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Soil resource assessment of watershed towards land use planning using satellite remote sensing and GIS techniques in Northern Karnataka, India

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Abstract
Soil resources inventory of Chikmegeri-3 micro watershed of Koppal district in Karnataka was conducted using remote sensing and GIS techniques using LISS IV satellite data. After detailed field study and laboratory analysis of collected soil samples Twenty one soil mapping units were identified and classified up to family level as per “Keys to Soil Taxonomy” (Soil Survey Staff, 2014). Three mapping units belonged to the land capability class III and eighteen mapping units belonged class IV. Taxonomically soils were classified under Inceptisols, Alfisols, Vertisols and Entisols. Soils were low in available nitrogen and organic carbon, medium in phosphorus, medium to high in available potassium, low to medium in available sulphur, micronutrients iron, copper and manganese were sufficient while, zinc was deficient.

Keywords: GIS, micro-watershed, Remote sensing, Soil resources

Introduction
Soil is a vital natural resource and its proper use decides the life supporting system of a country and the socio-economic development of its people. Soils provide food, fodder and fuel for meeting the basic needs of human beings and animals. With the growth of population, demand for food production is on the increase. However, the capacity of the soil to produce is limited. The production is limited mainly by intrinsic soil characteristics, agro-ecological settings and its management. It is very important for developing an effective land use system for augmenting agricultural production on a sustainable basis. Soil characterization is basically an inference process based on model (Jenny, 1941) [6]. A detailed characterization of land resources assessing its potential and constraints becomes a pre-requisite for planning.
Recent advances in science have led to development of techniques capable of rapidly and effectively mapping out areas under threat of degradation. These techniques include remote sensing (RS) and geographical information systems (GIS). Space borne remote sensing can effectively fulfill this role as it is proven tool for fast and accurate appraisal of natural resources (Annon, 2007) [1]. The opportunities offered by the above advances can be used to map out patterns of land degradation at various (1: 7920 m) scales relatively faster and with reasonably low cost. 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 Chikmegeri-3 micro- watershed was generated using satellite imageries, toposheets, geology and other secondary data in GIS.

Material and Methods
The study areas comprised of Chikmegeri-3 micro-watershed belongs to Bedwatti sub-watershed (4D4A1F1d) located in yelburga taluk of Koppal district, Karnataka. It lies 30 km away from Koppal district headquarter. The study area belongs to “Northern dry zone” (Zone 3), which receives lowest rainfall among all the dry zones of Karnataka. The selected Chikmegeri-3 micro-watershed is located between 15° 35' 50.69″ and 15° 33' 52.19″ N latitude, 76° 06' 23.08″ and 76° 05' 36.78″ E longitude. The climate of the district as a whole is semi-arid type characterized by hot summer and low rainfall.

The hot summer starts from middle of February to end of May. The climate is cool and pleasant during major part of the year except during the summer months of March to middle of June. The minimum temperatures during winter (December to January) reach up to 16 °C and maximum reaches up to 45 °C during hot summer. The district is characterized by dryness for the major part of the year because of less rainfall.

The average elevation of this area is 671 m above mean sea level. The relief is normally nearly level to very gently sloping. The general slope of the area is towards northeast and west. The drainage pattern is dendritic. The area falls in the Tugabhadra sub-basin of the Krishna basin. The Tungabhadra river has a large number of rivulets and streams serving as tributaries. The main streams draining the area are Maskinala, Ilkal-nadi and Hirenala which are ephemeral in nature with dendritic to sub dendritic drainage pattern (Anon., 2011b) [2]. The annual normal rain fall is 571.92 mm. Normally, rain commences in June and continues up to November and heavy rainfall during the months of September and October contributed by the south west monsoon forms 65 per cent of the annual rainfall. The availability of moisture is the limiting factor for crop production. The length of growing period (LGP) is <90 days (Ramamurthy *et al*., 2009) [16] which in turn influenced by soil type; red or black.

