SOIL RESOURCE APPRAISAL TOWARDS LAND USE PLANNING USING SATELLITE REMOTE SENSING AND GIS – A CASE STUDY IN MEDAK NALA WATERSHED IN NORTHERN KARNATAKA, INDIA

U. K. Shanwad

University of Agricultural Sciences,
Raichur, Karnataka State, India

V. C. Patil

Precision Agriculture Research Chair,
King Saud University,
Riyadh, Saudi Arabia

H. Honne Gowda and K. Ashoka Reddy

Karnataka State Remote Sensing Applications Center,
Bangalore, Karnataka State, India

ABSTRACT

In precision farming, knowledge of spatial variability in soil properties is important. The soil map shows soil series and phases like stoniness, gravelliness, salinity, sodicity, rockiness, surface crusting, soil erosion and wetness which limit the use of land for crop production. Soil resources inventory of Medak Nala watershed in Karnataka was conducted through visual interpretation of IRS IC/ID LISS III FCC in conjunction with geological and topographical information supported by limited field study and laboratory analytical data. Based on the visual interpretation and contour information from SOI (Survey of India) toposheets, a physiographic map was prepared; broadly seven physiographic units were identified. These were divided into 50 divisions based on tonal variations noticed in the imagery due to land use/ land cover, surface roughness, crop residues and tillage conditions. These physiographic units were merged and 26 soil mapping units were identified after detailed field study and laboratory analysis of the soil samples. Finally 20 soil series were identified and classified up to family level. Taxonomically soils were classified under Inceptisols, Alfisols, Vertisols and Entisols. Spatial distribution of soils under varied physiographic settings is mapped. Based on the morphological, physical and chemical properties of soils and related information, the soils have been classified into various land capability classes, which indicates the productive potentials and limitations. This information is very helpful in evaluation of the land and to suggest appropriate alternate land use practices.

Keywords: Remote sensing, GIS, Physiographic units, Soil mapping, Land use/ land cover

INTRODUCTION

The development of a watershed depends on its scientific resource action plans, their proper implementation and periodic monitoring. The management of rainfed agriculture and subsequent utilization of various natural resources, particularly land and water resources involves reliable and accurate database generation, integration of various terrain, topographic and environmental parameters to arrive at an alternate plan for decision making. The database on soil resources of Medak Nala watershed was generated using satellite imageries, toposheets, geology and other secondary data in GIS. Upon integration of resource themes along with collateral data, resource action plans for agriculture development were suggested.

MATERIAL AND METHODS

Study area

Medak Nala watershed was selected for the soil resources inventory study under Integrated Watershed Development Program (IWDP) is falls in northern Karnataka. The watershed area lies between $16^{0}52'$ to $17^{0}55'$ North latitude and $77^{0}22'$ to $77^{0}30'$ East longitude covering an area of 12,139 ha. The watershed comprises 18 villages. The average annual rainfall of Sedam taluk was 841.31 mm and that of Gulbarga district was 796.92 mm (Drought Monitoring Cell, Bangalore). Whereas, the average rainfall of the Medak Nala watershed was 610.10 mm, most of the rainfall is received during south-west monsoon period from June to October and October was peak rainfall month. Temperature is lowest during December and January with mean minimum of 16.77 ^{0}C and highest during April and May with mean maximum of 39.10 ^{0}C. The mean annual maximum and minimum temperature were 31.02 and 21.23 ^{0}C, respectively. The location map of the study area is shown in Fig. 1.

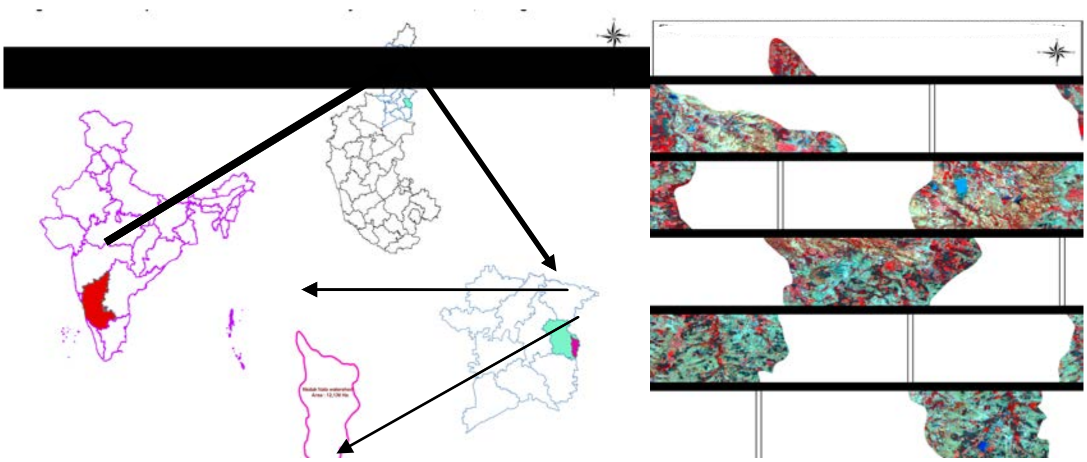


Figure 1: Location map of Medak Nala watershed

Figure 2: Satellite imagery of Medak Nala watershed

Database used

Satellite database

Indian remote sensing satellite imageries from IRS 1D for two seasons representing *rabi* (December 8 and 10, 2000) and summer (March 15, 2001) data were used for preparing the soil physiographic map by visual interpretation. For *rabi* season, LISS-III and PAN merged data (sharpened) was used to get the maximum possible information on various earth features on 1: 12,500 scale. Summer season data was basically the geo-coded LISS-III image as it was meant only for detecting any changes with respect to seasons. The satellite imagery of IRS 1D PAN + LISS III of Medak Nala watershed is shown in Fig. 2.

Secondary database

The Survey of India toposheets 56 G / 08 and 56 H / 05, which cover the Medak Nala watershed were used to prepare the base map, which is prior information to interpret the satellite imageries for soil physiographic units.

Ground truth database

The ground truth sites for the collection of the observational data required for the current study were selected from the watershed after conducting a preliminary survey of the study area. The ground truth sites of permanent features like settlements, road junction, road and rail interjection etc., were collected. A total of 45 ground truth sites were identified from the watershed. This will help traversing the study area and to identify the soil profile locations to be studied based on the physiographic map units generated from the interpretation of satellite imageries.

