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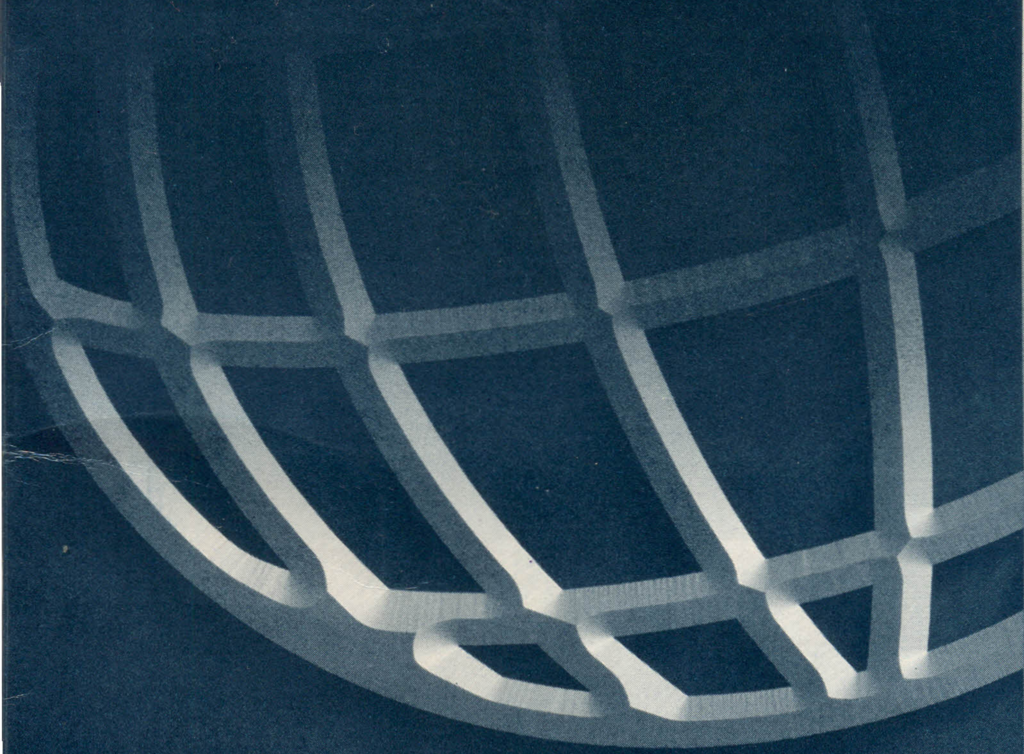

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Delineation and Prioritization of Macro Watersheds in Semi-Arid Anantapur District, Andhra Pradesh

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ABSTRACT : Anantapur district has a draught history date back to the thirteenth century and it is a poorly developed district of Andhra Pradesh. In the present study an attempt has been made to study physical characteristics viz. slope, drainage, geology, geomorphology, soils and water balance characteristics of the Anantapur district, Andhra Pradesh using remotely sensed data (IRS-IA LISS-I and Landsat TM), collateral data and selected field checks. Macro watersheds have been delineated and Sediment Yield Index (SYI) has been worked out using Flaxman model. The study indicates that out of fifty macro watersheds delineated thirteen are having SYI above 1300 and are prone to very high erosional hazard. Fourteen macro watersheds are under high erosion prone condition. Eight macro watersheds are having medium erosion prone and twelve watersheds are under low erosion prone. Only three macro watersheds are under very low erosion prone conditions. Twenty seven macro watershed, which, covers nearly 56 per cent of the total area of the district are under very high erosion prone conditions needs immediate land and water resource conservation measures to restore geoecological balance and obtain maximum productivity from available land and water resources of the droughtprone Anantapur district.

