Soil Suitability Evaluation using Remotely Sensed Data and GIS – A Case Study from Semi-Arid Tropics of India

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Abstract
Soil resource inventorisation through the establishment of soil-physiography relationship after identification and delineation of seven physiographic units developed on three geological formations were done in Peruguda micro-watershed from semi arid tropics of Ranga Reddy district of Andhra Pradesh based on the satellite image characteristics identified through the visual interpretation of IRS 1C LISS-III fused with PAN data (1:12,500 scale). Based on the characteristics of soils developed on different physiographic units, the soils were evaluated for land capability classification and soil-site suitability of major crops for sustainable development of the micro-watershed through efficient soil and water conservation. The result revealed that the deep soils with high clay content in the mesa top mostly appears as dark blue to blackish blue tone in the satellite imagery are grouped under land capability class III and are moderately suitable for rain fed cotton and sorghum while the shallow to moderately deep soils of foot slopes which appear as dark to light blue and white mixed tone in the imagery are grouped under land capability class III to IV, are marginally suitable for cotton and marginally to presently unsuitable for sorghum. Only the soils of mesa shoulder, mesa side slopes and rocky ridges with dark to light blue, white and pink mixed tone and also dark blue with yellow and white tone mixed in the imagery are placed under land capability class VI to VII and are moderately suitable for pasture or silvipasture purposes.

1. Introduction

Land and water are the most vital natural resources of the country and these are under tremendous stress due to ever increasing biotic pressure resulting the shrinking of the per capita area under agriculture. The optimal management of these resources with minimal adverse environmental impact is essential not only for sustainable development but also for human survival. To face the greatest challenge of the century to provide food, fuel and fodder for the burgeoning population and also to raise the farm productivity, efficient utilization of natural resources is needed. Sustainable land use planning on watershed/micro-watershed basis is the only way to manage land, water and biomass of degraded areas as well as to conserve the protected areas for future generations. Soil erosion is one of the important land degradation processes and it affects not only genesis and fertility status of the soils but also land use. Water erosion is the most widespread form of degradation and occurs widely in all agro-climatic zones. Dhruvanarayana and Ram (1983) analysed the existing soil loss data in the Indian context and indicated that soil erosion has been taking place at an average rate of 16.35 t ha^{-1} $year^{-1}$ totaling 5,334 M t $year^{-1}$. They also estimated that soils supporting rainfed agriculture are subject to severe sheet and rill erosion with an annual soil loss of 20-100 t ha^{-1} $year^{-1}$. The red soils in India covering about 70 m ha, are another major soil group subject to severe problem of water erosion. Since, soil is the base for every production system, knowledge of soil properties, their problems and potential, extent, distribution and suitability for present and or alternative use at waterhed level is extremely important for developing rational land use plan. It has long been recognized that land suitability is assessed as part of a 'rational' cropping system (FAO, 1976) and optimizing the use of a piece of land for a specified use (Sys et al., 1991) should be based upon its attributes (Rossiter, 1996). Furthermore, land may be considered either in its present condition, or after specified improvements. Although criteria may vary, they are essentially based on climate, soil, topography and water availability, which are the most important categories of environmental information required for judging land suitability. The land suitability evaluation is the process of estimating the potential of land for alternative kind of uses. The basic feature of it is the comparison of the requirements of a crop with the resources offered by the land (Dent and Young, 1981). The land evaluation thus is the assessment of land performance for a specific purpose. In fact, land suitability evaluation is an examination process of the degree of land suitability for a specific utilization type (Sys et al., 1991b) and/or description method or estimation of potential land productivity (Rossiter, 1994). It involves the interpretation of basic data on the climate and the characteristics of land under the existing land use (Sehgal, 1991). Assessing the suitability of an area for crop production requires a considerable effort in terms of information collection that presents both opportunities and limitations to decision-makers. Any scientific crop planning requires a detailed inventory of the soils pertaining to their physical, chemical, hydrological and site specific properties (Dent and Young, 1981). It has been recognized that land suitability is assessed as part of a "rational" cropping system (FAO, 1976) and optimizing the use of a piece of land for a specified use (Sys et al., 1991, 1993) and should be based upon analysis of its attributes (Rossiter, 1996). Some conventional approaches in integration of different parameters are inadequate to visualize the complex scenario's in crop suitability evaluation. Assessment of the land suitability requires integration of multi-disciplinary database. Remote sensing technology has demonstrated potential in furnishing information concerning the character, distribution, productivity and use of various natural resources. Up to date and relevant information, on a real time basis, based on remote sensing technology is considered as one of the crucial factors in achieving the food production target. Remote sensing technology integrated with conventional techniques has emerged an efficient, speedy, cost effective tool for the management of natural resources. Subsequently, the spatial and non-spatial information should be integrated to identify the problems/limitations of the resources and also to arrive at optimal solution/action plans for sustainable development. Similar studies on application of remote sensing data in the establishment of soil-physiography relationship were done by Karale et al., 1978, Sehgal et al., 1988, Chatterjee et al., 1990 and Rao et al., 1997. Geographic Information System (GIS) is used to store, manipulate, retrieve and integrate the analysis of voluminous data on natural resources. The GIS has eased the situation of interpretation of huge multi-disciplinary soil, land use and socio-economic data (Burrough, 1986). GIS enable processing spatial and non-spatial data generated from remotely sensed data and conventional methods to arrive at best action plan for the development of an area. Few studies have been carried out so far to suggest soil and water conservation measures, alternate uses, etc. on watershed basis through GIS (Behera and Mohapatra, 1996, Rao et al., 1997 and Maji et al., 1998, 2002, 2005). In the present study, the Peruguda micro-watershed in semi-arid tropics of Ranga Reddy district, Andhra Pradesh, India has been selected to determine the problems and potentials of soils and evaluate the soil site suitability for cotton and sorghum crops using remote sensing and GIS techniques.