Methodology

The satellite images of different seasons were geometrically registered to the Survey of India topographic sheet (1:50,000) with a pixel size of 23.5 m using nearest neighborhood resampling with second order polynomial equation.

Soil resource inventory

A base map with permanent land features like roads, river and water bodies along with major drainage lines was prepared using SOI toposheets. Later landform analysis was made using a geology map. The base map was overlaid on IRS IC LISS III geocoded FCC. Based on the image characteristics and contour information, physiographic units such as hills and ridges, isolated hillock, mounds, rolling lands (10-15%), undulating lands (5-10%), gently sloping lands

(36-5%), very gently sloping lands (1-3%) and valleys (0-1%) were demarcated. The number of physiographic units and their frequency of occurrence were listed.

Rapid traversing of the entire toposheet area was undertaken in order to check the physiographic delineations and correction of physiographic units was done wherever necessary. Considering the geographic distribution and frequency of occurrence of physiographic unit in a toposheet area, transects were delineated in such a way that it should cut across at least three or more physiographic units. In such physiographic units, profiles were studied depending upon slope element or length of the slope in order to establish the relationship between physiography and soils. Based on profile characteristics such as depth, colour, texture, gravelliness, structure, soil reaction, etc., pedons were classified as per USDA Soil Taxonomy Classification (Anonymous, 1996). In this way, all the profiles (33 profiles) were studied, classified and grouped into different series depending upon the above said characteristics. For each physiographic unit, soil composition was worked out and the final composition so arrived at for a given physiographic unit was checked at random (outside transect area) for the accuracy of soil composition. Based on weighted average of different characteristics of all the profiles are grouped under different series.

Horizon wise soil samples were collected from all the master profiles of different series for laboratory analysis (pH, EC, OC, available N, available P, available K, CEC and base saturation) using standard procedures (Table 1). Based on the final soil composition, the soil map was finalized with a legend showing the classification up to association of series level. Methodology for the preparation of a soil map is given in Fig. 3.

Table 1: Methods followed for laboratory analysis of soil samples

Sl. No	**Physico-chemical properties**	**Method followed**
1	Particle size analysis	International pipette method (Piper, 1966)
2	Soil pH	Potentiometric method (Jackson, 1973)
3	Electrical Conductivity	Conductometry method (Jackson, 1973)
4	Organic Carbon	Walkely and Black's wet oxidation method (Jackson, 1973)
5	Cation Exchange Capacity	Sodium acetate method (Jackson, 1973)
6	Exchangeable Potassium and Sodium	Flame photometer method (Jackson, 1973)
7	Exachangeable Calcium and Magnesium	Versenate method (Jackson, 1973)
8	Available Nitrogen	Alkaline potassium permanganate method (Subbaiah and Asija, 1956)
9	Available Phosphorus	Olsen's method (Jackson, 1973)

10	Available Potassium	Ammonium acetate method (Muhr *et al*., 1965)

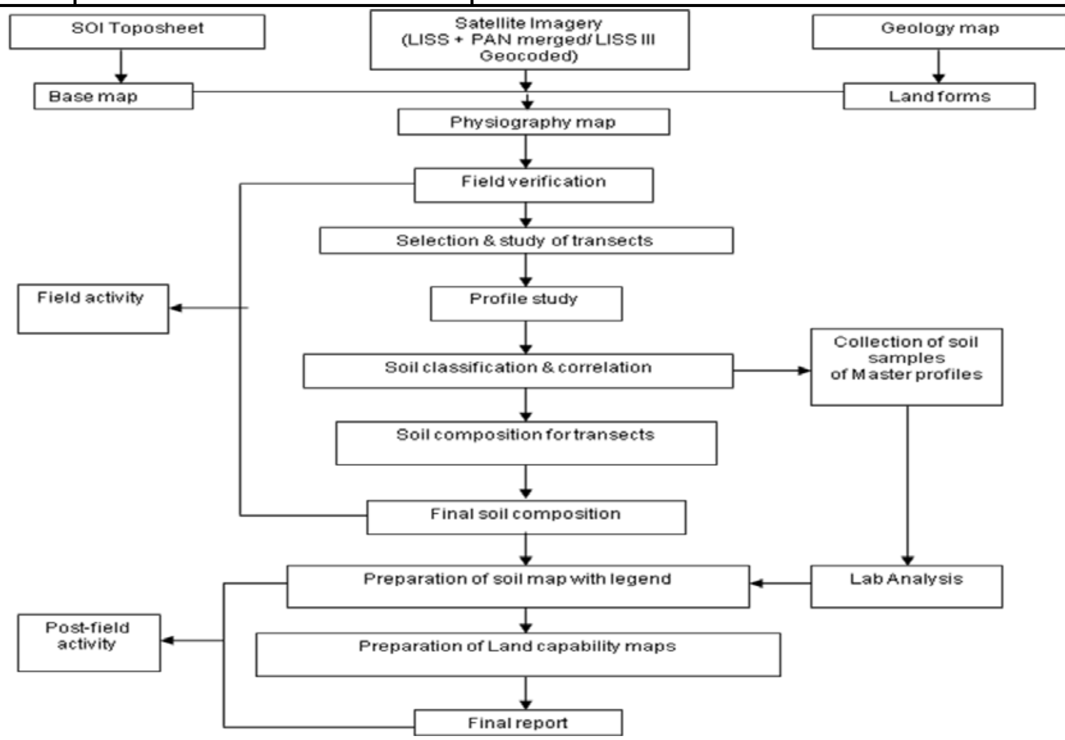


Figure 3: Methodology for preparation of soil map

Collection of soil samples

Totally one hundred and six soil samples at different depths (0-160 cm) from thirty-three soil profiles were collected in different landforms like basalt, granite, schist and laterite representing the entire watershed area of 12,139 ha.