Introduction

Soil and water are the basic resources of the country which must be carefully conserved and judiciously utilized to sustain the ever-increasing human and livestock population (Sharda, 2002). It is estimated that about 5334m tones of soil is getting eroded annually, which works out to 16.4 t ha^{-1} yr^{-1} (Dhruva Narayana and Ram Babu, 1983). The semi-arid and arid regions are characterized by highly unpredictable, erratic and insufficient rainfall. A part of the limited rainfall is lost as runoff, which also leds to soil erosion. Soil and water conservation and its efficient utilization through watershed approach is an alternate to arrest degradation of natural resources and restoring land productivity. Utilization of natural resources by maintaining or enhancing their qualities for posterity is one of the major goals of the current watershed development strategy (Samra, 2002). Rational utilization of land and water resources for optimum and sustained production with minimum hazard to natural ecosystem is the need of the day. It essentially relates soil and water conservation in the watershed, which means proper land use, protecting land against all forms of deterioration, maintaining soil fertility, conserving water for farm use, drainage management, sediment reduction and increasing productivity from all land uses (Tejwani, 1986).

Anantapur district has a drought history dates back to the thirteenth century and it is a poorly developed district of the state of Andhra Pradesh. Decline in rainfall, low humidity, uncertain monsoon, deforestation and limited surface water resources are the predominat causes for the droughtiness. Added to this, the overexploitation of groundwater resources through dug wells further aggravating the situation (Rao *et al.,* 1992). Remote sensing technology amalgamated with conventional methods has emerged now-a-days as an efficient and important tool for the proper management of natural resources of a region and the same is very much applicable to watershed studies as well (Meijerink 1988). Using remote sensing techniques Prabhakar Rao (1981) studied the geomorphological aspects in semi-arid tracts of Anantapur district. Karale *et al.,* (1985) have described various techniques in evaluating the soil resources and mapping them. At micro level Vinayan and Jayakumar (1987) have studied the land, water and other resources of Vattavada watershed of Indukki district, Kerala for an integrated development.

In the watershed studies the shape and size, slope, soils and their characteristics, precipitation, land use and land cover pattern are important factors that determine a watershed behaviour (Sharma and Kalia, 1987). Prioritization of erosion prone areas at watershed level enables to generate the action plan for land and water resources at sustainable basis. Many workers attempted to estimate sediment yield at various levels since the beginning of the twentieth century. Zingg (1940) developed an equation to calculate field soil loss in the corn belt of USA. The Universal Soil Loss Equation (USLE) was developed at National Runoff and Soil Loss Data Centre of Science and Education Administration of USA during 1954. Wischmeier *el al.,* (1958), Wischmeier and Smith (1960), Wischmeier and Smith (1978) went on to define the USLE. In addition to the advancement in USLE, Flaxman (1971) developed comprehensive equation for computing sediment yield at watershed level. In the present study, the semi-arid tract of Anantapur district has been selected to estimate the Sediment Yield Index (SYI) using Flaxman (1971) equation at macro watershed level and prioritized them based on the estimated Sediment Yield Index. Similar attempts have been made to prioritize the watersheds of Mahaboob nagar district of Andhra Pradesh using remotely sensed data (Prasad *et al.,* 1992(.

Study Area

The Anantapur district lies between 13°40' to 15°15' N latitudes and 76°50' to E longitudes. It is bounded on the north by Kurnool district, east by Cuddapah and Chittoor districts south and west by Karnataka state and it covers an area of about 19,125 sq. km. (Fig. 1). The general elevation ranges from 670m above msl in the south-west to 280m above msl in the north-eastern parts of the district. The annual mean temperature and rainfall of the district are 27.5°C and 558 mm, respectively.

Materials and Methods

The drainage pattern of the district was analysed and 50 macro watersheds were delineated

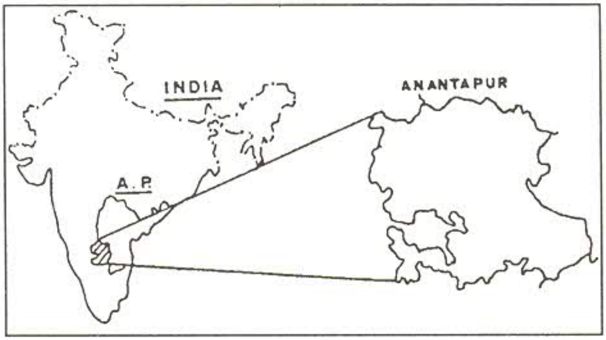

Fig. 1 Location of the study area

based on the water divide line concept using SOI topographical sheets on 1:250,000 scale. The slope analysis has been carried out based on the contour values and spot heights. The geological formations and geomorphological processes were analysed to delineate the different geomorphological units through visual interpretation using IRS-1A, LISS-1 FCC's and Landsat TM (bands 5 and 7) data in association with Survey of India topographical sheets on 1:250,000 scale and available collateral data. The major land use/land cover changes were delineated based on the visual interpretation of the satellite data (Gautam and Narayana, 1982).