The major agricultural crops grown in the study area includes sorghum, pearlmillet, maize, horsegram, cowpea, groundnut, cotton and sunflower etc. Tree species like *Prosopis juliflora*, *Acacia ferugenia*. Acasia (*Acasia auriculiformis*) and Neem (*Azadiracta indica*) are predominantly found in the study area. The location of micro-watersheds is shown in Fig. 1

Source of data

Satellite Database: For delineation and mapping Indian remote sensing satellite imageries from IRS P6 LISS-IV image of 2010 acquired from the Karnataka State Remote Sensing Application Centre (KSRSAC) of Karnataka was used (Fig. 1a). The data were used for preparing the soil physiographic map by visual interpretation and to get the maximum possible information on various earth features on 1: 7920m scale. Base map of Chikmegeri-3 micro-watershed was prepared using toposheet and cadastral maps. Methodology for preparation of Soil Map shown in Fig. 2.

Soil survey and site characterization

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. Based on the permanent land features like roads, river and water bodies along with major drainage lines were demarcated using SOI toposheets. Rapid traversing of the entire micro watershed area by considering the geographic distribution and frequency of occurrence of physiographic unit, transects were delineated. For non-transact areas of a given physiographic unit was checked at random for the accuracy of soil composition. 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.

Soil sampling Grid sampling was done in the study area from the fixed sampling points using hand held GPS by imposing grids of 10″ (250 m) interval in the micro-watershed. A total of 105 surface samples were collected from the fixed grid points. The processed soil samples were analyzed for nutrient availability by following Standard analytical techniques, Available nitrogen was determined by alkaline potassium permanganate method as described by Sahrawat and Burford (1982) [24]. Available phosphorus was determined by Olsen's method as described by Jackson (1967) [25]. Available potassium was extracted with neutral normal ammonium acetate (pH 7.0) and estimated by Flame Photometer (Jackson, 1967) [25]. Fertility status of N, P, K and K were interpreted as low, medium and high by following the criteria Micronutrients like Zinc, iron, manganese and copper were extracted using DTPA extractant as explained by Lindsay and Norvell (1978) [26]. The concentration of zinc, copper, iron and manganese in the extract was determined using atomic absorption spectrophotometer (AAS).

Morphological description of pedons

After intensive traversing, depending upon soil heterogeneity and slope, pedon locations were selected in the micro-watershed. Freshly dug pedons were studied for their morphological features in the field and horizon-wise samples were collected and analyzed for physico-chemical parameters. Morphological characteristics of each horizon like texture, colour, structure, consistency under dry and wet conditions along with depth, root distribution, coarse fragments, slickenside, quantity of conca and conir, etc. were studied. The morphological properties were described and horizons were identified and designated according to revised Keys to Soil Taxonomy (Soil Survey Staff, 2014) [9].

Results and Discussion

The geology of the Chikmegeri-3 micro watershed is comprised of predominant in basalt and gneissic terrain while, red soil in granites and grey granite area. Horizon differentiation in red soil pedons was relatively easy compared to that of black soil pedons, because of argillic pedoturbation in black soil pedons. Horizons were identified in red soil pedons based on colour, texture, abundance of coarse fragments and presence or absence of clay skins on ped surfaces. In black soil pedons horizon differentiation was based on the prominence, abundance and interaction of slickensides. Based on this, three to four horizons were identified namely; self-mulching surface horizon, horizons with pressure faces/slickensides, presenace of calcium carbonate. The black soil pedons were deep compared to red soil pedons. Similar observations were also made by Vinay (2007) [22] in Bhanapur micro-watershed of Koppal district, Karnataka.

The soils were shallow to deep in red soil areas while moderately deep to deep in areas dominated by black soils (Table 1). The variation of depth in relation to physiography, is mainly because of non-availability of adequate amount of moisture for prolonged period on upland soils associated with removal of finer particles and their deposition at lower pediplain have resulted in shallow soils in uplands and deeper soils in lowland physiographic units. The results obtained in the present study are in agreement with the findings of Ramprakash and Seshagiri Rao (2002) [14, 17] in this regard.