Preparation of soil samples

The soil samples collected from different profiles were dried under shade and the bulk soil samples were passed through 2 mm sieve. The stones and large gravels that were more than 2 mm were discarded. The soil samples were stored in the polythene bags for analysis. A portion of samples were drawn from the 2 mm sieved soil and was ground in an agate mortar and then passed through 0.2 mm sieve (70 mesh). These samples were stored in butter paper bags for analysis of organic carbon and exchangeable cations. The results of the soil physical and chemical analysis are presented in Table 2 and 3.

Table 2: Physical properties of soils of Medak Nala watershed, Sedam taluk, Gulbarga district, Karnataka State, India

Sl. No.	Soil series	Horizon	Depth (cm)	Particle size distribution				Textural class
				Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	
1.	Tulmamdi	Ap	0 – 9	34.20	30.68	10.35	23.68	Sandy clay loam
		Cr	9 – 25+	30.24	30.02	12.42	25.99	Sandy clay loam
2.	Kanagadda	Ap	0 – 15	33.32	12.36	11.45	41.29	Sandy clay
		Bwk	15 – 37	21.18	10.72	14.56	52.34	Clay
		Ck	37 – 50+					
3.	Ropampalli	Ap	0 – 10	29.45	25.79	18.80	24.80	Sandy clay loam
		Bw	10 – 20	23.98	21.52	22.66	30.50	Sandy clay loam
		Ck	20 – 40+					
4.	Sakalatpalli	Ap	0 – 5	36.80	28.82	15.66	18.49	Sandy loam
		Bw	5 – 12	12.56	35.10	22.20	29.08	Sandy clay loam
		Ck	12 – 22+					
5.	Medak	Ap	0 - 10	34.72	12.15	10.49	42.28	Sandy clay
		Bw	10 - 32	14.28	20.02	12.10	51.94	Clay
		Ck	32 – 55+					
6.	Buragapalli	Ap	0 – 25	23.56	15.26	9.50	50.47	Clay
		BSS1	25 – 42	20.10	14.80	8.82	55.24	Clay
		BSS2	42 – 65	21.62	8.87	5.00	63.60	Clay
		Cr	65 – 88+					
7.	Itakal	Ap	0 – 10	22.72	18.70	21.62	36.32	Clay loam
		Cr	10 – 26+	22.10	22.61	23.50	30.03	Clay loam
8.	Gangaravalapalli	Ap	0 – 20	33.73	23.50	10.26	32.10	Sandy clay loam

Sl. No.	Soil series	Horizon	Depth (cm)	Particle size distribution				Textural class
				Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	
		BSS1	20 – 34	26.56	24.42	11.48	36.99	Sandy clay
		BSS2	34 – 60	21.44	18.48	16.33	42.40	Clay
		Cr	60 – 100+					
9.	Narapalli-I	Ap	0 – 30	34.62	16.75	13.54	34.31	Sandy clay loam
		Bt1	30 – 60	32.18	12.10	14.20	39.75	Clay loam
		Bt2	60 – 100	27.09	18.33	9.55	43.56	Clay
		Cr	100 – 160+					
10.	Narapalli-II	Ap	0 – 20	31.22	21.62	10.45	33.50	Sandy clay loam
		Bt	20 – 40	28.96	23.13	7.18	39.20	Sandy clay
		Cr	40 – 65+					
11.	Krishnapur	Ap	0 – 10	38.66	21.61	12.15	26.52	Sandy clay loam
		Bwk	10 – 20	34.90	23.50	9.25	31.14	Sandy clay loam
		Ck+	20 – 48	26.83	24.10	7.56	40.77	Sandy loam

12.	Chandapur	Ap Bw1 Bw2 Cr	0 - 15 15 – 23 23 – 42 42 – 80+	37.15 30.77 25.42	23.66 20.83 24.44	15.26 18.47 13.10	22.32 28.53 35.68	Sandy clay loam Sandy clay loam Sandy clay
13.	Yenkatapur	Ap Bw Cr	0 – 25 25 – 40 40 – 92+	46.44 34.18	23.89 25.62	10.25 10.84	18.49 27.56	Sandy loam Sandy clay loam
14.	Gadedonal	Ap A2 Bw1 Bw2	0 – 17 17 – 30 30 – 45 45 – 95+	33.21 28.37 14.76	24.53 19.12 20.41	7.48 10.02 9.81	33.10 41.76 53.87	Sandy clay loam Sandy clay Clay
15.	Malkapalli	Ap Bw1 Bw2 Cr	0 – 12 12 – 25 25 – 40 40 – 95+	43.79 44.10 36.05	17.40 11.50 14.25	6.93 7.50 6.25	30.69 35.55 41.68	Sandy clay loam Sandy clay Sandy clay
16.	Kankurti	Ap Bw1 Bw2 Cr	0 – 10 10 – 26 26 – 40 40 – 95+	45.75 38.92 21.22	11.77 12.95 19.43	8.16 6.28 10.02	33.10 41.76 48.50	Sandy clay loam Sandy clay Clay
17.	Gopanapalli	Ap Bw1 Bw2 Bw3 Cr	0 – 20 20 – 35 35 – 55 55 – 70 70 – 105+	33.81 17.96 31.52 14.08	18.10 22.78 16.19 24.20	12.25 14.15 8.50 13.12	34.80 44.71 43.11 46.96	Sandy clay loam Clay Clay Clay
18.	Silarkoturga	Ap Bw	0 – 15 15 – 32	61.23 56.44	15.44 9.90	7.93 14.52	14.56 18.19	Loamy sand Sandy loam
19.	Kadlapur	Ap	0 - 20	34.25	21.22	10.72	32.46	Sandy clay loam

		Bw Cr+	20 – 42 42 – 60	14.32	26.45	15.65	42.51	Clay
20.	Varapalli	Ap Bw1 Bw2 Cr+	0 – 10 10 – 22 22 – 35 35 - 43	43.78 23.55 25.69	17.13 22.40 20.36	9.28 18.60 12.18	28.37 34.63 40.43	Sandy clay laom Sandy clay loam Sandy clay

Table 3: Chemical properties of soils of Medak Nala watershed, Sedam taluk, Gulbarga district, Karnataka State, India