The rainfall data for a period of 90 years from 1901 to 1990 has been collected from the available thirteen stations of the district for the analysis of total annual precipitation, potential and actual evapotranspirations, annual moisture adequacy, aridity index and computation of water balance. The soil variability in the district has been analysed by studying the lithology and landforms, their position in toposequence,, drainage networks and their inter-relationship. The soil boundaries were delineated precisely using the image characteristics such as tone, texture, pattern, shape and size (Ravi Sankar *et al.,* 1988). The data on soil particle size was collected at mandal level from District Agricultural department.

The Sediment Yield Index (SYI) has been calculated using the Flaxman (1971) model, which is given below.

$$\text{Log}\,(100 + Y) = 6.63792 - \text{Log}\,(100 + X1)^{2.40504} + \text{Log}\,(100 + X2)^{0.06567} -$$

$$\text{Log}\,(100 + X3)^{0.01820} + \text{Log}\,(100 + X4)^{0.04019}$$

where,

Y = Sediment yield in acre-feet/square mile/year

X1 = Average annual precipitation in inches/mean annual temp. in degree F

X2 = Average slope

X3 = Percent of soil particles coarser than 1 mm on the top 2" of soil profiles

X4 = Percent of 2 microns or finer soil particles on the top 2" of soil profiles

X_4 is the assigned positive value, if the soil is alkaline and negative if it is neutral or acidic.

The Sediment Yield Index values were worked out for all the delineated 50 macro watersheds. Based on the range of Sediment Yield Index (SYI) values the macro watersheds have been prioritized as very high, high, medium, low and very low erosion susceptibility. The watersheds, which are having very high value of SYI have been characterized as highly erosion prone, whereas the watersheds which are having the very low SYI value have been characterized as very low erosion prone. The erosion susceptibility zone map has been prepared and area of the individual macro watershed has been calculated using a digital planimeter.

Results and Discussion

The analysis shows that the size of the macro watershed ranges from elongated (Gooty) to semi-circular (Penakacherla) in nature. The size is ranging between 72,500 ha (Bommanahal) to 3,750 ha (Hemavathi). The analysis of physical characteristics such as slope, drainage, geology, geomorphology, soils, and water balance characteristics using satellite data and collateral were summarized below.

Slope

The slope analysis of the district reveals that 0 to 2 per cent slopes are encountered in the alluvial and colluvial plains, 2 to 5 per cent slopes are occupied by the pediplains, 5 to 10 per cent slopes are mostly found in the dissected pediments, 10 to 20 per cent slopes are associated with narrow dissected pediments and adjoining denuded areas and more than 20 per cent slopes are mostly akin to the denuded hilly terrains.

Drainage

The Pennar, Chitravati and Hagari are the three major rivers and the direction of the drainage is towards north and north-east and majority of the streams are ephemeral in nature except those locally fed by through flow and return flow on the lower reaches. The general drainage pattern of the stream networks is mostly dendritic, which is freely developed followed by parallel to sub-parallel patterns which are controlled by joints, fracture zones, incipient fault lines in the granite-gneissic rocks. The high drainage density was observed on denuded hills, dissected pediments and their adjoining areas.

Geology

Geologically the district can be broadly divided into two distinct and well marked groups. The older group of metamorphic rocks belong to the Archean and the younger sedimentary rocks pertain to the Proterozoic age. The Archeans have been subsequently metamorphosed and intruded by various igneous rocks and comprises of gneisses, younger granites, pegmatites veins, basic dykes which occupy a greater part of the district mainly in northern, central, western and southern parts of the district. The younger sedimentary rocks belong to Cuddapah and Kurnool Super Groups and they consist of clastic rocks such as sand stone, shale and chemical precipitation of limestones. These rocks were formed by the denudation of the pre-existing Archean rocks. These formations occupy northern, north-eastern parts of the district.