The colour of red soils varied from dark reddish brown (2.5 YR) to dark brown 7.5 YR 3/4. In case of black soil pedons, it varied from very dark brown (10 YR 5/3) to very dark gray (10 YR 4/2). The soil texture varied from sandy clay (red soil pedons) to clay (black soil pedons). Generally, the clay content increased with depth. The argillic horizon was observed in pedons 1, 2, 6, 8, 9, 12, 13 and 16. The slickensides were prominently seen in black soil pedon 10. The dark matrix colour of surface horizon was due to presence of high organic matter content (Tripathi *et al*., 2006) [21]. Whereas, the sub-surface horizons had comparatively brighter colour throughout the profile, which might be due to low organic matter content and higher iron oxide. Similar observation was made by Pulakeshi *et al*. (2014).

The red soil pedons, soils were sandy clay loam to sandy clay in texture and clay to sandy clay in case of black soil pedons This variation in texture was mainly because of difference in deposition of finer fractions (Arun Kumar *et al*., 2002) [3]. Clay loam texture of pedons, might be due to lesser mobilization and translocation of finer fractions. According to Nayak *et al*. (2002) [9] texture variation is mainly due to differences in physiography. Similar texture was reported by Yurembam, 2015 in Someshwar watershed of Uttarakhand. The morphogenetic expression of most of the black soils showed considerable homogeneity. However, prominent slickensides were observed in subsurface horizons. These findings were in conformity with the observations of Dasog and Patil (2011) [11].

The fertility status of the study area reveled that generally, the soils were low in available nitrogen and organic carbon, low to medium in available phosphorus, medium to high in available potassium, low to medium in available sulphur (Table 2). Among the micronutrients estimated, iron, copper and manganese were sufficient while, zinc was deficient in the study area. Soils of semi arid type of climate with high temperature prevailing in the area resulted in low to medium organic carbon status (Patil *et al*., 2011 and Kebede and Solomon, 2011) [11, 7]. The variation in N content might be related to soil management; application of FYM and fertilizer to previous crop etc. (Ashok, 2000) [4]. The variation in soil properties like clay content, CEC and P fixation capacity, In addition to this it was observed that the farmers are using only DAP as a source of nutrients in adequate quantity. Similarly, Dasog and Patil. (2011) [11] reported that soils of the soils of north Karnataka (Zone 3) were medium in available phosphorus status. The higher Potassium content might be due to the predominance of potash rich micaceous and feldspars minerals in parent rocks Dasog and Patil, 2011 [11]. Cultivation of high yielding crops, use of high analysis fertilizers and intensive cultivation are depleting available macro and micro nutrients from soils, putting at risk the soil health.

Based on morphological, physical and chemical properties of soils, soils were classified up to family level as per "Keys to Soil Taxonomy" (Soil Survey Staff, 2014) [19]. The black soil pedons were classified as Very fine, smectitic, isohyperthermic, super active, clay, Typic Haplusterts. The red soil pedons were classified as 1) Fine, mixed, isohyperthermic, active, sandy clay, Typic Rodustalfs, 2) Loamy-skeletal, mixed, isohyperthermic, super active, sandy clay loam, Typic Haplustepts, 3) Fine, mixed, isohyperthermic, super active, sandy clay, Typic Haplustepts, 4) Loamy-skeletal, smectitic, isohyperthermic, super active, sandy clay loam, Typic Rodustalfs, 5) Fine, mixed, isohyperthermic, super-active, sandy clay, Typic Haplustalfs, 6) Loamy-skeletal, mixed, isohyperthermic, super-active, sandy clay loam, Typic Haplustalfs, 7) Loamy-skeletal, mixed, isohyperthermic, super-active, sandy clay loam, Typic Rodustalfs, 8) Loamy-skeletal, mixed, isohyperthermic, super-active, sandy clay loam, Fluventic Haplustepts, 9) Loamy-skeletal, mixed, isohyperthermic, super-active, sandy loam, Fluventic Haplustepts and 10) Clayey, smectitic, isohyperthermic, super-active, sandy clay, Lithic Ustorthents. Based on soil texture, depth, slope and erosion, twenty one soil series were mapped (Table 1).

The 21 mapping units were grouped under two land capability classes with four sub classes. Three mapping units belonged to the land capability class III with three sub classes viz; IIItsf, IIItwsf and IIIts (Fig.3). Eighteen mapping units belonged to the land capability class IV with two sub classes viz; IVsf and IVts. These soils had slight to severe limitations of texture, coarse fragments, subsurface coarse fragments, soil depth, drainage, cation exchange capacity, base saturation and organic carbon.