Sl. No.	**Soil series**	**Horizon**	**pH**	**EC (dSm^{-1})**	**Org. C (g/kg)**	**Available N (kg/ ha)**	**Available $P_2 o_5$ (kg/ha)**	**Available K_2o (kg/ha)**	**Exchangeable cations (C mol/kg)**				**CEC (C mol/ kg)**	**Base Saturation (%)**
									Ca	**Mg**	**Na**	**K**		
1	Tulmamdi	Ap	7.80	0.44	0.37	252	62	225	12.23	5.64	2.178	0.358	19.00	80.63
		Cr	7.85	0.38	0.20	226	53	204	15.54	6.52	3.251	0.259	24.50	87.38
2	Kanagadda	Ap	7.70	0.33	0.40	295	49	264	15.27	7.12	2.434	0.619	28.50	87.89
		Bwk	8.00	0.36	0.24	204	40	241	18.22	7.59	2.694	0.412	27.00	84.50
3	Ropampalli	Ap	7.75	0.28	0.32	215	42	210	16.16	6.24	2.520	0.363	25.60	85.46
		Bw	7.80	0.32	0.26	208	39	225	19.21	7.10	2.632	0.361	28.80	86.97
4	Sakalatpalli	Ap	6.96	0.21	0.35	291	40	196	11.25	4.75	0.430	0.516	16.80	83.01
		Bw	7.00	0.24	0.27	256	31	183	13.10	5.56	0.478	0.412	26.70	94.88

5	Medak	Ap	7.58	0.29	0.30	205	42	232	15.26	6.24	2.501	0.360	25.32	84.59
		Bw	7.90	0.36	0.24	200	36	208	18.22	6.35	2.960	0.365	27.75	85.92
6	Buragapalli	Ap	7.75	0.35	0.40	296	50	246	15.27	7.59	2.434	0.619	28.50	87.89
		BSS1	7.55	0.30	0.35	214	42	235	15.54	7.12	2.632	0.412	27.00	84.69
		BSS2	7.90	0.36	0.24	202	36	208	18.22	6.35	2.694	0.363	28.80	86.87
7	Itakal	Ap	7.60	0.34	0.37	264	57	178	14.92	6.46	2.125	0.525	27.46	85.92
		Cr	7.45	0.28	0.31	189	49	161	15.10	6.21	2.346	0.268	29.12	86.25
8	Gangaravalayali	Ap	7.80	0.32	0.40	296	48	245	15.27	7.59	2.434	0.617	28.50	87.50
		BSS1	7.95	0.34	0.35	220	42	231	18.22	7.12	2.632	0.415	27.00	84.23
		BSS2	8.00	0.36	0.24	212	35	205	17.65	6.35	2.695	0.362	28.80	86.85
9	Narapalli	Ap	6.10	0.15	0.32	312	30	204	16.10	5.96	0.260	0.728	20.50	88.14

		Bt1	6.25	0.08	0.42	302	32	198	12.24	5.24	0.235	0.516	25.00	86.76
		Bt2	6.75	0.12	0.40	205	28	172	18.17	6.58	0.219	0.980	28.80	89.89
10	Narapalli	Ap	6.35	0.10	0.47	298	36	215	17.52	6.34	0.281	0.464	26.90	87.17
		Bt	6.53	0.07	0.43	294	29	205	16.55	6.64	0.260	0.619	25.60	84.48
11	Krihsnapur	Ap	7.85	0.43	0.27	193	76	212	10.11	3.64	3.347	0.361	18.50	74.10
		Bwk	8.15	0.54	0.21	154	70	190	16.21	4.52	4.607	0.258	27.05	79.56
12	Chandapur	Ap	7.95	0.38	0.40	315	52	276	15.25	7.59	2.454	0.620	28.70	87.90
		Bw1	7.97	0.35	0.30	296	49	265	15.56	7.12	2.675	0.415	27.10	84.56
		Bw2	7.60	0.36	0.35	251	35	210	18.22	6.35	2.688	0.372	28.82	86.94
13	Yenkatapur	Ap	5.92	0.09	0.35	258	36	200	15.56	5.64	0.260	0.206	24.60	83.25
		Bw	6.20	0.11	0.23	240	30	186	20.89	5.52	0.347	0.258	29.40	87.09

14	Gadedosal	Ap	8.20	0.41	0.40	218	68	208	17.66	6.30	5.302	0.201	31.23	74.09
		A2	8.60	0.58	0.16	210	75	200	15.65	5.20	5.905	0.203	32.56	86.25
		Bw1	9.05	0.65	0.24	173	42	164	14.90	5.09	7.640	0.204	28.28	96.31
15	Malkapalli	Ap	6.72	0.08	0.35	245	35	214	6.52	4.99	0.175	0.258	10.15	87.81
		Bw1	6.60	0.06	0.27	215	38	207	10.23	5.64	0.178	0.154	19.00	80.63
		Bw2	6.65	0.15	0.19	159	25	156	15.54	6.52	0.251	0.159	24.54	87.38
16	Kankurti	Ap	7.65	0.32	0.41	302	52	326	13.40	6.92	2.635	0.624	27.72	85.46
		Bw1	7.85	0.33	0.30	282	42	314	15.26	7.12	2.580	0.418	25.61	86.92
		Bw2	7.70	0.35	0.32	214	40	256	18.22	6.35	2.694	0.365	28.52	87.13
17	Gopanapalli	Ap	6.72	0.21	0.45	286	49	284	9.15	4.65	2.154	0.592	25.75	86.12
		Bw1	7.80	0.27	0.41	210	46	278	12.24	5.32	2.432	0.617	27.26	84.56

		Bw2	7.75	0.30	0.36	195	35	225	16.95	6.56	2.640	0.415	28.81	85.92
		Bw3	7.90	0.25	0.29	136	28	156	18.17	5.92	2.695	0.366	29.10	86.02
18	Silarkotuga	Ap	7.20	0.26	0.42	292	52	244	11.10	6.76	2.096	0.566	23.75	81.46
		Bw	7.80	0.33	0.32	244	41	165	17.02	7.52	2.728	0.512	29.65	88.82
19	Kadlapur	Ap	7.75	0.37	0.44	296	55	226	15.45	7.35	2.562	0.626	28.15	87.19
		Bw	7.80	0.33	0.32	244	41	165	17.02	7.52	2.728	0.512	29.65	88.82
20	Varapalli	Ap	7.50	0.29	0.30	021	40	210	15.20	6.25	2.510	0.365	25.64	86.42
		Bw1	7.80	0.32	0.26	194	46	194	16.12	6.56	2.641	0.421	26.13	84.10
		Bw2	7.65	0.34	0.27	125	35	167	16.56	7.02	2.686	0.389	28.66	87.25

