with mean annual rainfall of Pulivendla is 564mm and 43 rainy days. The LGP varied from 90-105 days for Pulivendla and Vemula, 105-120 days for Lingala and Tondur and 120-135 days for Simhadripuram and Vempalli. mandals. As per the land evaluation guidelines, this region comes 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 in the western parts, cherty dolomites near vempalli, quartzites in Pulivendula and shales near balapanur (Nagaraja Rao, et al.,1987). The study area is characteristically occupied by the Papaghni and Chitravati group of rocks of Cuddapah Super Group. Papaghni group includes a) Gulcheru formation comprising quartzite, arkose and conglomerate; b) Vempalli formation comprising dolomites, chert, mudstone, quartzite, basic flows and intrusive.

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

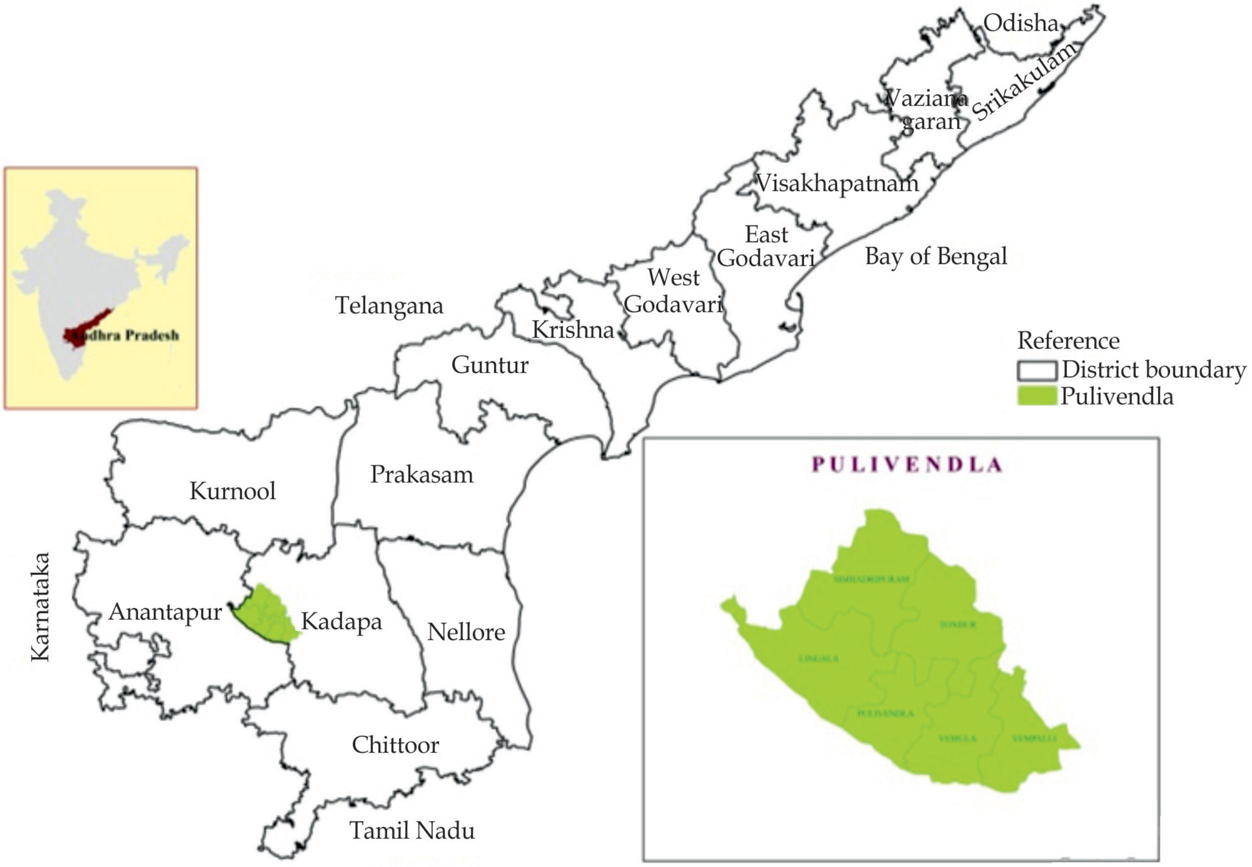

Fig. 1: Location map of Pulivendula tehsil, Andhra Pradesh. (Source: Google map.)

outcrops (54135 ha 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.

Soil survey and mapping

A field survey was conducted using false colour composites (FCC's) of P6-LISS IV imagery to prepare a landform map on 1:25,000 scale. In pulivendula tehsil, 66 soil transects were selected and studied about 330 profiles to a depth of 2m or upto the bedrock contact. along with 120 random checks for verification of occurrence of soils with respect to landform units.