Similar, attempts were made to classify soils of North Karnataka, of course in different areas viz., Rudramurthy and Dasog (2001) [5] in red and black soil areas, in Malaprabha Right Bank Command, in Raichur, Sumithra *et al*. (2012) [20] in Timanhal micro-watershed and Madhu *et al*. (2012) [8] in Patapur micro-watershed, in Matangi village. The soils belonged to Alfisols, Inceptisols, Entisols and Vertisols.

Table 1: Soil Phases Distribution of Chikmegeri-3 micro-watershed

Si No.	Soil Phase	Physiography	Classification (upto family level)	LCC	Description
1	CHK1-sc-d4/Ae1	Upland	Fine, mixed, active, Isohyperthermic, Typic Rhodustalfs	IVsf	Very deep, reddish brown to dark reddish brown colour sandy clay texture with sub soil argillic horizon and moderately well drained.
2	CHK2-sc-d2/Ae1	Mid land	Fine, mixed, super-active, Isohyperthermic, Typic Rhodustalfs	IVsf	Very deep, reddish brown to dark reddish brown colour sandy loam to sandy clay texture with sub soil argillic horizon and moderately well drained.
3	CHK3-scl-d3/Ae1	Side slope midland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Haplustepts	IVsf	Very deep, reddish brown to yellowish red colour sandy clay loam to sandy clay subsoil texture and moderately drained.
4	CHK4-sc-d4/Ae1	Upland	Fine, mixed, super-active, Isohyperthermic, Typic Haplustepts	IVsf	Very deep, light brown to brown colour, sandy clay to clay subsoil texture and moderately well drained.
5	CHK5-sc-d4/Be2	Side slope midland	Fine, mixed, super-active, Isohyperthermic, Typic Haplustepts	IVsf	Very deep, dark reddish brown to red colour, loamy sand to sandy clay texture and moderately well drained.
6	CHK6-scl-d5/Ae1	Midland	Loamy-skeletal, smectitic, super-active, Isohyperthermic, Typic Rhodustalfs	IVsf	Very deep, dark reddish brown to red colour sandy loam to sandy clay loam texture with sub soil argillic horizon and moderately drained.
7	CHK7-sc-d4/Ae1	Side slope	Fine, mixed, super-active, Isohyperthermic, Typic Haplustepts	IVsf	Very deep, dark reddish brown to dark brown colour sandy clay subsoil texture and moderately well drained.
8	CHK8-sc-	Midland	Fine, mixed, super-active,	IVsf	Very deep, dark reddish brown to reddish brown colour

