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Meenkshi Bai R
Department of Soil Science and Agricultural Chemistry, UAS Raichur, Karnataka, India

Vidyavathi GY
Department of Soil Science and Agricultural Chemistry UAS, Dharwad, Karnataka, India

Yadahalli GS
Senior Farm Superintendent and Agronomist, MARS, UAS, Raichur, Karnataka, India

Rudramurthy HV
Department of Soil Science and Agricultural Chemistry, UAS Raichur, Karnataka, India

Rajesh NL
Department of Soil Science and Agricultural Chemistry, UAS Raichur, Karnataka, India

Correspondence
Meenkshi Bai R
Department of Soil Science and Agricultural Chemistry, UAS Raichur, Karnataka, India

Land resource characterization and soil classification of Pannur North-3 microwatershed using RS and GIS in Manvi Taluk, Raichur district

Meenkshi Bai R, Vidyavathi GY, Yadahalli GS, Rudramurthy HV and Rajesh NL

Abstract
Use of RS and GIS for land resources of Pannur north-3 microwatershed was carried out by using cadastral map (1:50000 scale) as base. Apart from the cadastral map, remote sensing data products from Cartosat-1 PAN imagery (2.5m spatial resolution) merged with Resourcesat-2 LISS IV imagery (5.8 m spatial resolution) were used to identify the landforms and other surface features. Five soil profiles representing the study area were selected based on the topography from various physiographic units identified by field survey. Depth of the soils ranged from moderately deep to very deep, colour varied from dark brown to dark gray. Texture was found to be clay, surface structure was moderate, medium, subangular blocky, whereas in subsurface, the structure ranged from moderate, medium, angular blocky to strong, coarse, angular blocky. Consistency varied from slightly hard to hard, very hard, friable to firm, slightly sticky to very sticky and slightly plastic to very plastic under dry, moist and wet condition, respectively in all the mapping units. The soil reaction (pH) was moderately alkaline to alkaline, low to medium in EC, organic carbon content was found to be low to medium which ranged between 4.3 to 5.8 g kg^{-1}, free calcium carbonate ($CaCO_3$) was moderately calcareous which ranged from 10.7 to 13.2 percent, cation exchange capacity (CEC), ESP and base saturation ranged from 45.1 to 62.4 (cmol (P^+) kg^1), 7.88 to 8.93 percent, and 91.86 to 94.69 percent, respectively.

Keywords: Soil resources, cadastral map, soil profile, microwatershed

Introduction
Knowledge of soil and land resources with respect to their spatial distribution, characteristics, potentials, limitations and their suitability for alternate land use helps in formulating strategies to obtain higher productivity on sustained basis. This calls for systematic and reliable inventory of natural resources like soil, water, land use, forest, *etc.* at a quicker phase through scientific and modern tools like remote sensing (RS) and geographic information system (GIS). Thus the advent of remote sensing and GIS has revolutionized in mapping and management of voluminous spatial and non-spatial natural resource information which helps in evolving a variable decision support system for achieving sustainable development of agriculture with an objective to characterize soil in respect to physical and chemical properties and soil classification, the suitability for various crops were computed with GIS to determine the effect of soil properties on various crops. The Systematic study of soil as natural resource provides information on nature and type of soil, their constraints, potentials, capabilities and their suitability for various uses (Sehgal, 1996) [17]. Several workers have utilized this technique for soil mapping on different terrain conditions at different scales (Srivastava and Saxena 2004; Velmurugan and Carlos 2009) [20, 22] and on watershed basis (Shukla *et al.* 2009; Patil *et al.* 2010). Considering the above points, therefore, the present investigation was under taken to assess the Land resources inventory of Pannur North-3 microwatershed using RS and GIS in Manvi taluk of Raichur district.

Material and methods
Study area
Pannur North-3 microwatershed is located in Manvi taluk, of Raichur district, Karnataka lies between 16° 12′ N latitude and 77° 22′ E longitudes and having total area of 640.78 hectares and microwatershed is surrounded by Chikalparvi, Hosur, Pannur and Mustur village and the location of study area is depicted in Fig.1.