RESULTS AND DISCUSSION

The soils of Medak Nala watershed occur on basaltic and lateritic landform and are characterized by the physiographic units such as rolling lands (10-15 %), undulating lands (5-10 %), gently sloping lands (3-5 %), very gently sloping lands (1-3 %) and valleys (0-1 %). In Medak Nala watershed, 20 soil series were identified and classified up to family level. Rock formations noticed in the watershed may be grouped as basalt, laterite, schist, granite and sandstone conglomerate. Geological units and their extent identified in Medak Nala watershed is shown in Fig. 4. The Medak Nala watershed has been broadly classified into various geomorphic units, which have been evaluated for their ground water potential. Fig. 5 shows the spatial distribution of different hydro-geomorphic units delineated in the study area. The drainage network of Medak Nala watershed resembles a dendritic pattern. There are about 35 water bodies of various dimensions in the watershed of which, two are major, six medium and the rest are of small size water bodies. The distribution of the water bodies denotes that there is very good scope for runoff collection during the precipitation period. The drainage map of Medak Nala watershed is depicted in Fig. 6. Taxonomically soils were classified under inceptisols, alfisols, vertisols and entisols. Spatial distribution of soils under varied physiographic settings are mapped and shown in Fig. 7.

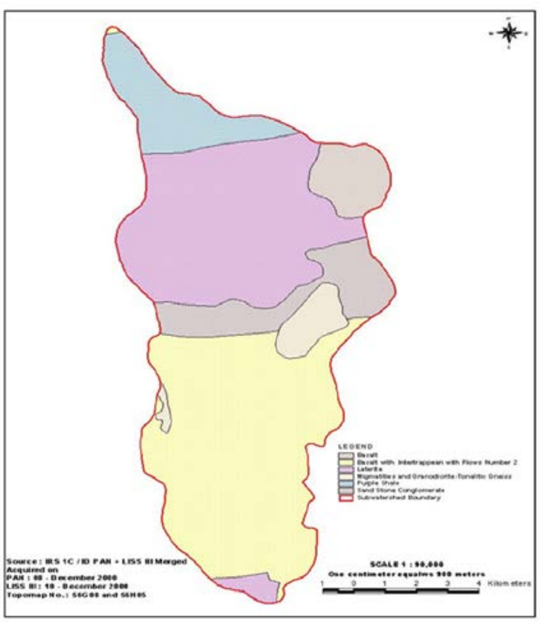


Figure 4: Geology map of Medak Nala watershed

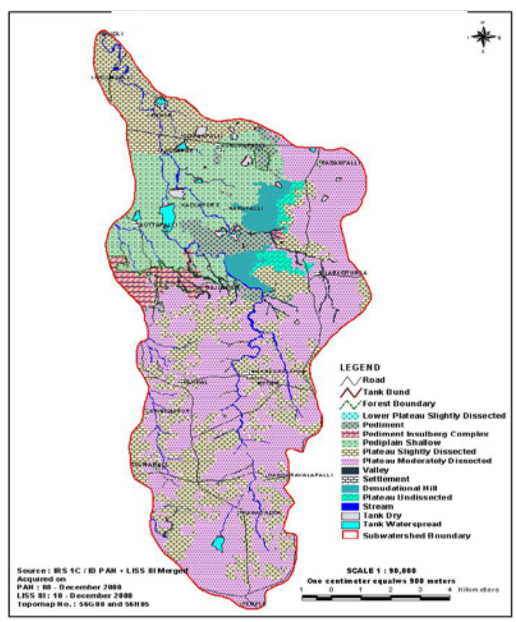
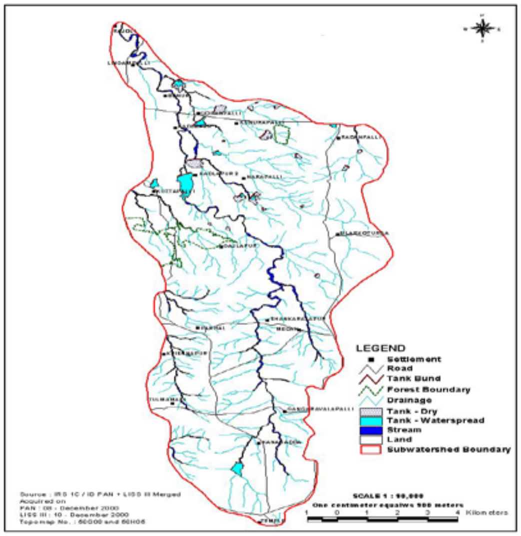