2. Study Area

The Peruguda micro-watershed of Bachpalli sub-watershed under Yeliminedu Vagu macro-watershed is situated between 17°02'13" to 17°02'49" N latitude and 78°25'35" to 78°26'14" E longitude in Ranga Reddy district of Andhra Pradesh covering an area of 677.77 ha and consists of Peruguda, Akabarjaguda and part of Nednur and Bachpalli villages (Figure 1). The study area is represented by granitic terrain with undulating topography. The upper relief zone comprises basalt with conspicuous mesa top. The main stream is developed by alluvial material carried and deposited from upstream. The soil profiles were exposed and the horizon wise soils were studied for their morphological, physical and chemical characteristics following standard procedure (AIS and LUS, 1970, Black, 1965 and Jackson, 1967). The soils were classified as per Soil Taxonomy (Soil Survey Staff, 1998). The main physiographic units in the study area are mesa top, mesa shoulder, mesa foot slopes, undulating plain, rocky ridge and narrow to broad valley. The area is drained by Yeliminedu Vagu and its numerous tributaries, which are seasonal in nature. The drainage density in the hilly areas and upper slopes are high while it is moderate in the lower slopes. The drainage pattern is dendritic. The elevation of the area ranges from 620 to 700 m above mean sea level (MSL). The relief of the area is mostly normal to sub-normal in the valley except the mesa slopes and ridges where it is excessive. The study area is characterized by semi-arid tropical climate with a mean annual rainfall of 764 mm of which 80 per cent is received from June to September. The rainfall pattern is bi-modal with two peaks, one in July and another in September although there is considerable variation in rainfall from year to year. The temperature and moisture regime of the study area is 'Ustic' and 'Hyperthermic'. The natural vegetation of this area is tropical dry deciduous type. The common tree species are Babul (*Acacia arabica*), Sitaphal (*Anona squamosa*), Neem (*Azadirachta indica*), Pipal (*Ficus religiose*).

The common grass type is Garica gaddi (*Cynodan dactylan*).

3. Methodology

3.1 Interpretation of Remote Sensing Data

Indian Remote Sensing (IRS)-1C LISS-III merged with PAN data of Peruguda micro-watershed (Path 99 Row 60) of 5th May 1996 (1:12,500 scale) was geo-referenced and was used for visual interpretation for delineation of the physiographic units based on the photo elements like tone, texture, size, shape, pattern, association, etc. The physiographic map thus generated was enlarged to a scale of 1:4000 scale and the ground truth was checked with the help of cadastral map of the area (1:4000 scale) and the base map was produced by overlying the remotely sensed data with the ground truth checking.