Geomorphology

The major geomorphic units of the district have been delineated based on the visual interpretation of IRS-1A, LISS-I data for the district (Sambasiva Rao *et al.,* 1979). The analysis reveals that there are five major geomorphic units. The denudational hills, which are the remnants of the natural dynamic processes of weathering and denudation aided by fluvial action and they are mostly scattered in nature. The dissected pediments formed by sheet flow and / or sheet wash processes occupy large area and overlie granite-gneisses, megmatite and schistose terrain. Pediplains are flat or gently sloping surfaces, they are infact the end product of the coalescence of several pediments at the foot hill slopes and are spread over partially weathered granite-gneisses, schist, and sedimentary rocks. The sediments derived from the upper reaches of the above landforms are transported down slopes and they are deposited along the major river courses. They are grouped under alluvial fills and consist of flood plain deposits including natural levees and river terraces. The colluvial fills consist of sheet wash/slope wash materials derived from the adjoining uplands, transported over a short distance into narrow valley floors. They are presently occupying the minor nalas and intermittent streams within the pediplains and dissected pediments. The analysis of landforms reveals that the type of landform and geomorphological processes play a significant role in soil attachment and erosion process.

Soils

The delineated soil units from visual interpretation of IRS-IA, LISS-I satellite data in conjunction with collateral data reveals that the colluvic-alluvial soils are deep to very deep, calcareous with yellowish brown to grey brown colours and fine loamy to coarse loamy texture (Reddy, *et al.,* 1996). The soils overlain by colluvic-alluvial deposits are fine loamy to clayey with reddish brown to brown colour. Soils developed on gently sloping lands are deep to very deep, very dark grey in colour fine to very fine clayey-skeletal texture. Soils developed on pediplains with lower topographic situation are moderately deep, gray to grayish brown colours with gravely clay to clay loam texture with high organic content. Dissected pediments of undulating biotite gneiss and hematite quartzites are characterised by shallow to moderately deep, dark reddish brown to red with clayey-skeletal texture. The denudational hills of granite-gneisses, schistose and quartzite formations are associated with very shallow to shallow soils, gravelly to very gravelly with fine to coarse texture and reddish brown to brown with rock outcrops.

Water balance

The mean annual rainfall in the district is about 558 mm which is not only scanty but also erratic in its temporal and spatial variability. The distribution shows that it is less than 550 mm in the western, central and eastern parts, varies between 550 and 600 mm in the northern and southern parts and about 600 mm in the south-eastern parts. Similarly the spatial distribution of potential evapo-transpiration is less than 1500 mm in the south-western parts, varies between 1500 and 1700 mm in the central, northern and southern parts and exceeds 1700 mm in the north-western parts. At the same time, the actual evapo-transpiration shows that it is less than 750 mm in the western and central parts, varies between 750 and 800 mm in the south-eastern, southern and south-western parts and exceeds 800 mm in the northern parts. The distribution of index of annual moisture adequacy (Ima) is less than 45 per cent in the central parts, between 45 and 50 per cent in the western, south-eastern, southern and eastern parts and exceeds 50 per cent in the northern and south-western parts. The Aridity Index (Ia) is less than 50 per cent in the northern, southern and south-western parts, between 50 and 55 per cent in the western, south-eastern and eastern parts and exceeds 55 per cent in the central parts.

Prioritization of macro watersheds and Erosion susceptibility zoning

The Sediment Yield Index (SYI) values at macro watershed level reveals that the values ranges from highest in Golla macro watershed (1479) to lowest in Hemavathi macro watershed (994) (Table.1). Based on the estimated SYI values an erosion susceptibility zone map has been prepared (Fig. 2) to take ameliorative measures by the user agencies to arrest the accelerated soil erosion in the very high to high erosion prone watersheds.