Figure 5: Hydro-geomorphology map of Medak Nala watershed



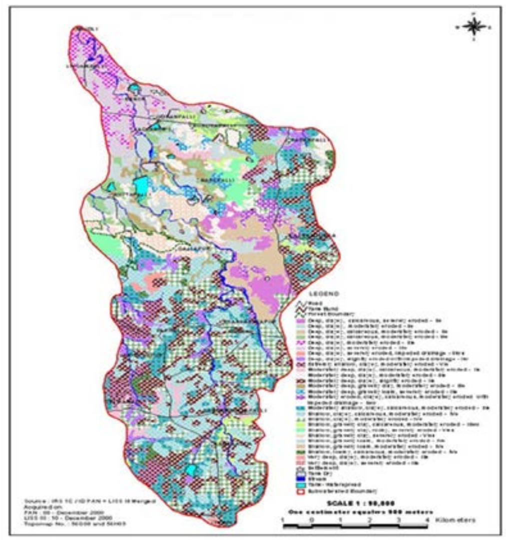


Figure 6: Drainage map of Medak Nala watershed

Figure 7: Soil map of Medak Nala watershed

Soil resources inventory was conducted through visual interpretation of IRS IC/ID LISS III FCC in conjunction with geological and topographical information supported by limited field study and laboratory analytical data. Based on the basic visual interpretation and contour information from toposheets. A physiography map was prepared; broadly seven physiographic units were identified. These were divided into 50 divisions based on tonal variations noticed in the imagery due to land use/ land cover, surface roughness, crop residues and tillage conditions. These physiographic units were merged and 26 soil mapping units were identified in the final map by generalization process after detailed field study and laboratory analysis of the soil samples. Based on physiographic soil relationship, soil profiles were excavated in a transect from ridge to valley. Similar to the study conducted by Prabhakar *et al*. (1996), Kanda Kumar *et al*. (1983) in Tamil Nadu and Prasad *et al*. (2001) in Andhra Pradesh. Thus the visual interpretation technique helps in minimizing reconnaissance survey for locating and plotting soil boundaries thereby reducing about 60 to 70 per cent of field work as compared to the conventional soil survey; Karale (1992) was also of the same opinion. In the traditional system, plotting of soil boundaries is directly related to the skills of the soil surveyor and the traversing plan, where as visual interpretation of satellite data provides accurate soil boundaries which reduces the time and cost involved in survey and mapping. The results showed that the satellite data in conjunction with limited field studies provided details of soil features that were not always recorded even in ground surveys through reconnaissance and semi-detailed intensities. Similar opinion was expressed by Karale *et al*. (1991) in Tamil Nadu.

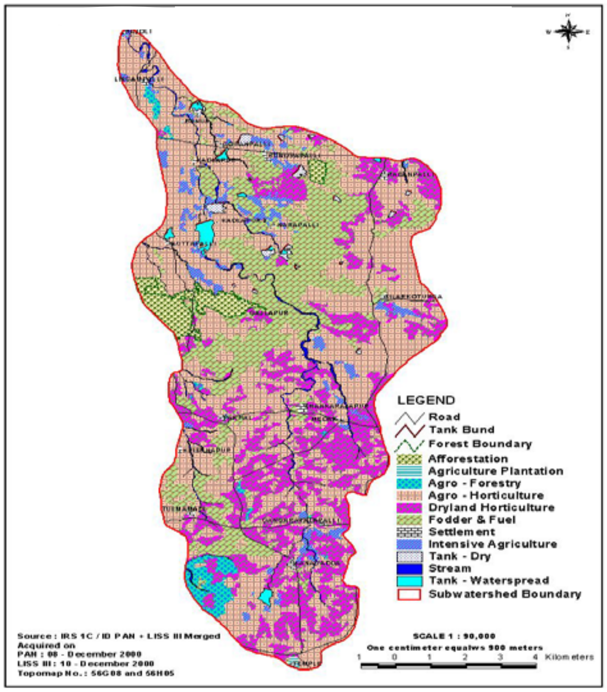


Figure 8: Alternate land use suggested for Medak Nala watershed

The physiographic units observed while delineating the satellite data have a sort of relationship with the soil formations, which was ascertained during the field visit, which confirms that the physiographic condition has a direct bearing on the soil formation of the terrain which is in tune with the studies of Goyal *et al.* (1988) in Haryana. The soils of Medak Nala watershed are black sandy loam to sandy clay loam and clay loam to clayey soils in the command areas of irrigation tanks. Taxonomically these soils belong to soil orders Vertisols, Alfisols, Entisols and Inceptisols. Similar observations were made in the study conducted by Labrandero and Palou (1978) in central Spain. The soils in general are free from salinity or alkalinity. The soil pH ranges from 5.90 to 7.80 in most areas, but pH of 7.50 to 8.60 is noticed in the narrow valleys of tank command areas reflecting the poor drainage conditions. The electrical conductivity varies from 0.06 to 0.65 dSm^{-1} indicating that these soils are normal. The CEC values vary from 16.80 to 31.23 C mol/kg of soil depending on the clay content.

Based on the study of soil profiles for its horizon wise physico-chemical properties along with field traversing, four land capability classes namely class II, III. IV and VI were assigned to different soil types identified in the study area (Table 4). These were divided into sub classes according to the main limitation for land use such as erosion and soil root zone limitation, as suggested by Klingabeil and Montgomery (1961). These land capability classes were used to suggest appropriate land use for a particular type of soil. Similar results were reported by Shanwal *et al.* (1988); Shivaprasad *et al.* (1990) and Sangwan *et al.* (1994).

Table 4: Soil series distribution of Medak Nala subwatershed, Sedam Taluk, Gulbarga District, Karnataka State, India

Sl. No.	Physiography	Soil series	Phases	Description	LCC	Classification	Area (ha)	Per cent of total area
Soils of Basalt land form								
1	Rolling Land B 1.1	Manikyagiri	e_3	Very deep, excessively drained, dark red sandy clay surface soil followed by red to dark red clayey sub soil with argillic horizon, occurring along moderately slopping land and mounds, slopes ranging from 8-30% developed on basalt, severely eroded.	III e	Fine, Typic Haplustepts	21.47	0.18
2	Rolling Land B 1.2 B 1.3	Manikyagiri	e_2	Very deep, excessively drained, dark red sandy clay surface soil followed by red to dark red clayey sub soil with argillic horizon, occurring along moderately slopping lands and mounds, slopes ranging from 8-30% developed on basalt, moderate erosion.	III e	Fine, Typic Haplustepts	60.76	0.52
3	Undulating to gently sloping lands B 2.1 B 3.2	Tulamamdi	e_2	Extremely shallow, well drained, yellowish brown, sandy clay loam soil with slight effervescence, underlined by soft basalt, occurring along undulating to gently sloping land with slopes of 3 – 8%, moderately eroded.	VI e	Clayey, Paralithic Ustorthent.	410.56	3.51