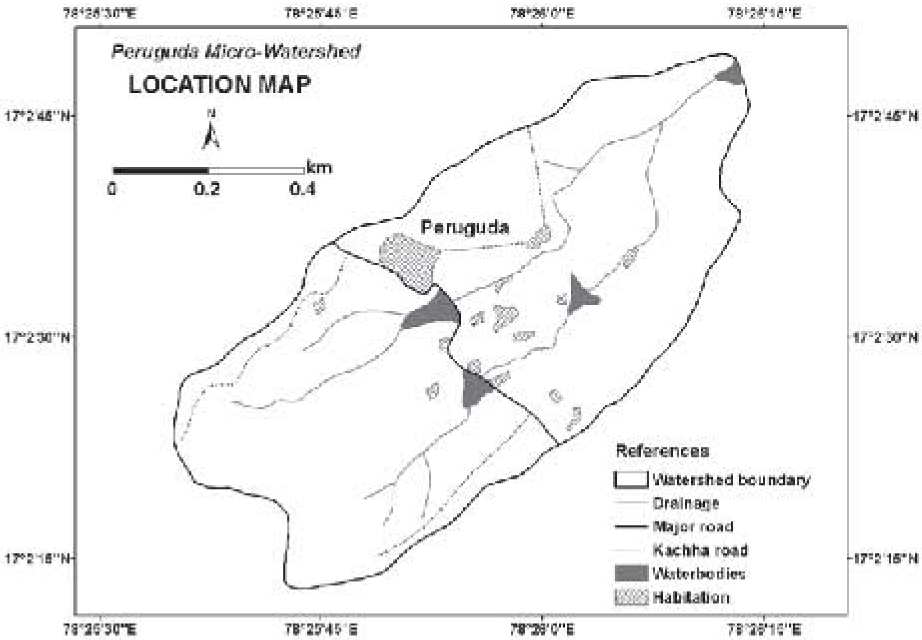

Figure1: Location map of Peruguda micro-watershed

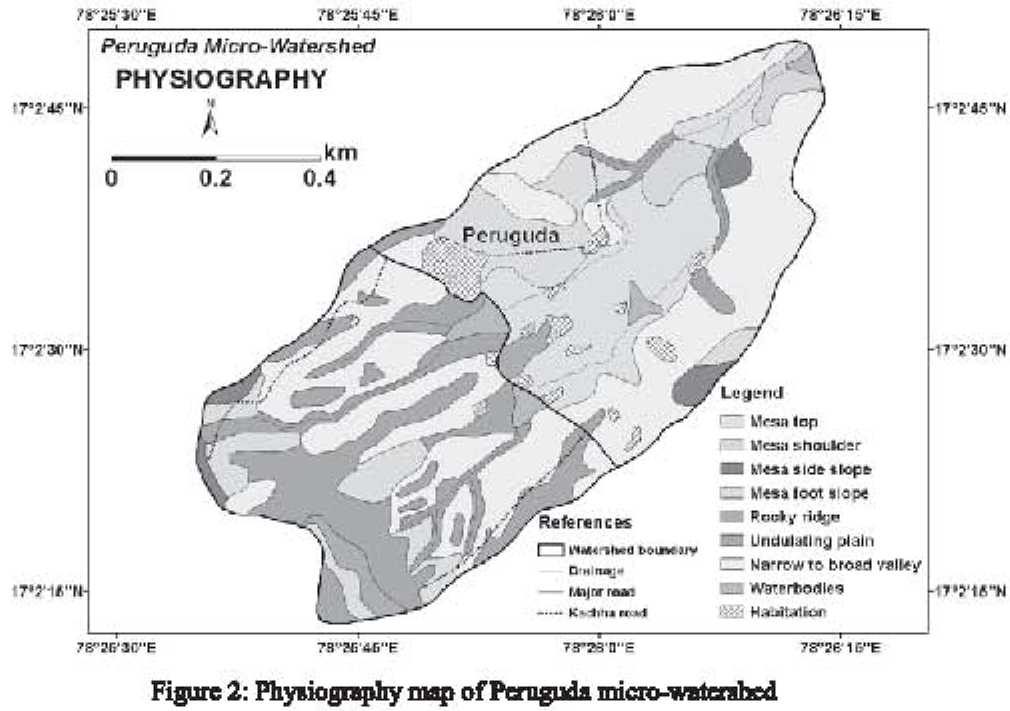

Figure 2: Physiography map of Peruguda micro-watershed

3.2 Development of Thematic Database

The various layers of thematic maps including soil map were prepared by interpretation of satellite data along with cadastral map as inputs to ARC/INFO GIS (Ver. 7.03) system for the generation of database. The ultimate maps were generated on 1:22,000 scale after considerable reduction. Using the soil morphological and physico-chemical properties, attribute/non-spatial data was compiled for all the 23 mapping units in the micro-watershed. This attribute data was linked to the spatial data of soils by adding items in the polygon attribute table (PAT) of soil coverage following map generalization procedure. These were subsequently made into individual covers using 'Dissolve Operation' thus forming different derivative layers of the study area. The slope, drainage, texture, coarse fragments, depth, CEC and pH covers were overlayed to form a composite map using 'Union Operation'. This composite map was subjected to logical operations in GIS involving the units of the above coverages in the form of decision trees developed according to soil site suitability criteria to derive the soil suitability maps for cotton and sorghum crops (FAO, 1976). Area analysis for the derived maps was carried out.

3.3 Soil-Site Suitability Evaluation

The composite map produced by the overlaying of the different thematic layers was subjected to logical operations in GIS in the form of decision trees developed as per the methodology given in the FAO framework on land evaluation (FAO, 1976), modified by Sys et al., (1991) and NBSS&LUP (1994) to derive the suitability map for two major crops, viz. cotton and sorghum. The suitability maps have been prepared using reclassification technique through dissolving the homogeneous mapping units in GIS. Map compositions were done in ARC/PLOT for these suitability maps as well as the soil map and land capability map.

4. Results and Discussion

4.1 Physiography

Visual interpretation of FCC's generated from spectral bands 2,3 and 4 in conjugation with detailed ground truth data, seven physiographic units i.e. mesa top, mesa shoulder, mesa side slope, mesa foot slope, rocky ridge, undulating plain and narrow to broad valley were identified and delineated (Figure 2). The image interpretation key based on the photo elements is shown in (Table 1).

Table1. Physiographic units and their image characteristics in Peruguda micro-watershed

Physiographic unit	Tone	Texture	Size	Pattern	Association
Mesa top	Dark blue to blackish blue	Fine	Varying	Continuous elongated	Associated with elevated, plain land with fine soils having swelling and shrinking properties, mostly cultivated in kharif season
Mesa shoulder	Dark and light blue mixed with white, gray and pink	Medium to coarse	Varying	Scattered	Associated with shallow, gravelly soils at slightly higher elevation which is mainly used for rainfed cultivation
Mesa side slope	Dark to light blue, white and pink mixed	Fine to medium	Varying	Patchy	Association with shallow, gravelly soils on side slope with severe erosion and stoniness which require appropriate soil-water conservation measure
Mesa foot slope	Dark to light blue and white mixed	Fine	Varying	Patchy	Associated with moderately deep soil on moderately sloping foot slope cultivated in kharif season and mostly remains fallow in rabi season
Rocky ridge	Dark blue with yellow and white mixed	Fine to medium	Varying	Elongated/ Dendritic	Associated with shallow soils on rocky ridge with severe erosion and stoniness, mostly remains fallow may be used for social forestry purposes
Undulating plain	Blue, white and gray mixed	Medium to coarse	Varying	Continuous	Associated with elevated plain land and adjoining narrow valley mostly cultivated in kharif season and the low lands may be cultivated for vegetables in rabi season
Valley fill	Light blue, yellow, white and pink mixed	Medium to coarse	Varying	Continuous	Associated with low lying areas and used for cultivation of paddy in kharif season and vegetables in rabi season

4.2 Slope

The slope of land has a great influence on the soil and water loss from the area and thereby influences the land use. In the micro-watershed, using contour information available on Survey Of India (SOI) toposheet (1:25,000 scale) and intensive ground truth checking, total six slope classes viz. nearly level (0-1%), very gently sloping (1-3%), gently sloping (3-5%), moderately sloping (5-10%), strongly sloping (10-15%), moderately steeply sloping (15-30%) have been identified (Table 2). The analysis shows that very gently slope occupies majority of the area (42.6%) followed by gently slope (22.7%), nearly level (20.8%), moderately slope (4.9%), moderately steeply slope (3.8%) and strongly slope (1.2%).