After soil correlation, twenty five soil series were identified and prepared soil map of 43 mapping units. The soil morphological properties were described as per Schoeneberger, et al. (2002) and used the Muencheberg soil quality rating (SQR, Mueller, et al., 2007) within a 100 point scale.

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

The final basic score ranged from 0 to 34. It was a measure of soil quality for farming. Values less than 20 indicated poor soils, values greater than 27 were good soils. In second step, hazard indicators were 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 was valid one. 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 were rated as : < 20 = Very poor, 20 - 40 = Poor, 40 - 60 = Moderate, 60 - 80 Good, > 80 = Very good.

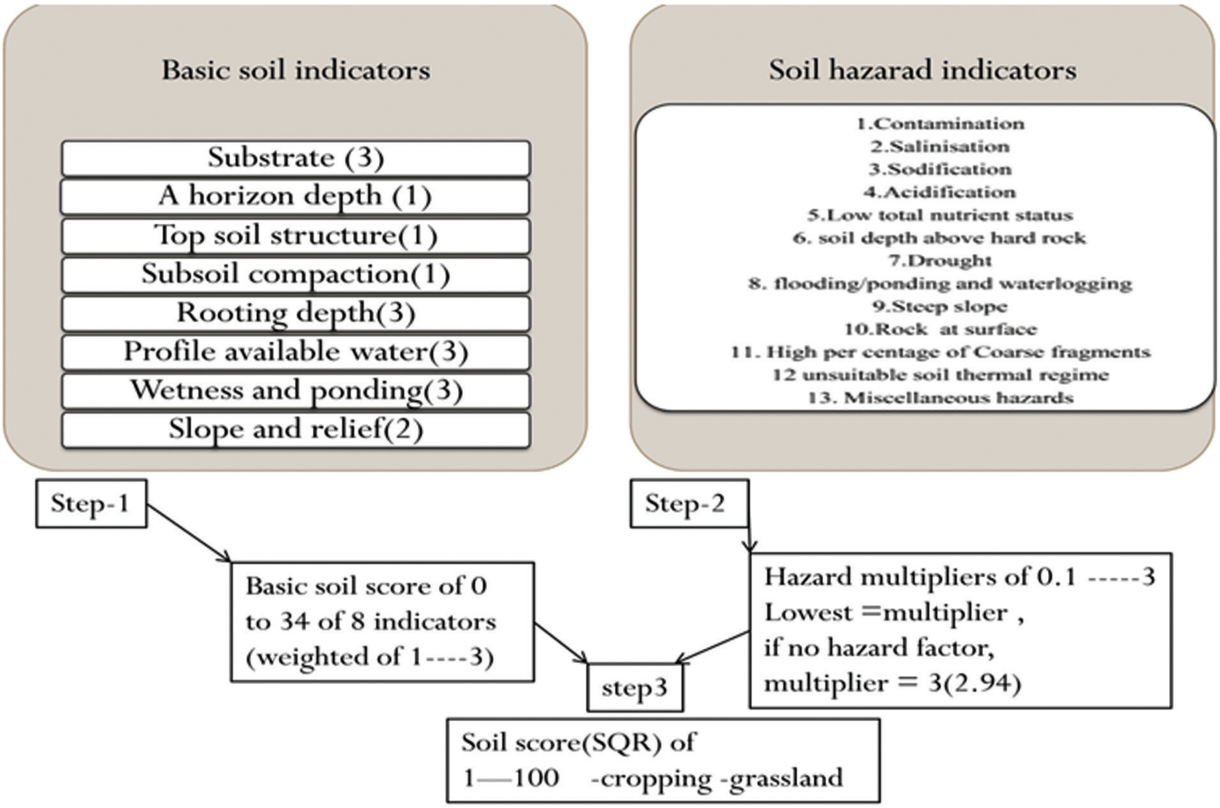

Fig. 2: Flow chart of Muencheberg soil quality rating (SQR).

Laboratory Analysis

Horizonwise soil samples of twenty five soil series were collected and air dried to pass through <2mm sieve for fine earth fraction to determine physical (particle size distribution) and chemical (pH in 1:2.5 soil water), Organic carbon by wet digestion, Exchangeable bases by IN NH4OAc extractable and distillation of ammonium for CEC, avaliable N,P,K and DTPA extractable Fe, Mn, Cu, and Zn as per standard procedures described in Dewis and Freitas (1970).