Very High

Thirteen macro watersheds having SYI above 1300 with very high erosion susceptibility are located in the central, central western and south-eastern parts of the district. These watersheds are mostly associated with denudatinal hills and dissected pediplains, gentle to steep slopes, very shallow to moderately deep soils with thin vegetative cover. These watersheds require immediate site-specific soil and water conservation measures to avoid gulley and sheet erosion.

High

Fourteen macro watersheds are having high erosion susceptibility with SYI value ranging between 1200 and 1299 are scattered in the northern, north-western, north-eastern and southern parts of the district. These are mostly associated with denudatinal hills, dissected pediments, alluvial and colluvial fills with moderate to steep slopes, shallow to moderately deep soils and thin vegetative cover.

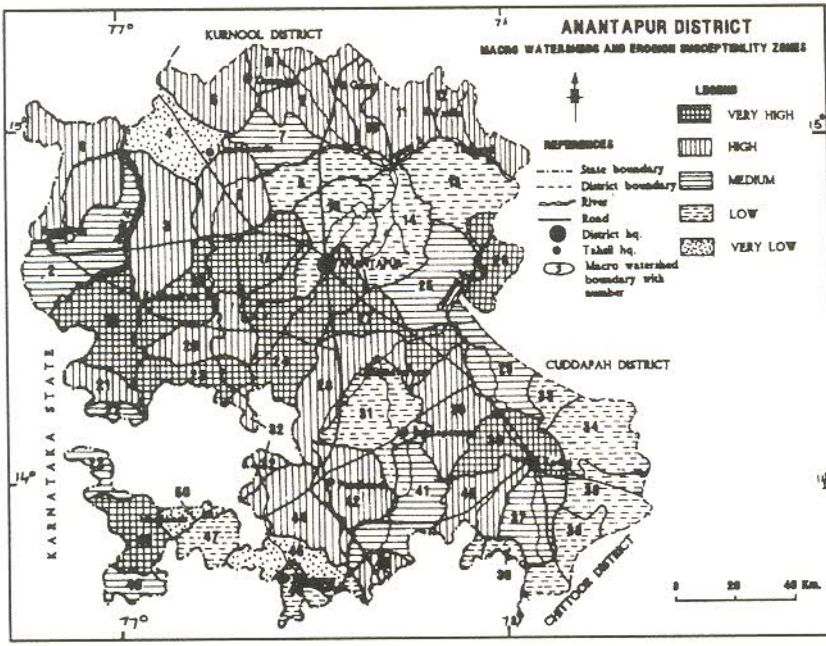

Fig. 2

Medium

Eight macro watersheds associated with medium erosion susceptibility with SYI value between 1100 and 1199 are located in the western, eastern, southern and south-western parts of the district. These watersheds characterized with denudational hills, pediplains and alluvial fills with moderate to steep slopes, shallow to moderately deep soils with sparse canopy cover.

Low

Twelve macro watersheds with low erosion susceptibility with SYI between 1000 and 1099 are spread in the central, eastern, south-eastern and southern parts of the district. These watersheds associated with denudatinal hills, pediplains alluvial and colluvial fills with level to moderate slopes, moderate to deep soils and moderate canopy cover.

Very Low

Only three macro watersheds with very low erosion susceptibility having the SYI value less than 1000 are located in the southern and north-western parts of the district. These are associated with mainly pediplains, colluvial and alluvial fills with moderately shallow to deep soils, level to gentle slopes and fairly good canopy cover.

TABLE 1. Prioritization of macro watersheds and their characteristics in Anantapur district