4.3 Soils

The soil map prepared after establishing physiography-soil relationship indicates the kind and distribution of soils in the micro-watershed along with their extent (Figure 3 and Table 3). The soils of this area constitute three geological formations viz. Granite, Basalt and Alluvium. The soils developed from basalt are generally black in colour, clayey in texture with varying depth. The soils of mesa top, periphery, foot slopes and undulating plains are deep, fine to very fine in textural class. The soils of mesa shoulder and side slopes are shallow in depth, skeletal in nature. In the granitic landscape, except the rocky ridges and undulating side slopes with rills/gullies and gravels, all the soils are deep, loamy in texture.

The valley soils are mostly deep, coarser in texture and developed from the deposition of alluvial material carried by the surface runoff water from the surrounding uplands.

4.4 Soil Depth

Soil depth is the most important and primary characteristics of soils that regulates moisture available to the plants that is ultimately reflected in crop growth and yield. In the micro-watershed, based on the soil information of different soil units, total five depth classes viz. very shallow (0-7.5 cm), shallow (7.5—22.5 cm), moderately deep (22.5- 45 cm), deep (45-90 cm) and very deep (> 90 cm) were identified. The data revealed that deep soils occupy major areas (50.3%) followed by very deep (21.1%), moderately deep (14.8%), shallow (6.0%) and very shallow (3.8%), respectively (Table 4).

4.5 Soil Erosion

Soil erosion is the process of loss of soil from both agriculture and non-agriculture lands. During soil survey in the field, based on the satellite image characteristics, slope gradient, soil site characteristics and land use/land cover, four categories of soil erosion classes and the type of erosion is given qualitatively as none to slight erosion (e1) for sheet or rill erosion, moderate erosion (e2) for deep rills, severe erosion (e3) for deep gullies and very severe erosion (e4) for ravenous land (Sujatha, 2000). Later, the soil erosion was quantitatively represented by the soil loss in tones per ha per year as follows:

Degree of erosion	Kind	Symbol	Soil loss (estimated in t/ha/yr)
None or slight	Sheet	e1	5-10
Moderate	Rill	e2	10-20
Severe	Gullied	e3	20-40
Very severe	Ravinous	e4	> 40

Table 2: Soils under different slope classes in Peruguda micro-watershed

Slope class	Mapping unit	Area (ha.)	% of TGA
Nearly level (0-1%)	1,2,12,21,22	141.18	20.8
Very gently sloping (1-3%)	9,13,14,15,19,23	288.49	42.6
Gently sloping (3-5%)	3,4,6,7,10,16,17,18	153.67	22.7
Moderately sloping(5-10%)	8,20	33.62	4.9
Strongly sloping (10-15%)	11	8.09	1.2
Moderately steeply sloping (15-30%)	5	25.87	3.8
Miscellaneous	-	26.85	4.0

Table 3: Physiography-soil relationship in Peruguda micro-watershed

Soil mapping unit	Geology	Physio-graphy	Soil characteristics	Soil Taxonomy	Area (ha)	% TGA
1	Basalt	Mesa top (Central zone)	Deep, imperfectly drained, fine soils in control section on nearly level mesa top with moderate erosion	Fine, montmorillonitic, hyperthermic Typic Haplustert	94.99	14.0
2	"	Mesa top (Periphery)	Moderately deep, well drained, fine soils in control section on nearly level mesa top (Periphery) with slight erosion	Fine, mixed, hyperthermic Typic Ustorthent	2.65	0.4
3	"	Mesa shoulder (Upper part)	Shallow, excessively drained, clayey soils in control section on mesa shoulder (upper part) with severe erosion	Clayey, mixed, hyperthermic, Lithic Ustorthent	9.79	1.4
4	"	Mesa shoulder (Lower part)	Shallow, excessively drained, clayey-skeletal soils in control section on mesa shoulder (lower part) with severe erosion and stoniness	Clayey-skeletal, mixed, hyperthermic Lithic Ustorthent	8.02	1.2
5	"	Mesa side slope	Very shallow, excessively drained, loamy-skeletal soils in control section on mesa side slope with very severe erosion and stoniness	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthent	25.87	3.8
6	"	Mesa foot slope (Upper smooth)	Deep, well drained, fine soils in control section on mesa foot slopes (Upper smooth) with moderate erosion	Fine, mixed, hyperthermic, Typic Ustochrept	53.40	7.9
7	"	Mesa foot slope (Upper hills)	Deep, well drained, fine soils in control section on mesa foot slope (Upper hills) with severe erosion	Fine, mixed, hyperthermic, Typic Ustochrept	21.1	3.1
8	"	Mesa foot slope (Lower)	Shallow, excessively drained, clayey soils in control section on mesa foot slope with severe erosion	Clayey, mixed, hyperthermic, Lithic Ustorthent	10.98	1.6
9	"	Undulating plain (Summit)	Deep, imperfectly drained, fine soils in control section on very gently sloping plain summit with moderate erosion	Fine, montmorillonitic, hyperthermic, Typic Haplustert	25.53	3.8
10	"	Side slope of undulating plain	Shallow, well drained, clayey soils in control section on gently sloping side slopes of the summit with severe erosion	Clayey, mixed, hyperthermic, Lithic Ustorthent	3.73	0.6
11	Granite	Rocky ridge	Shallow, excessively drained, loamy-skeletal soils in control section on strongly sloping ridge with very severe erosion	Loamy-skeletal, mixed, hyperthermic, Lithic Ustorthent	8.09	1.2
12	"	Undulating plain (Summit smooth)	Moderately deep, well drained, fine-loamy soils in control section on nearly level pediplain summit with slight erosion	Fine-loamy, mixed, hyperthermic, Typic Ustochrept	6.71	1.0
13	"	Undulating plain (Summit-gravel/ stone)	Moderately deep, well drained, coarse loamy soils in control section on very gently sloping pediplain summit with moderate erosion	Coarse-loamy, mixed, hyperthermic, Typic Ustorthent	10.54	1.6
14	"	Undulating plain (Summit-Rock outcrop)	Moderately deep, well drained, coarse loamy soils in control section on very gently sloping pediplain summit with moderate erosion	Fine-loamy, mixed, hyperthermic, Typic Ustorthent	12.44	1.8
15	Granite	Side slopes of undulating plain (very gently sloping)	Deep, well drained, fine-loamy soils in control section on very gently sloping pediplain side slopes with slight erosion	Fine-loamy, mixed, hyperthermic, Typic Haplustalf	16.78	2.5