The soil map is generated for 43 mapping units as series and its association in GIS environment (ARC info. Version 10). Soil erodability and soil loss estimations were made as per USLE equation (Wischmeier and Smith, 1978) and categorized soil loss in to different soil erosion risk zones based on Uddin, et al. (2018) as: very low = soil loss of < 0.5t/ha/year, low = 0.5- 1t/ha/year, low-medium = 1-2 t/ha/year; medium =2-5t/ha/year; high - medium = 5-10t/ha/year, high =10-20t/ha/year, very high = 20-50t/ha/year and extremely high = > 50t/ha/year. The soil organic carbon(Poeplau, et al., 2017): and inorganic carbon stocks (Wang et al., 2012) were calculated as per the equations given below :

- SOCi stock (Mg C ha^{-1} 1375) = OCi x BDfine1i x (1- vGi) x ti x 0.1

where, SOCi (Mg C ha^{-1} 1362) is the soil organic carbon stock of depth increment i.

OCi (mg C g^{-1} fine earth) is the organic carbon content of the fine earth fraction (<2 mm) of the depth increment i.

BDi (g soil cm^{-3} soil) is the mass of soil per total volume of the soil sample of the depth increment i.

gGi (g coarse fragment g^{-1} soil) is the mass fraction of coarse mineral fragment, thus (1-gGi) is the mass fraction fine earth (g fine earth g^{-1} soil) of the depth increment i.

ti is the thickness (depth, in cm) of the depth increment i 0.1 is a factor for converting mg C cm-2 to Mg C ha-1

- The stocks of SIC were calculated as follows:

$$M=0.1\times D\times B\times Z\times((100-G)/100) \quad (1)$$

where M is soil carbon stock per unit area (Mg ha^{-1}); D is soil depth (cm); B is bulk density (g cm-3); Z is carbon content (g kg^{-1}) and G is the relative amount of gravel (%). The gravel content was 0 because there was no gravel in the soil. A factor of 0.12, the mole fraction of carbon in $CaCO_3$, was used to convert calcium carbonate to SIC content.

Results and Discussion

Climatic Characteristics

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 30.70 C to 36.90 C and an aridity index of 11.29 to 14.25 indicating semiarid conditions during southwest monsoon. September is rainy with mean of 186.82 ± 81.56 mm and 43.61 per cent of variation whereas October receives mean rainfall of 100.28 ± 60.01 mm (1941-1950) but 152.24 ± 88.70 mm (1971-1980) and August with irregular rainfall trends from 65.26 ± 30.25 mm (1921-1930) to 119.87 ± 40.78 mm (1991-2002).

The De Martonne Aridity Index (Im) below 15 is reported for 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 mostly 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.

Soil Morphology

The brief description of twenty five soil series identified in Pulivendula tehsils is discussed as given under. The five soil series on hills and ridges are Kanampalli (Kpl), Ganganapalle(Ggp), Lingala (Lgl), Rachakuntapalle (Rkp) and Mupendrapalle(Mpl). These soils are mostly associated with rockoutcrops and more than 60 per cent of surface is covered with stones. These soils are very shallow, well drained with A horizons having reddish brown (Kanampalli series and Lingala series) to red (Ganganapalle series), dark reddish brown (Mupendranpalle series) and yellowish red (Rachkuntapalle series). The dark red cambic B horizons (Lingala) to yellowish red (Rachakuntapalle) and dark reddish brown (Mupendranpalle) are observed with gravelly clay loam to clay texture. These soil series are used to make eight soil mapping units (as series association) with rockoutcrops.

The soil on interhill basin have six soil series viz., Tallalapalle (Tlp), Santakovur (Skv), Tatireddipalle (Trp), Murarichintala (Mct), Kottalu (Ktl) and Cherlapalle soil series (Cpl).The A horizons have yellowish red to dark reddish brown (Tlp), reddish brown (Skv, Ktl and Mct), very dark grayish brown(Trp) and dark brown (Cpl) with sandy loam to gravelly clayloam texture.The B horizons are dark reddish brown (Tlp,Skv, Mct), very dark grayish brown(Trp), dark brown (Cpl) and dark red(Ktl)with sandy clay loam to clay texture. These soils are mostly developed on shale with varying soil depth from shallow (<50cm, Tlp) to moderately deep (Skv, Trp), deep(Cpl)and very deep(.150cm, Ktl and Mct).