4	Undulating to gently sloping lands B 2.2 B 3.1	Ropampalli	e_2	Shallow, well drained very dark grayish brown, sandy clay loam surface soil followed by very dark pale brown to yellowish brown sandy clay loam calcareous soil with cambic horizon developed on basalt, occurring on undulating to gently sloping land moderately eroded.	IV e	Fine Loamy, Typic Haplustepts	115.92	0.99
5	Very Gently to Gently sloping uplands B 3.3 B 3.4 B 4.5	Kanagadda	e_2	Shallow, well drained, very dark grayish brown to pale brown, clay to sandy clay surface soil followed by dark gray to very dark gray, calcareous clayey subsoil with cambic horizon developed on basalts, occurring along gently to very gently sloping upland with slopes of 1 – 5 %. Moderately eroded.	IV e	Fine Loamy, Typic Haplustepts	1533.17	13.11
6	Very Gently sloping up lands B 4.1	Medak	e_2	Moderately shallow, well drained, dark brown, sandy clay surface soil followed by very dark grayish brown to pale brown, cracking clayey calcareous subsoil developed on basalts, occurring along very gently sloping uplands. Moderately eroded.	III e	Fine, Calcareous, Vertic Haplustepts	1096.58	9.37
7	Very Gently sloping lands B 4.2	Buragapalli	e_1	Moderately deep, well drained very dark grayish brown clayey soil with cracking sub surface and pressure faces and intersecting slicken slides developed on basalts occurring along very gently, slopping uplands. Slightly eroded.	II e	Fine, Typic Haplusterts	1510.11	12.91

8	Very Gently sloping & Valley B 4.3	Itakal	e_2	Extremely shallow, well drained. Yellowish brown sandy clay surface followed by very dark grayish brown calcareous clayey cracking sub soil, occurring along very gently sloping uplands slopes of 1-3% developed from basalts. Moderately eroded.	II e	Fine,Calcareous, Vertic Haplustepts.	218.59	1.87
9	Very Gently sloping & Valley B 4.4 B 4.5	Gangaravalapalli	ew	Deep soils, moderately well drained, very dark grayish brown, clayey surface followed by very dark gray to very dark grayish brown, clay sub soil with slicken slides intersecting developed on basalt occurring along nearly level to very gently sloping lands, slightly eroded.	II w	Fine Typic Haplusterts	353.38	3.02
10	Very gently sloping land B 4.6	Sakalatapalli	e_2	Shallow, well drained, yellowish brown sandy clay loam surface followed by brown to yellowish brown sandy clay sub surface with cambic horizon, developed from basalts occurring along very gently sloping lands, moderately eroded.	IV e	Clayey, Typic Haplustepts	1480.89	12.66
Soils of Granite land form								
11	Rolling Land G 1.1	Narapalli	e_3 Rg_2	Soils of moderately deep, well to excessively drained dark reddish brown sandy clay surface 60% gravel followed by red sandy clay sub surface with argillic horizon, 65% gravel underlined by soft weathered granite occurring along rolling lands with 10-15 % slopes. Rocky surface severely eroded.	VI es	Clayey skeletal Typic Haplustalfs	233.03	1.99

12	Undulating Lands G 2.1 G 2.3	Narapalli	e_2 g_2	Soils of moderately deep, well to excessively drained dark reddish brown sandy clay surface 60% gravel followed by red sandy clay sub surface argillic horizon 65% gravel underlined by soft weathered granite occurring on undulating lands with slopes of 5-10 %, surface rock absent.	VI es	Clayey skeletal Typic Haplustalfs	352.69	3.02
13	Gently sloping lands G 3.1	Yenkatapur	e_2	Moderately deep, well drained, dark brown loamy sand surface followed by dark brown to dark reddish brown, sandy to clay sub soil with cambic horizon, developed on granites, occurring along gently sloping lands, moderately eroded.	III e	Fine Typic Haplustepts	654.78	5.60
14	Gently sloping lands G 3.3 G 3.5	Malkapalli	g_2 e_3	Moderately deep, dark yellowish brown, gravelly loamy sand surface with 40% gravel followed by brown to strong brown sandy loam to sandy clay loam sub soil with cambic horizon, occurring along gently sloping land, severely eroded.	III e	Fine, Typic Haplustepts	191.43	1.64
15	Very Gently sloping lands G 4.1 G 4.2 G 4.5 G 4.7	Gadedonal	e_2	Deep, yellowish brown, sandy clay loam surface followed by stratified layers of yellowish brown loamy sand and very dark grayish brown calcareous clayey sub soil with cambic horizon, occurring along very gently sloping lands, moderately eroded.	III e	Fine, Calcareous Typic Haplustepts	446.29	3.82

16	Very Gently sloping lands G 4.3 G 4.4 G 4.6 G 4.8	Kankurti	e_2	Deep, moderately well drained, dark grayish brown sandy clay surface followed by olive brown to grayish brown clayey sub soil with cambic horizon developed on granite, occurring very gently sloping land, moderately eroded.	II e	Fine, Typic Haplustepts	625.93	5.35
17	Valley G 5.1	Krishnapur	e_2 w	Shallow, moderately well drained, very dark grayish brown clay surface followed by very dark grayish brown to grayish brown calcareous gravelly clay sub surface, occurring along valleys, nearly level land, moderately eroded.	III ew	Clayey, calcareous, Typic Haplustepts	170.79	1.46
18	Valley G 5.2	Chandapur	e_2	Shallow, well drained, dark brown sandy clay loam surface followed by dark brown to reddish brown clay to gravelly clay sub soil with cambic horizon, developed on alluvium from granite, occurring along nearly level valley, moderately eroded.	III e	Fine, Typic Haplustepts.	300.33	2.57
Soils of Schist parent material								
19	Very gently Sloping lands S 1.1 S 1.2 S 1.3	Gopanapalli	e_2	Moderately shallow, well drained, very dark grayish brown clayey surface followed by very dark grayish brown to very dark gray clayey sub soil, developed on weathered schist, occurring along very gently sloping land, moderately eroded.	III e	Fine, Typic Haplustepts.	308.74	2.64