16	"	Side slopes of undulating plain (Gently undulating)	Deep, well drained, fine-loamy soils in control section on gently sloping pediplain side slopes with moderate erosion	Fine-loamy, mixed, hyperthermic, Typic Rhodustalfs	12.62	1.9
17	"	Side slopes of undulating plain (Undulating rill/gullies)	Moderately deep, excessively drained, loamy-skeletal soils in control section on gently sloping pediplain side slopes with severe erosion	Loamy-skeletal, mixed, hyperthermic, Typic Ustorthent	33.19	4.9
18	"	Side slopes of undulating plain (Undulating with gravel)	Moderately deep, well drained, loamy-skeletal soils in control section on gently sloping pediplain side slopes with severe erosion	Loamy-skeletal, mixed, hyperthermic, Typic Ustorthent	11.82	1.7
19	"	Valley (Narrow-level)	Deep, well drained, fine soils in control section on moderately sloping narrow valley with slight erosion	Fine, mixed, hyperthermic Udic Haplustalfs	116.79	17.2
20	"	Valley (Narrow-broad)	Moderately deep, well drained, loamy-skeletal soils in control section on very gently sloping narrow valley with very severe erosion	Loamy-skeletal, mixed, hyperthermic, Typic Ustorthent	22.64	3.3
21	Alluvium	Valley fill (Level)	Very deep, moderately well drained, coarse-loamy soils in control section on nearly level broad valley with slight erosion	Coarse-loamy, mixed, hyperthermic, Udic Ustifluvents	31.42	4.6
22	"	Valley fill (Concave)	Very deep, imperfectly drained, coarse-loamy soils in control section on nearly level broad valley with slight erosion	Coarse-loamy, mixed, hyperthermic, Udic Ustifluvents	5.41	0.8
23	"	Valley fill (Dissected)	Very deep, imperfectly drained, fine-loamy soils in control section on very gently sloping broad valley with severe erosion	Fine-loamy, mixed, hyperthermic, Udic Ustifluvents	106.41	15.7
		Habitation and tanks			26.85	4.0