The soil on gently sloping middle sector have seven series viz., Balapanur (Bpr), Simhadripuram (Spm), Agraharam (Ahm), Sunkesula (Skl),Vemula (Vml), Velpula (Vpl) and Parnapalle (Prp). These soils are moderately deep to deep with dark reddish brown(Vml) to dark yellowish brown (Skl)to very dark grayish brown (Ahm).The Velpula (Vpl)and Vemula (Vml) series have thick patchy clay skins in agrillic B horizons with gravelly clay to sandy clay texture whereas Simhadripuram (Spm), Balapanur (Bpr) and Agraharam (Ahm) series have slickensided clay horizons with moderate , medium and subangular blocky structure and of cambic clay enriched B horizons in Sunkesula (Skl) series. The Parnapalle series (Prp) have Ap-C horizons, very deep grayish brown to dark brown matrix with sandy loam texture.

The seven soils on colluvic-and alluvic sector are Bhadrampalle (Bpl), Agadur (Agd), Tondur (Ydr), Pernapadu (Ppd), Gondipalle (Gpl), Pulivendula (Pvd) and Goturu (Gtr), These soils are developed over shale withAp- Bw horizon sequence, dark brown matrix and shallow in depth with gravelly clay texture (Gondipalli). Goturu series (Gtr) with Ap-Bw horizons is moderately deep, dark yellowish brown to dark brown matrix having clay texture and moderate, medium subangular blocky structure. The other series are also moderately deep with dark brown matrix (Pvd & Ppd) to very dark grayish brown(Agd)with clay texture in cambic B horizons. The Bhadrampalle series (Bpl) is very deep, dark bown Ap horizons but changed to dark yellowish brown in slicken sided horizons with clay texture and coarse, medium subangular blocky structure.

Table 1: Textural and chemical properties of soil series.

soil series /soil taxonomy	Particle size distribution(%) sand	silt	clay	pH	EC (dSm-1)	Organic Carbon (g/kg)	$CaCO_3$ (g/kg)	CEC cmol/kg	PBS	ESP	Soil depth (cm)
Kanampalli(Kpl)- Lithic Ustorthents	72.1	4.3	23.6	8.3	0.14	16.3	10	12.9	71	0.16	21
Ganganapalle (Ggp)- Lithic Ustorthents	32.1	20.5	47.4	7.1	0.23	17.7	30	30.5	100	0.39	15
Lingala(Lgl) Lithic Haplustepts	44.4	23.8	31.8	8.1	0.22	11.9	20	26.6	100	0.15	47
Rachakuntapalle(Rkp) -Lithic Haplustepts	57.3	18.3	24.4	7.2	0.16	8.4	-	25.7	46	0.16	40
Mupendranapalle (Mpl) -Lithic Haplustepts	29.5	29	41.5	8.4	0.38	10.7	40	29.1	100	0.76	40
Tallalapalle(Tlp) -Lithic Haplustepts	40.9	19.6	39.5	7.9	0.19	9.7	70	28.3	100	1.13	40
Santhakovur (Skv) -Typic Haplustepts	48.8	18.7	32.5	7.9	0.29	9.2	150	21.7	100	2.76	62
Tatireddipalli(Trp) -Vertic Haplustepts	14.9	27.8	57.3	7.7	0.22	11.2	40	54.5	100	0.26	55
Cherlapalle(Cpl) -Vertic Halaquepts	32.5	21.2	46.3	8.1	0.34	6.2	110	33.2	100	23.64	105
Kottalu(Ktl)- Typic Rhodustalfs	74.9	10.3	14.8	7.9	0.16	3.6	20	7.6	100	1.97	142
Murarichintala(Mct)- Typic Paleustalfs	71.1	14.2	14.7	8	0.25	4.7	10	7.2	100	0.14	155
Vemula(Vml) -Calcic Haplustalfs	32.8	24.9	42.3	8	0.2	7	160	30.1	100	1.79	72
Sunkesula(Skl) -Vertic Haplustepts	50.1	15.4	34.5	8	0.3	11.1	40	28	100	1.61	70
Simhadripuram(Spm)- Sodic Haplusterts	23.2	21.5	55.3	8	0.25	8.4	140	42.7	100	6.46	92
Velpula(Vpl)- -Typic Haplustalfs	60.7	13.5	25.8	7.9	0.14	3.3	50	13	100	2.31	138
Agraharam(Ahm)- -Sodic Haplusterts	23.6	18.2	58.2	8.3	0.21	9.3	110	44.2	100	2.22	120
Balapanur(Bpr) Sodic Haplusterts	23	24	53	8	0.41	5.7	100	37.4	100	11.04	14
Parnapalle(Prp)- Typic Ustorthents	78.4	8.9	12.7	7.8	0.31	5	20	10.3	100	4.95	150
Gondipalle(Gpl) -Lithic Haplustepts	29.5	19.4	51.1	7.9	0.21	14.7	150	35.8	100	0.87	44
Goturu(Gtr)- Typic Haplustepts	42	13.9	40	8.2	0.47	8.4	90	36.9	100	15.77	70
Pulivendula(Pvd)- Aeric Halaquepts	38.6	1.2	60.2	8.5	1.47	2.6	110	24.2	100	67.89	135
Pernapadu(Ppd)- Vertic Haplustepts	33.4	19.3	47.3	8	0.19	6.3	130	45	100	0.33	103
Agadur(Agd)- Vertic Haplustepts	32.6	19.8	47.6	7.8	0.19	5.4	100	42.6	100	0.45	145
Tondur(Tdr)- Vertic Haplustepts	29.8	22.3	47.9	8.1	0.25	5.8	100	41.9	100	4.6	152
Bhadrampalle(Bpl)- Sodic Haplusterts	45	5.9	49.1	7.9	0.33	4.1	100	27.3	100	8.79	150