Macro Watersheds No.	Name of the Watershed	Normal Rainfall (mm)	Mean Elevation (mts)	Average slope (%)	Major Landforms	Soil Depth in range	Area in (ha)	Sediment Yield Index (SYI)	Prioritization of Watershed
Very High									
8	Nelagonda	520.0	400-500	2-5–5-10	Pediplains	Very Shallow-Shallow	25,000	1343	Very high
9	Yarragudi	413.8	300-500	2-5–5-10	Dissected hills, Pediplains	Very Shallow-Shallow	34,375	1434	Very high
10	Gooty	574.4	300-500	2-5–10-20	Dissected hills, Pediplains	Shallow Moderate	30,000	1352	Very high
17	Kudair	516.0	400-600	2-5–10-20	Denudational hills, Pediplains	Moderately deep	45,000	1368	Very high
18	Golla	483.0	400-600	2-5–10-20	Pediplains	Shallow-Mod.deep	45,625	1479	Very high
19	Setturu	491.0	500-600	2-5–5-10	Dissected pediplains	Very Shallow-Shallow	50,600	1363	Very high
23	Kambadur	515.0	500-750	2-5–5-10	Pediplains, Alluvial fills	Moderately deep	30,000	1307	Very high
24	Hampapuram	568.0	300-600	2-5–10-20	Dissected hills, Pediplains	Moderately deep	68,125	1375	Very high
26	Yellanuru	401.5	<300	<2–5-10	Denudational hills, Alluvial fills	Mod. deep–Deep	20,000	1300	Very high
27	Bathalapalli	518.0	300-400	2-5–7-20	Pediplains, Alluvial fills	Very Shallow-Shallow	37,500	1340	Very high
36	Nallamada	625.0	400-600	5-10-10-20	Denudational hills	Very shallow	25,000	1332	Very high
43	Chilamathuru	580.0	600-700	2-5–10-20	Denudational hills, Alluvial fills	Very Shallow-Shallow	19375	1307	Very high
49	Gudibanda	481.0	600-700	5-10-10-20	Dissected hills, Pediplains	Very Shallow-Shallow	32,500	1365	Very high
High									
1	Bommanahal	414.0	400-600	2-5	Pediplains	Deep-Very deep	72,500	1207	High
3	Beluguppa	483.0	400-500	<2	Alluvial & Colluvial fills	Shallow-Deep	57,500	1265	High
5	Penakacherla	498.0	300-500	2-5–5-10	Pediplains, Alluvial fills	Shallow-Deep	45,000	1299	High
6	Vidapanakallu	459.0	400-500	2-5	Pediplains	Deep-Very deep	40,000	1216	High
11	Kristipadu	520.0	300-400	2-5–5-10	Dissected hills, Pediplains	Shallow-Mod. deep	43,125	1266	High

Macro Watersheds No.	Name of the Watershed	Normal Rainfall (mm)	Mean Elevation (mts)	Average slope (%)	Major Landforms	Soil Depth in range	Area in ha	Sediment Yield Index (SYI)	Prioritization of Watershed
12	Yadiki	498.1	<300-400	2-5–5-10	Dissected hills, Colluvial fills	Shallow-Mod. deep	40,625	1267	High
20	Nuthimadugu	515.0	400-600	2-5	Pediplains	Moderately deep	36,875	1283	High
21	Mulakaledu	510.0	500-600	5-10	Dissected pediments	Moderately deep	18,500	1259	High
28	Dharmavaram	533.7	300-500	2-5–10-20	Denudational hills, Pediplains	Shallow-Mod. deep	51,250	1282	High
30	Sankepalli	482.0	300-600	2-5–10-20	Denudational hills, Pediplains	Shallow-Mod. Deep	48,750	1236	High
32	Peruru	555.0	500-600	2-5	Pediplains, Alluvial fills	Mod. deep	16,875	1228	High
40	O.D.Cheruvu	592.0	500-700	2-5–10-20	Denudational hills, Pediplains	Shallow-Mod. deep	43,750	1295	High
42	K. Cherlopalli	585.6	400-700	2-5–10-20	Denudational hills, Alluvial fills	Very Shallow-Shallow	40,000	1242	High
44	Somandepalli	586.0	500-700	2-5	Pediplains, Alluvial fills	Shallow-Mod. deep	44,375	1202	High
Medium									
2	Kanekal	421.6	400-600	2-5	Pediplains	Shallow-Deep	62,500	1182	Medium
7	Vajrakarur	507.0	400-500	2-5–5-10	Pediplains, Alluvial fills	Shallow-Deep	28,750	1116	Medium
22	Kundurpi	477.0	500-600	2-5	Pediplains, Alluvial fills	Mod, deep	25,000	1106	Medium
25	Tadimarri	467.0	<300-400	2-5–5-10	Pediplains, Alluvial fills	Shallow-Mod. deep	58.750	1182	Medium
29	Maddileru	492.0	300-500	2-5–5-10	Alluvial fills, Pediplains	Very shallow-Shallow	33,125	1150	Medium
37	Kadiri	617.0	400-600	2-5–10-10	Denudational hills, Pediplains	Very Shallow-Mod. deep	37,500	1110	Medium
41	Gorantla	593.0	500-700	2-5–10-20	Denudational hills, Pediplains	Shallow-Mod. deep	48,750	1163	Medium
48	Rolla	523.0	600-760	2-5	Pediplains, Colluvial fills	Mod. deep	21,200	1118	Medium