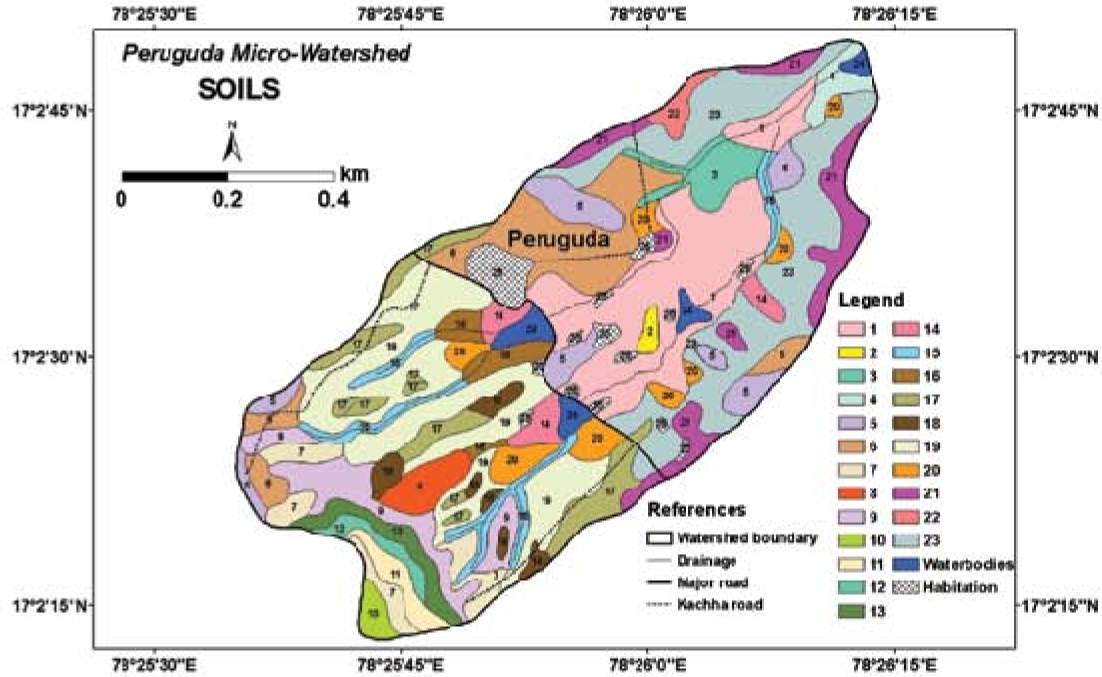

Figure 3: Soil map of Peruguda micro-watershed

Table 4: Soils under different depth class in Peruguda micro-watershed

Depth class	Mapping unit	Area (ha.)	% of TGA
Very deep >(90 cm)	21,22,23	143.24	21.1
Deep (45-90 cm)	1,6,7,9,15,16,19	341.21	50.3
Moderately deep (22.5 – 45 cm)	2,12,13,14,17,18,20	99.99	14.8
Shallow (7.5 - 22.5 cm)	3,4,8,10,11	40.61	6.0
Very Shallow (0-7.5 cm)	5	25.87	3.8
Miscellaneous	-	26.85	4.0

Table 5: Soils under different erosion class in Peruguda micro-watershed

Erosion class	Soil mapping unit	Area (ha.)	% of TGA
None to slight (e1)	2,12,15,19,21,22	179.76	26.5
Moderate (e2)	1,6,9,13,14,16	209.52	30.9
Severe (e3)	3,4,7,8,10,17,18,20,23	226.68	33.6
Very severe (e4)	5,11	33.96	5.0
Miscellaneous	-	26.85	4.0

Table 6: Land capability, limitations and potential of the soils in Peruguda micro-watershed

Land Capability Class	Land Capability sub-Class	Limitations	Potentials	Area (ha.)	% of TGA
III (Moderately good cultivable land)	III e2s	Moderate limitation of water erosion, heavy texture and poor permeability	All climatically adapted crops can be grown including cotton cultivation	198.98	29.4
III (Moderately good cultivable land)	IIIs	Soils with moderate problems of soil depth, soil texture	Cultivation with careful selection of crops adapted to soil limitations	179.76	26.5
IV (Fairly good land, suited for occasional or limited cultivation)	IV e3s	Soils with limitations of slope, soil depth, erosion and stoniness	Occasional cultivation of selected crops with proper soil conservation measures, Agri- horti-silvipasture can be done	21.11	3.1
VI (Well suited for grazing or Forestry)	VIe2s	Soil with moderate limitations of erosion, soil depth , gravells and stones	Suitable for pasture, silvipasture, forestry	10.54	1.6
VI (Well suited for grazing or Forestry	VIe3s	Soils with severe limitations of soil depth, gravellness and stoniness	Suitable for pasture, silvipasture, forestry	183.94	27.1
VII (Fairly well suitable for grazing or forestry	VII e4s	Soils with very severe limitation of slope, erosion , soil depth excessive drainage, stoniness and gravellyness	Grazing or forestry or both	56.50	8.3
Miscellaneous	-	-	-	26.85	4.0

The soils of the micro-watershed were grouped under four types of soil erosion classes viz. none to slight (5-10 t/ha/yr) (e1), moderate (10-20 t/ha/yr) (e2), severe (20-40 t/ha/yr) (e3), and very severe (>40 t/ha/yr) (e4), in which severe erosion occupies 33.6% area followed by moderate, slight and very severe occupying 30.9, 26.5 and 5.0 per cent area, respectively (Table 5). The soils of undulating side slopes with rills/gullies, mesa shoulder, dissected valley fill possesses severe erosion hazard (33.6% of the micro watershed) as evidenced by the dark to light blue, yellow, white mixed tone in the satellite imagery while mesa side slopes, rocky ridges and narrow to broad valley possesses very severe erosion hazard (5.0%), which is reflected by dark blue, yellow and white mixed tone in the imagery. Slight and moderate erosion occupies major areas of the micro-watershed. The different thematic information viz. soil depth, slope and erosion of watershed area were generated based on the soil survey data are of immense useful for land use planning and also for conservation purposes.

5. Land Capability Classification

The soils of the micro-watershed have been classified into four different capability classes viz. III, IV, VI and VII depending on the land features and the climate (FAO, 1983). Based on the number and severity of limitations, the soils of the study area have been subdivided into 6 capability sub-classes viz. IIIs, $IIIe_2s$, IVe_3s, VIe_2s, VIe_3s and $VIIe_4s$ (Figure 4). The result revealed that maximum area (29.4%) is covered by the soil with land capability subclass $IIIe_2s$ followed by VIe_3s, IIIs, $VIIe_4s$, IVe_3s and VIe_2s occupying 27.1, 26.5, 8.3, 3.1 and 1.6 per cent area, respectively (Table 6). The soils of mesa foot slopes and narrow valley were classified into capability class IV due to the severe limitation of erosion, soil depth slope, etc. These soils can be used for agricultural purposes after adopting efficient soil conservation measures. The soils of a part of mesa shoulder, foot slope with rills and rocky ridges are not at all suitable for agriculture and thus they have been classified in the capability class VI and VII. These soils can be used as pasture or some silviculture purposes.