Soil textural and chemical characteristics

The mean pH of the soils is 7.68±0.68 with coefficient of variation of 7.99 per cent on quartzite (P1 to P5) and 8.01±0.2 with coefficient of variation of 2.47 per cent in soils on shale. These soils have extremely low organic carbon of 2.6 gkg^{-1} in Pulivendula soil (P21) but is more than 10 gkg^{-1} in P8, P13 and P19 in soils developed over shale with mean of 7.26 ± 3.13gkg^{-1} (Table 1). 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 have negative relation with soil depth (r = -0.79**) indicating decreasing trends.

The Cation Exchange Capacity (CEC) of soils of Pulivendula tehsil is varied from 7.2cmol (+) kg^{-1} in P11 to 54.5cmol(+)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}. 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 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. The calcium carbonate has a positive relation with clay (r =0.62**) significant at 1% level. 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. There is a positive relation between pH and ESP (r = 0.44*) at 5%level.

Soil organic and inorganic carbon stocks

The study further shows that the 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 is above the mean value of 52.47±17.55Mg/ha followed by Pernapadu (80.56Mg/ha) < Sunkesula (77.27Mg/ha) <Agadur (73.21Mg/ha) < Simhadripuram (72.43Mg/ha). These soils are mostly occur in interhill basins and colluvio-alluvial sectors of Pulivendula (Table 2).

The SIC stock is relatively more to that of SOC and recorded a maximum of 334.74Mg/ha in Tondur series (Tdr) and almost nil in Rachkuntapalle series. The mean SIC stock is 134.52±106.71Mg/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 level.

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 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, 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 & Lal, 2016).

These soils have mean clay content of 39.64±14.25% in Ap horizons but showed gradual increase upto 58.06±15.52% in Bss horizons and 36.72±7.32 per cent in clay enriched argillic horizons. The texture is sand loam to clay with clay fraction dominates with 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 o.5 in majority of soils but more than 1.0 in Parnapalle, Tatireddipalle and Sunkesula but exceeding in soils of Kanampalle, and Lingala occurring on hills and ridges.

Soil Map

Soil map with forty three mapping units was made on 1:25000 scale. Broadly the soils on quartzitic hills and ridges have eight mapping units mostly associated with rock outcrops, very shallow, some what excessively drained, moderately alkaline, sandy loam to clay loam textured soils and covers 54812 hectare (42.62% of total area, Table 3).

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

Table 2: Soilseries wise SOC and SIC stocks along with ratio.

Soil Series	Stock (Mg/ha)		
/ Soil Taxonomy	SOC	SIC	SOC/SIC
Kanampalli(Kpl)- Lithic Ustorthents	46.89	2.93	16.00
Ganganapalle(Ggp)- Lithic Ustorthents	31.06	6.36	4.88
Lingala(Lgl)-Lithic Haplustepts	63.36	5.40	11.73
Rachakuntapalle(Rkp) -Lithic Haplustepts	43.36	0.00	-
Mupendranapalle (Mpl) -Lithic Haplustepts	44.98	22.46	2.00
Tallalapalle(Tlp)-Lithic Haplustepts	39.68	44.47	0.89
Santhakovur(Skv) -Typic Haplustepts	50.92	199.69	0.25
Tatireddipalli(Trp) -Vertic Haplustepts	61.95	37.89	1.63
Cherlapalle(Cpl)-Vertic Halaquepts	55.92	154.22	0.36
Kottalu(Ktl)- Typic Rhodustalfs	27.68	132.89	0.21
Murarichintala(Mct)- Typic Paleustalfs	74.40	33.89	2.20
Vemula(Vml)-Calcic Haplustalfs	49.37	243.03	0.20
Sunkesula(Skl)-Vertic Haplustepts	77.27	54.44	1.42
Simhadripuram(Spm)- Sodic Haplusterts	72.43	220.73	0.33
Velpula(Vpl)- -Typic Haplustalfs	30.97	232.48	0.13
Agraharam(Ahm)- -Sodic Haplusterts	74.89	185.90	0.40
Balapanur(Bpr)-Sodic Haplusterts	51.02	203.27	0.25
Parnapalle(Prp)-Typic Ustorthents	28.52	26.99	1.06
Gondipalle(Gpl) -Lithic Haplustepts	65.39	113.85	0.57
Goturu(Gtr)-Typic Haplustepts	58.11	86.14	0.67
Pulivendula(Pvd)- Aeric Halaquepts	22.87	234.37	0.10
Pernapadu(Ppd)- Vertic Haplustepts	80.56	262.32	0.31
Agadur(Agd)- Vertic Haplustepts	73.21	217.53	0.34
Tondur(Tdr)- Vertic Haplustepts	55.28	334.74	0.17
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