Macro Watersheds No.	Name of the Watershed	Normal Rainfall (mm)	Mean Elevation (mts)	Average slope (%)	Major Landforms	Soil Depth in range	Area in ha	Sediment Yield Index (SYI)	Prioritization of Watershed
Low									
13	Putluru	461.0	<300	<2	Alluvial fills	Deep-Very deep	48,750	1050	Low
14	Narpala	473.0	<300-400	2-5	Alluvial fills	Deep-Very deep	47,500	1001	Low
15	Pamidi	498.0	<300-400	2-5	Alluvial fills	Deep-Very deep	30,625	1042	Low
16	Kotanka	500.0	300-400	5-10	Pediplains, Alluvial fills	Shallow-Moderate	46,250	1076	Low
31	C. K. Palli	535.0	400-600	5-10-10-20	Pediplains, Alluvial fills	Mod. deep	56,250	1068	Low
33	Peddannavari Palli	574.0	500-600	2-5–5-10	Alluvial fills, Pediplains	Shallow-Mod. deep	10,300	1003	Low
34	Talupula	574.0	400-600	2-5-5-10	Denudational hills, Alluvial fills	Shallow-Mod. deep	43,750	1006	Low
35	N.P.Kunta	592.0	400-600	2-5-5-10	Denudational hills, Alluvial fills	Shallow-Mod. deep	34,375	1037	Low
38	Nallacheruvu	570.0	500-700	2-5-10-10	Denudational hills, Pediplains	Very shallow-Shallow	28,125	1083	Low
39	Amadaguru	553.0	600-700	2-5	Denudational hills, Pediplains	Shallow-Mod. deep	19,375	1078	Low
46	Lepakshi	580.0	600-700	2-5	Alluvial & Colluvial fills	Mod. deep	35,000	1070	Low
47	Madakasira	599.0	600-760	2-5	Pediplains, Colluvial fills	Shallow-Mod. deep	28,128	1031	Low
Very Low									
4	Uravakonda	518.9	400-500	<2	Pediplains	Deep-Very deep	40,000	979	Very low
45	Parigi	582.0	600-700	2-5	Pediplains, Alluvial fills	Mod. Shallow-Deep	28,125	946	Very low
50	Hemavathi	600.0	600-700	2-5	Pediplains, Colluvial fills	Mod. Shallow-Deep	3,750	994	Very low

Conclusions

The study shows that the detailed visual interpretaiton of remotely sensed data coupled with collateral and selected field checks information can be effectively utilised for assessing the characteristics of physical resources at watershed level. Delineation and prioritization of macro watersheds using Flaxman model reveals that the watersheds having high to very high SYI are in association with dissected hills, denudational hills and dissected pediplains and mostly under sparse to very sparse canopy cover are covering nearly 56 per cent of the district. Where as the watersheds which are having very low SYI are associated with plain lands with level to moderate slopes and moderate to good canopy cover. The erosion susceptibility zone map in association with drainage, slopes, geology, geomorphology, soil depth, and rainfall characteristics at a macro watershed level is highly useful for user agencies to take up ameliorative measures for land and water resource planning and conservation. Watersheds having very high erosion susceptibility conditions need immediate soil and water conservation measures to restore geo-ecological balance of the district and obtain maximum productivity from available resources on sustainable basis.

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