6. Soil-Site Suitability

Productivity of a particular crop depends on land resources and the climate of the area. Identification of crop requirements and matching them with the resources available to optimize the productivity in sustainable manner assumes a greater importance as the present level of productivity of most of the crops either reached to the plateau or started declining. The crop management practices based soil and site suitability criteria may help to overcome the constraints of crop planning for maximizing the production with reference to a rain fed agriculture.

6.1 Soil-Site Suitability for Cotton

Cotton is the most important cash crop in the study area. Based on the climate, soil and soil-site characteristics, the soils of the micro-watershed were evaluated for soil-site suitability of cotton crop (Table 7) as per their requirements (Sys, 1991, NBSS and LUP, 1994 and Naidu et al., 2006). In the micro-watershed about 16.2 per cent area covering mesa top, periphery of mesa top and side slopes of very gently undulating plain were found to be moderately suitable for cotton while 27.6 per cent area found to be marginally suitable occupying mesa foot slope, undulating plain, side slopes of undulating plain and valley fill area. About 39.6 per cent area covering side slopes of undulating plain with rills/gullies, gravels and also dissected valley fill etc. were found to be presently unsuitable and about 12.6 per cent area covering mesa shoulder, mesa side slope, rocky ridge and narrow to broad valley were found to be permanently unsuitable for cotton (Figure 5 and Table 8).

Table 7: Soil-site suitability criteria for cotton in Peruguda micro-watershed

Land use requirement		Rating			
Land quality	Soil-site characteristic	Highly suitable, S1	Moderately suitable, S2	Marginally suitable, S3	Not suitable, N
Temperature regime	Mean temperature in growing season (°C)	20–30	31-35	<19 >35	-
Moisture availability	Length of growing period (days)	180–240	120-180	<120	-
Oxygen availability to roots	Soil drainage (class)	Well drained–mod. well drained	Imperfectly drained	Poor Somewhat excessive	Stagnant/ excessive
	Waterlogging in growing season (days)	1-2	2-3	3-5	>5
Nutrient availability	Texture	Sic, c	Sicl, cl	Si, sil, sc, scl, l	sl,
	Soil reaction (pH) (1:2.5)	6.5-7.5	7.6-8.0	8.1-9.0	>9.0 <6.5
	OC (%)	>1.00	0.75-1.0	0.50-0.75	<0.50
	$CaCO_3$ in root zone (%)	<3	3-5	5-10	10-20
Nutrient retention	Texture (class)	Loamy Fine loamy	Loamy-skeletal	Fine	
Rooting conditions	Effective soil depth (cm)	100-150	50-100	25–50	<25