total area). These soils are shallow and well drained with strongly alkaline gravelly clayloam 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 (22-446 ha, 0.3%), Velpula-Vemula association in Tondur mandal (28-712 ha, 0.5%).

This mapping unit is associated with very deep, moderately well drained, calcareous, strongly to moderately alkaline black soils with shrink-swell potentials. Soils of colluvic and alluvial plains cover 28542 ha (22.19% of total land area) with association of Tondur–Pernapadu series, Pernapadu-Gondipalle association, Goturu-Gondipalle association, and AgadurPernapadu association.

Soil loss on soil quality and suitability for banana

The estimated K values for soils vary from 0.15 ± 0.03 t ha h ha^{-1} MJ^{-1} mm^{-1} (14 soil series not susceptible to water erosion: K < 0.20, 0.25 ± 0.023t ha h ha^{-1} MJ^{-1} mm^{-1} for 10 soil series with weakly susceptible to water erosion: K = 0.20–0.30 and 0.33t ha h ha^{-1} MJ^{-1} mm^{-1} for 1 series (santakovur, SVK) with medium susceptible to water erosion (K = 0.30–0.40). The cient of variation is 9.39 to 19.15% (Table 3).

The soil erosion risk zones based on soil loss of each mapping unit are computed and categorized into six classes in the study area (Table 4). Based on area estimations, the soil erosion risk zones are arranged in ascending order as: high-medium (39142 ha, 31.16%) > high (276696 ha, 22.05%) > medium (23378 ha, 18.6%) > extremely high (16364 ha, 13.03%) > low - medium (12025 ha, 9.57%) > very high (7007 ha, 5.58%).

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, Gondip [alle, Bhadrampalle, Velupula and Murarichintala series. Over all, 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 pHthat 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 R2 = 0.51 , R2 =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 maily 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, Gondip[alle, Bhadrampalle, Velupula and Murarichintala series. Over all, the mean SQR is 33.78±1.44 per cent with coefficient of variation of 30.91 percent 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 adjudgedas suitable for banana (Table 3). In colluvio-alluvial sector, four soil mapping units have moderate SQR covering 6261 ha but evaluated only 633ha as marginally

Table 3: Soil mapping unit wise SQR, Soil loss and suitability for Banana.