20	Very gently sloping land S 1.4 S 1.5 S 1.6 S 1.7 S 1.8	Gopanapalli	e_3	Moderately shallow, well drained very dark grayish brown clayey surface followed by very dark grayish brown very dark gray clayey sub soil, developed on weathered schist, occurring along very gently sloping land, severely eroded, rarely calcareous sub surface.	III e	Fine, Typic Haplustepts.	566.88	4.85
21	Valley S 2.1	Gopanapalli	e_1	Moderately shallow, well drained very dark grayish brown clayey surface followed by very dark grayish brown very dark gray clayey sub soil, developed on weathered schist, occurring along very gently sloping land, severely eroded, rarely calcareous sub surface and drainage Impedance.	III ws	Fine Typic Haplustepts.	58.55	0.50
Soils of Laterite land scape								
22	Undulating Land L 1.1 L 1.2 L 1.3	Silarkoturga	e_2 g_2 e_2	Shallow, well drained, dark yellowish brown, sandy clay loam surface followed by dark grayish brown sub surface with cambic horizon, developed on laterites, occurring along undulating lands with stones of 5 – 10%, >35% surface gravel, moderately eroded.	IV e	Loamy, Typic Haplustepts	56.26	0.48
23	Gently sloping lands L 2.1 L 2.2	Silarkoturga	e_2	Shallow, well drained, dark yellowish brown, sandy clay loam surface followed by dark grayish brown sub surface with cambic horizon, developed on laterites, occurring along undulating lands with stones 5 – 10%, >35% surface gravel, moderately eroded.	VI e	Loamy, Typic Haplustepts	157.60	1.35

24	Very Gently sloping lands L 3.1 L 3.2	Varapalli	e_2	Shallow, well drained, strong brown, sandy clay surface soil followed by very dark grayish brown to very dark gray calcareous clayey sub soil with cambic horizon, developed on alluvium of laterites, occurring along gently sloping lands moderately eroded.	II e	Fine,Calcareous, Typic Haplustepts	310.94	2.65
25	Very Gently sloping lands L 3.3 L 3.4 L 3.5	Varapalli	e_3	Deep well drained, strong brown sandy clay surface on followed by very dark grayish brown to very dark gray calcareous clayey sub soil with cambic horizon, developed on alluvium of laterites, occurring along gently sloping lands, severely eroded,	II e	Fine,Calcareous, Typic Haplustepts	302.25	2.58
26	Valley L 4.1	Kadlapur	e_2	Moderately shallow, moderately well drained dark brown clay surface soil followed by dark grayish, developed on alluvium laterite, sub soil occurring along valley. Moderately eroded.	II ew	Fine,Calcareous, Typic Haplustepts	159.36	1.36

CONCLUSION

Remote sensing has grown as a potential alternate source for natural resources database generation and their management within the shortest time. The synoptic view and its repetitive coverage helps in inventory of natural resources and generating reliable and accurate database quickly when compared to the conventional systems. The information that is generated upon integration with the attribute data in a Geographic Information System provides information on composite resource units. The resource unit shows information about soil, its potential, constraints, ground water potential and topography, which acts as a guide in suggesting soil and water conservation measures and alternate land use practices which are technically feasible, economically viable and socially acceptable.

REFERENCES

Anonymous, 1996, Integrated Mission for Sustainable Development, Satellite Remote Sensing, Bulletin, DOS, Bangalore, p. 160.

Goyal, V.P., Kuhad, M.S. and Sangwan, P.S., 1999, Utilisation of Remote Sensing data for soil characterization and preparation of geomorphic-soil maps of Rewari district of Haryana, Proceedings of ISRS National Symposium, January 19-21, 1999, Bangalore, pp. 140-144.

Jackson, M.L., 1973, Soil Chemical Analysis, Prentice Hall of India Private Ltd., New Delhi, p. 278.

Kanda Kumar, M., Manchanda, M.C. and Iyer, H.S., 1983, Use of Landsat imagery for soil survey using multistage approach. Proceedings of 4th Asian Conference Remote Sensing, Nov. 10-15, 1983, Colombo, p. 4.

Karale, R.L., 1992, Remote sensing with IRS – IA in soil studies: Development, status and prospects. Natural Resources Management – a New Perspective, NNRMS, DOS, Bangalore, pp. 128-144.

Karale, R.L., Venkataratnam, L., Sehgal, J.L. and Sinha, A.K., 1991, Soil mapping with IRS-1A data in areas of complex soil-scapes. Current Science, 10 (3&4): 198.

Kilngebeil and Montgomery, 1961, Land capability classification, US, Department of Agriculture, USA, p. 1682.

Labrandero, J.L. and Palou, F., 1978, Soil inventory in central Spain by digital analysis of Landsat data. Proceedings of International Symposium on Remote Sensing for Observation and Inventory of Earth Resources and the Endangered Environment, July 2-8, 1978, Germany, p. 2309.

Murthy, K.S.R., Amminedu, E and Venkateswara RAO, V., 2003, Integration of thematic maps through GIS for identification of groundwater potential zones. Journal of Indian Society of Remote Sensing, 31(3): 197-210.

Piper, C.S., 1966, Soil and Plant Analysis, Hans Publishers, Bombay, p. 362.

Prabhakar, K.S., Ramesh, K.S., Lingaraju, Y. and Hegde, V.S., 1996, Characterisation of Watershed using IRS data – a case study covering Hesaraghatta catchment. Proceedings of Workshop on Application of Remote Sensing Techniques in the Field of Agriculture and Rural Development, February 12-13, 1996, Dharwad, pp. 275-282.

Prasad, P.R.K., Anitha, G., Rajendra Prasad, B. and Raghu Babu, M., 2001, Survey and Mapping of salt affected soils and waterlogged areas using remote sensing techniques in parts of Krishna western delta, Prakasam district of Andhra Pradesh. Proceedings of ICORG-2000, Vol. II, 2-5th Feb. 2001, Hyderabad, pp. 374-382.

Sangwan, B. S., Attar Sing and Goyal, V. P., 1994, Application of remote sensing technique for land use planning in southern part of Rohtak district, Haryana. Proceedings of the 15th Asian Conference on Remote Sensing, November 17-23, 1994, Bangalore, p. H-2.

Shanwal, A. V., Kuhad, M. S., Jain, A. K. and Karwasra, S. P. S., 1988, The sue of arial photo interpretation for land evaluation in the Yamuna Alluvial plains (Sonepat) Haryana. Proceedings of National Symposium on Remote Sensing in Rural Development, November 17-19, 1988, Hissar, pp. 269-281.

Shivaprasad, C. R., Thayalan, S., Reddy, R. S. and Reddy, P. S. A., 1990, Use of land sat imagery for mapping soil and land resources for developmental planning in parts of Northern Karnataka. International Journal of Remote Sensing, 11 (10): 1889-1900.