	d4/Ae1		Isohyperthermic, Typic Haplustalfs		sandy clay to sandy clay loam texture with sub soil argillic horizon and moderately well drained.
9	CHK9-sc-d3/Ae2	Midland	Fine, mixed, super-active, Isohyperthermic, Typic Haplustalfs	IVsf	Very deep, reddish brown to dark red colour sandy clay to clay texture with sub soil argillic horizon and moderately well drained.
10	CHK10-c-d5/Be2g1	Upland	Very fine, smectitic, super-active, Isohyperthermic, Typic Haplusterts	IIItsf	Very deep, very dark grayish brown to very dark gray colour clay texture with sub soil slickensides, imperfect drainage.
11	CHK11-sc-d4/Be1	Midland	Fine, mixed, super-active, Isohyperthermic, Typic Haplustalfs	IVsf	Very deep, dark reddish brown to brown colour sandy clay subsoil texture and moderately well drained.
12	CHK12-scl-d4/Ae2	Midland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Haplustalfs	IVsf	Very deep, dark reddish brown to yellowish red colour sandy clay loam to clay texture with sub soil argillic horizon and moderately well drained.
13	CHK13-scl-d2/Ae2g2	Upland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Rhodustalfs	IVtsf	Very deep, dark reddish brown colour sandy clay to clay texture with sub soil argillic horizon and moderately well drained.
14	CHK14-scl-d2/Ae2	Midland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Rhodustalfs	IVsf	Very deep, dark reddish brown to reddish brown colour sandy clay sub soil texture and moderately well drained.
15	CHK15-scl-d4/Ae1	Midland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Fluventic Haplustepts	IVsf	Very deep, dark reddish brown to reddish brown colour loamy sand to sandy clay subsoil texture and moderately well drained.
16	CHK16-scl-d5/Ae1	Lowland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Haplustalfs	IVsf	Very deep, dark brown to dark reddish brown colour loamy sand to sandy clay loam texture with sub soil argillic horizon and imperfectly drained.
17	CHK17-scl-d3/Be2	Upland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Haplustepts	IVsf	Very deep, brown to very dark brown colour sandy loam to sandy clay loam subsoil texture and moderately well drained.
18	CHK18-sl-l4/Ae2	Lowland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Fluventic Haplustepts	IIItwsf	Very deep, reddish brown to dark grayish brown colour sandy loam to sandy clay loam texture, strong effervescence with dilute HCl and moderately well drained.
19	CHK19-sc-d2/Ae1g1	Midland	Clayey, smectitic, super-active, Isohyperthermic, Lithic Ustorthent	IVsf	Very deep, dark brown to brown colour sandy clay to sandy clay loam sub soil texture and moderate drained.
20	CHK20-cl-d2/Ae2g1	Midland	Clayey, smectitic, super-active, Isohyperthermic, Lithic Ustorthent	IVsf	Very deep, dark gray colour, clay subsoil texture and somewhat poor drained.
21	CHK21-scl-d4/Be1	Lowland	Loamy-skeletal, mixed, super-active, Isohyperthermic, Typic Haplustepts	IVsf	Very deep, red to dark reddish brown colour sandy loam to sandy clay subsoil texture and moderately well drained.

Table 2: Fertility status of soils of Chikmegeri-3 micro-watershed

Soil property	Black soil			Red soil		
	Range	Mean	SD	Range	Mean	SD
pH	7.56 -8.86	8.05	0.35	6.85 - 7.84	7.33	0.24
Electrical conductivity (dS m^{-1})	0.11 - 0.58	0.30	0.14	0.06 - 0.88	0.36	0.20
Organic carbon (g kg^{-1})	4.3- 6.6	4.9	0.6	1.0 – 6.4	4.1	0.14
Available N (kg ha^{-1})	135.0 - 205.0	180.2	20.88	105.0 - 198.0	152.9	30.28
Available P_2O_5 (kg ha^{-1})	18.5 – 32.3	26.73	5.08	11.0 – 33.1	22.42	5.24
Available K_2O (kg ha^{-1})	285.0 - 480.0	375.1	50.05	105.0 - 335.0	293.2	66.53
Available S (kg ha^{-1})	6.5 - 11.6	9.03	1.23	6.2 - 17.7	10.45	2.76
Exchangeable Ca [(cmol (p^+) kg^{-1})]	16.3 - 34.0	25.72	5.08	8.1 - 41.2	16.68	4.90
Exchangeable Mg [(cmol (p^+) kg^{-1})]	6.1 - 18.4	11.98	3.05	4.0 - 22.1	8.30	2.65
Available Zn (mg kg^{-1})	0.22 - 0.57	0.41	0.10	0.18 - 0.96	0.51	0.13
Available Fe (mg kg^{-1})	1.29 - 5.64	2.88	1.38	2.40 - 18.92	8.01	3.70
Available Mn (mg kg^{-1})	3.51 - 13.08	6.33	2.47	4.96 - 28.04	13.60	4.24
Available Cu (mg kg^{-1})	0.54 - 4.65	2.26	1.18	0.83 - 5.23	3.21	1.05

Conclusion

Increasing population and stagnating agricultural production, an inventory of the land resource base is a prerequisite not only to understand their potential and constraints, but also plan towards sustained agricultural production. A detailed characterization of land resources assessing its potential and constraints becomes a pre-requisite for planning. The information that is generated upon integration with the attribute data in a Geographic Information System provides information on composite resource units. For this, resource units generated from soil survey helps to describe and classify soils and predict their potentials for sustainable land use practices which are technically feasible, economically viable and socially acceptable.

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