Landform	Soil mapping unit	Area	Soil loss (t/ha/year) / soil erosion risk		SQI Rating	Quality rating Class	Banana suitability	
		ha						
Hills and ridges	Rock outcrops(R)- Kanampalli (Kpl)	7953	25.11	high	12.31	Very poor	3.34	N2
	Rockoutcrops(R)- Ganganapalle(Ggp)	7464	57.94	high	12.31	Very poor	9.65	N2
	Rockoutcrops(R)- Rachukuntapalle(Rkp)	24939	9.91	high-medium	13.32	Very poor	3.72	N2
	Rockoutcrops(R) - Lingala(Lgl)	6410	102.80	extremely high	14.74	Very poor	4.26	N2
	Rachakuntapalle(Rkp) - .Rockoutcrops(R)	1333	8.93	high medium	14.97	Very poor	4.12	N2
	Ganganapalle(Ggp) -Rockoutcrops(R)	677	57.94	extremely high	13.47	Very poor	16.4	N2
	Rockoutcrops(R)- Mupendranpalle(Mpl)	3572	8.6	high medium	15.43	Very poor	15.6	N2
	Mupendranapalle(Mpl)-. Rockoutcrops(R)	2464	8.56	high medium	18.14	Very poor	11.32	N2
Interhill basin	Tallalapalle(Tlp)	1829	8.97	high medium	25.50	Poor	14.21	N2
	Murarichintala ((Mct)	1934	8.90	high medium	46.43	Moderate	15.83	N2
	Tatireddipalle((Trp)	788	1.33	low medium	32.04	Poor	49.42	S3
	Kottalu(Ktl)	372	3.46	Medium	50.00	Moderate	69.04	S2
	Santakovur(Skv)	548	11.84	High	29.86	Poor	41.42	S3
	Murarichintala ((Mct)- Tallalapalle(Tlp)	508	8.92	high medium	38.06	Poor	43.73	S3
	Cherlapalle(Cpl)	184	5.27	high medium	34.29	Poor	19.81	N1
	Balapanur(Bpr)	6559	24.23	Very high	50.57	Moderate	41.18	S3
	Simhadripuram (Spm)	7583	1.82	Low medium	35.36	Poor	43.73	S3
	Simhadripuram (Spm) - Agraharam((Ahm)	9125	2.68	medium	41.27	Moderate	61.29	S3
	Balapanur (Bpr) - Sunkesula(Skl)	4294	3.65	medium	43.49	Moderate	52.89	S3
	Vemula(Vml)	1667	7.65	High-medium	34.50	Poor	40	S3
	Velpula(Vpl)	1326	4.12	Medium	42.00	Moderate	68.64	S2
	Parnapalle(Prp)	446	1.36	Low-medium	43.54	Moderate	30.78	N1
	Agraharam(Ahm)	2690	3.59	Medium	50.14	Moderate	76.71	S2
	Sunkesula(Skl)	2778	2.97	Medium	32.86	Poor	64.6	S2
	Agraharam(Ahm)- Sunkesula(Skl)	802	3.61	Medium	43.23	Moderate	71.87	S2
	Agraharam(Ahm)- Simhadripuram(Spm)	369	2.78	Medium	44.23	Moderate	66.82	S2
	Sunkesula(Skl) - Simhadripuram(Spm)	741	2.65	Medium	33.86	Poor	58.34	S3
	Velpula (Vpl)- Vemula(Vml)	712	5.36	Hogh-medium	39.00	Poor	61.16	S2

Colluvial - alluvial pediplains	Bharampalle(Bpl)-Agadur(Agd)	788	19.34	High	33.88	Poor	29.84	N1
	Tondur(Tdr)-Pernapadu((Ppd)	1351	85.36	Extremely high	41.08	Moderate	31.12	N1
	Tondur(Tdr)	3568	102.80	Extremely high	44.36	Moderate	29.07	N1
	32.Agadur(Agd)	633	1.86	Low medium	40.50	Moderate	48.45	S3
	33. Pernapadu(Ppd)-Gondipalle(Gpl)	853	5.68	high medium	31.74	Poor	29.17	N1
	34.Tondur(Tdr)-Agadur(Agd)	709	90.56	Extremely high	42.81	Moderate	34.88	N1
	35.Pulivendula(Pvd)-Pernapadu(Ppd)	101	15.32	High	34.71	Poor	23.27	N2
	36.Goturu(Gtr)-Gondipalle(Gpl)	1501	2.75	Low-medium	29.84	Poor	33.8	N1
	37.Pernapadu(Ppd)	3689	17.31	High	36.16	Poor	34.2	N1
	38.Pernapadu(Ppd)-Tondur(Tdr)	4358	85.36	Extremely high	39.44	Poor	32.15	N1
	39.Gondipalle(Gpl)	1683	3.10	Medium	25.11	Poor	22.72	N1
	40.Goturu(Gtr)	1707	1.33	Low-medium	33.00	Poor	41.18	S3
	Agadur(Agd)-Pernapadu(Ppd)	3613	15.36	High	38.76	Poor	42.75	S3
	Bhadrampalle(Bpl)	448	24.23	Very high	29.46	Poor	17.44	N2
	Pulivendula(Pvd)	3540	17.31	High	33.75	Poor	15.99	N2
	Total	128609						

suitable for banana.

Conclusions

The appraisal of soil resources data base of hot semiarid Pulivendula tehsil (128609 ha of mapped area) generated through IRA-P6 – LISS-IV data on 1:25000 scale in conjunction with field survey yielded twenty three soil series and forty three soil mapping units as series and it associations.

The morphological characteristics were used to derive Muencheberg soil quality rating SQR and rated soil mapping units on hills and ridges as very poor (20), covering 42.61 per cent of total area with severe limitations of shallow to extremely shallow with more than 60 per cent of coarse fragments in A-C horizons and mainly associated with rock outcrops.