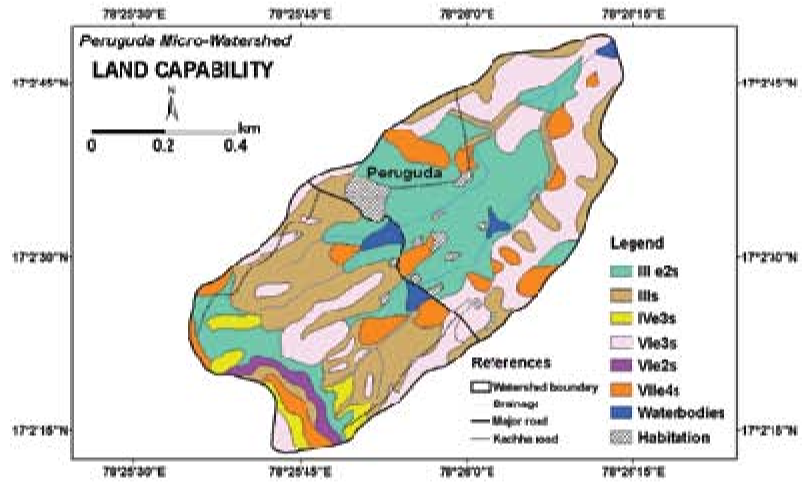

Figure 4: Land capability map of Peruguda micro-watershed

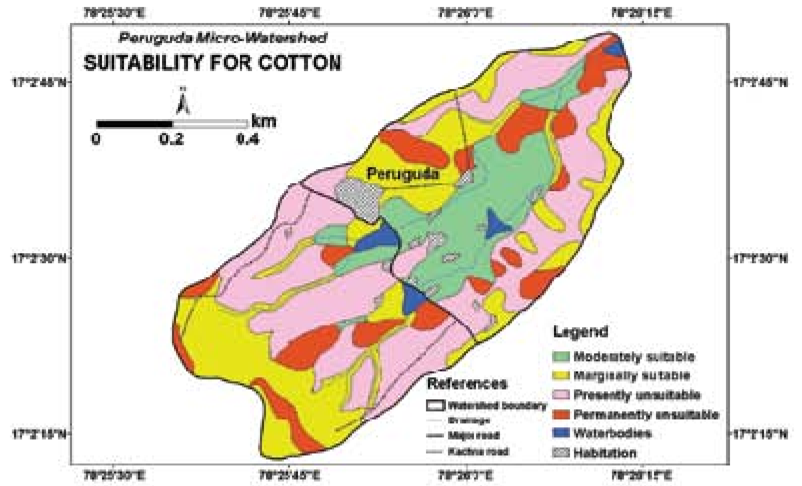

Figure 5: Suitability map for Cotton in Peruguda micro-watershed

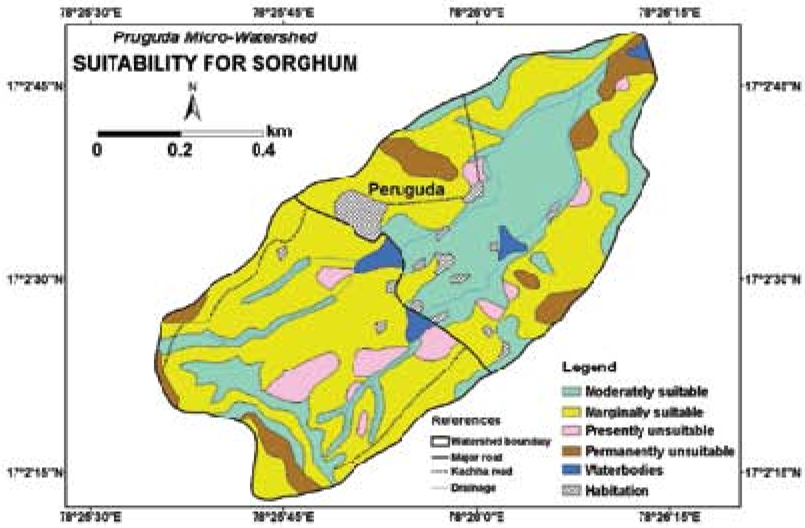

Figure 6: Suitability map for Sorghum in Peruguda micro-watershed

Table 8: Soils under different suitability classes for cotton in Peruguda micro-watershed

Suitability class	Soil map unit	Area (ha)	% of TGA
Moderately suitable (S2)	1, 2 , 16	110.26	16.2
Marginally suitable (S3)	6,7,9,10,12,13,14,15,21,22	187.06	27.6
Presently unsuitable (N1)	17,18,19,23	268.21	39.6
Permanently unsuitable (N2)	3,4,5,8, 11,20	85.39	12.6
Miscellaneous	-	26.85	4.0

Table 9: Soil-site suitability criteria for sorghum in Peruguda micro-watershed

Land use requirement		Rating			
Land quality	Soil-site characteristic	Highly suitable, S1	Moderately suitable, S2	Marginally suitable, S3	Not suitable, N
Temperature regime	Mean temperature in growing season (°C)	26–30	30–34; 24–26	34–40; 20–24	>40; <20
Moisture availability	Length of growing period (days)	120–150	90–120	<90 150-180	>180
Oxygen availability to roots	Soil drainage (class)	Well drained–mod. well drained	Somewhat excess. drained	Excessively drained	-
	Waterlogging in growing season (days)				
Nutrient availability	Soil reaction (pH)	Neutral	Slightly acidic and alkaline	Mod. acidic	
	$CaCO_3$ in root zone (%)				
Nutrient retention	Texture (class)	Loamy Fine loamy	Loamy-skeletal	Fine	
Rooting conditions	Effective soil depth (cm)	>75	51–75	25–50	<25
	Gravel content (% by vol.)	<15	15-40	>40	
Soil toxicity	Salinity (EC satn extract, dS m^{-1})	Nil Negligible	Slight	-	-
	Sodicity (ESP, %)				
Erosion hazard	Slope (%)	<8	8–15	15-30	>30

Source: NBSS & LUP (1994)

Table 10: Soils under different suitability classes for sorghum in Peruguda micro-watershed

Suitability class	Soil map unit	Area (ha)	% of TGA
Moderately suitable (S2)	1,2,9,12,15,21,22	183.49	27.1
Marginally suitable (S3)	6,7,10,13,14,16,17,18,19,23	382.04	56.3
Presently unsuitable (N1)	3,8,20	43.41	6.4
Permanently unsuitable (N2)	4,5,11	41.98	6.2
Miscellaneous	-	26.85	4.0

6.2 Soil-Site Suitability for Sorghum

Sorghum is the one of the important semi arid crop in the study area. Based on the climate, soil and soil-site characteristics, the soils of the micro-watershed were evaluated for soil-site suitability of sorghum crop (Table 9) as per their requirements (Sys, 1991, Sehgal, 1986, NBSS and LUP, 1994 and Naidu et al., 2006). Analysis shows that for sorghum crop, about 27.1 per cent area occupying the mesa top, undulating plain, valley fill area (part) were found to be moderately suitable while 56.3 per cent area covering mesa foot slope, side slopes of undulating plain, narrow valley and rest of the valley fill were found to be marginally suitable showing 7.6 per cent area as presently unsuitable and 5.0 per cent area mainly mesa side slope and rocky ridge as permanently unsuitable (Figure 6 and Table 10).

7. Conclusion

The analysis of IRS-1C LISS-III and PAN fused data in association of field survey reveals that the Peruguda micro-watershed represents a unique combination of landscape, geo-agro climatic scenario where three geological formations gives rise to the formation of soils under seven identified landforms. Generally the deep soils with high clay content in the mesa top were qualified for capability class III with moderate problems of soil and water erosion and moderately suitable for cotton and sorghum. However, shallow to moderately deep soils of foot slope were qualified for capability class III and IV and found to be marginally suitable to presently unsuitable for sorghum and marginally suitable for cotton. Only the soils of mesa shoulder, mesa side slope and rocky ridge having land capability class VI and VII are permanently unsuitable for all the crops studied. The valley soils were classified under land capability class III and VI and were found marginally suitable to presently unsuitable for cotton and sorghum. Hence for the conservation of soil resources and to increase the productivity in this area, efficient soil and water conservation measures are needed. The areas under land capability class VI and VII may be recommended for pasture or silvipasture purposes. The study demonstrated that application of remote sensing and GIS will be of immense help in soil resource inventory and identification of potential areas for crop suitability for optimal utilization of available natural resources to achieve higher productivity at micro level.

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