In Interhill basin, the soils (17338ha, 13.48%) are rated as poor SQR with a mean of 33.53 ± 3.88 per cent and CV of 11.59 and evaluated 15325ha as moderately to marginally suitable for banana with limitations of alkalinity, organic carbon and exchangeable K. These soils belongs to the subgroups of entisols, inceptisols, alfisols and vertisols. These soils have low organic carbon storage and high inorganic carbon storage having strong relation with SQR (r = 0.5*). The pedotransfer function was derived using five soil properties such as clay, CEC, OC, pH and soil loss for approximating SQR and yield an equation that is significant at 1% level.

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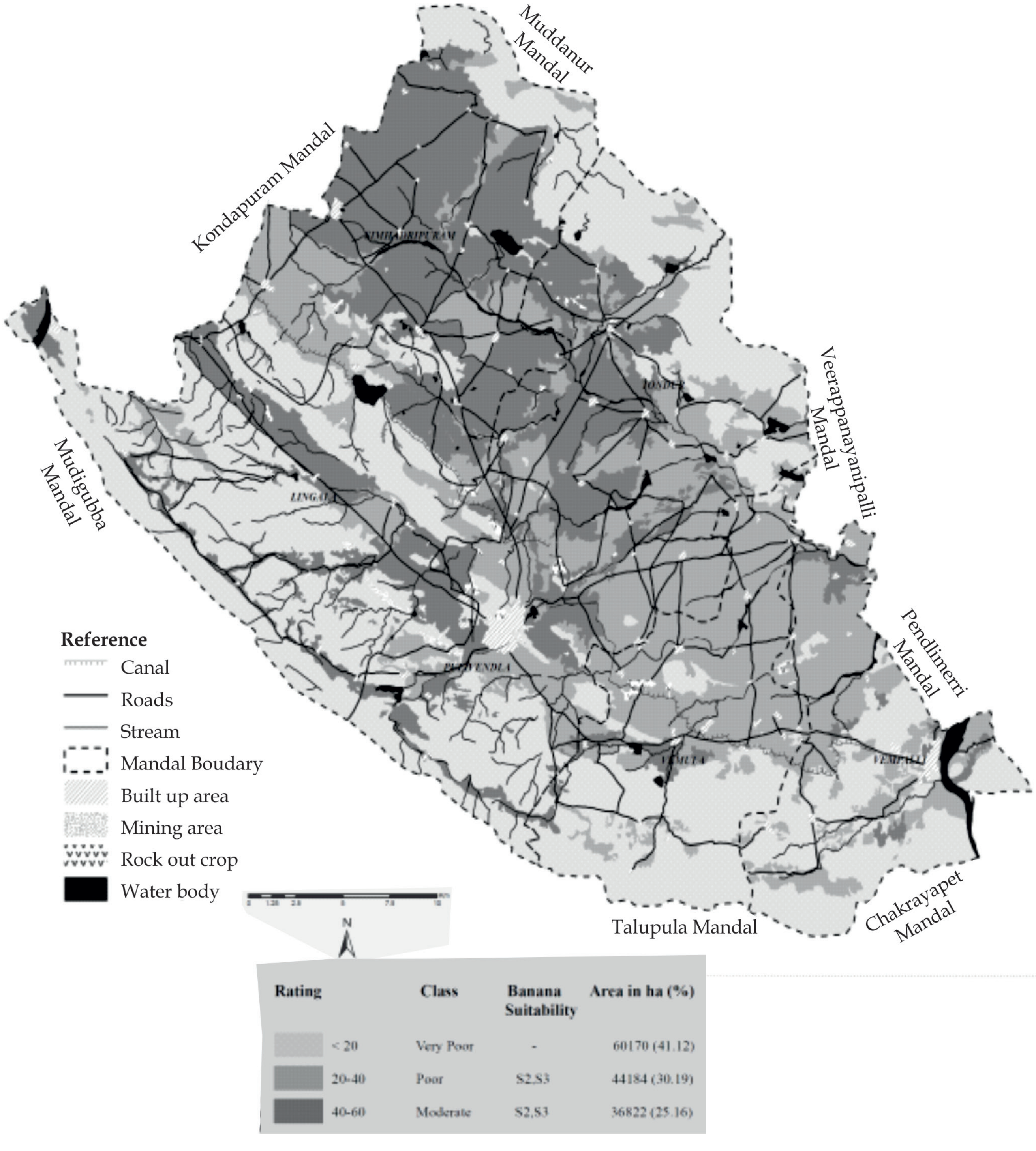

Rating	Class	Banana Suitability	Area in ha (%)
< 20	Very Poor	-	60170 (41.12)
20-40	Poor	S2,S3	44184 (30.19)
40-60	Moderate	S2,S3	36822 (25.16)

Fig. 3: Map showing soil quality and suitability for banana in Pulivendula tehsil.

study.

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