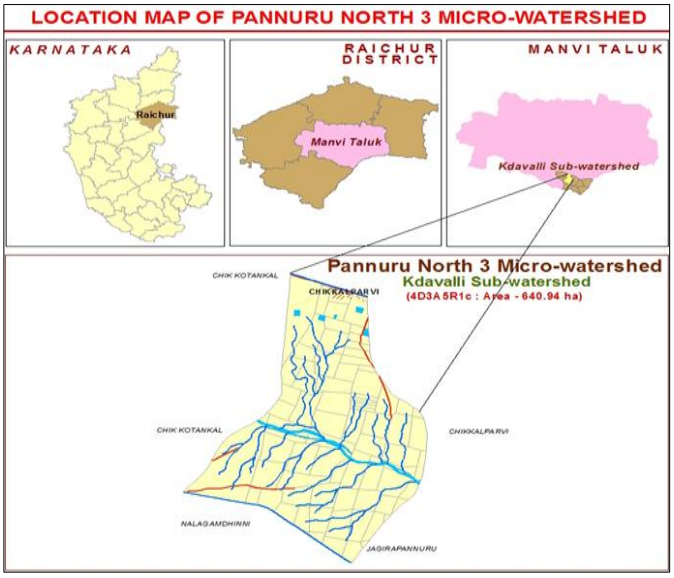

Fig 1: Location of the Pannur North-3 MWS

Semi arid climate prevails on Pannur north-3 microwatershed and it belongs to North Eastern Dry zone of Karnataka state. The average annual rainfall is 707.16 mm. Mean maximum and minimum temperatures are 33.82 °C and 21.16 °C, respectively. The highest rainfall was received during the month of September (164.90 mm). The length of growing period, which indicates the availability of water for plant growth, is about 150 to 180 days in a year. It starts from the middle July and continues up to the end of December. The area qualifies for *hyperthermic* temperature regime.

Soil survey methodology

The purpose of the soil resource inventory is to delineate similar areas, which respond or expected to respond similarly to a given level of management. This was achieved in Pannur North-3 micro watershed by studying geo morphological features (slope, surface stoniness, erosion, drainage, gravels *etc*.) of landscape and morphological features (soil depth, texture, color, structure, consistency, coarse fragments, porosity, soil reaction *etc*.) of the pedons. Based on these soil–site characteristics Pannur North-3 micro watershed area was divided into different homogeneous units known as mapping/management units. The extent of area and distribution of these management units are marked with boundary on Pannur North-3 cadastral map. The high intensity survey (at 1:8,000 scale) was carried out in 640.78 ha area of the Pannur North-3 during 2016. Analysis of soil physical properties (Soil texture, Soil structure, Soil colour, Soil consistency, Bulk density (Mg m^{-3}, Porosity (%) and MWHC), physcio-chemical properties (Soil reaction, Soluble salts EC (dS m^{-1}), chemical properties ($CaCO_3$ (%), Organic carbon (g kg^{-1}), Exc. Ca and Mg (cmol (p+)kg^{-1}), Exc. Na cmol (p+)kg^{-1}), Exc. Sodium percentage (cmol (p+)kg^{-1}) and Cation exchange capacity cmol (p+) kg^{-1})) were analyzed by following standard procedure.

Maps used

Detailed survey of the land resources in the MWS was carried out by using cadastral map as a base. The cadastral map (Fig. 2) shows field boundaries with their survey numbers, location of tanks, streams and other permanent features of the area.

Fig 2: Cadastral map of Pannur North-3 MWS

The cadastral map overlaid IRS data of Cartosat-1 PAN imagery (2.5m spatial resolution) merged with Resourcesat-2 LISS IV imagery (5.8 m spatial resolution) obtained from KSRSAC, Bangalore has helped in the identification and delineation of boundaries between, uplands and lowlands, water bodies, forest and vegetated areas, roads, habitations and other cultural features of the area. Apart from the imageries, the Survey of India (SOI) topo sheet of the area (1:50,000 scales) was used for initial traversing, identification of contours, landform, drainage features and for the selection of transects.

Based on these soil–site characteristics Pannur North-3 micro watershed area was divided into different homogeneous units known as mapping/management units. Mapping units under study were YADmC (A)1, PNUmC2, HSRmB2 and MASmC2 & MASmC3 under Yadavalli, Pannur, Hosur and Maskihalla series, respectively (Fig. 3). Among five mapping units obtained three different landforms *viz.*, upland, midland and stream revealed the slope varying from very gentle sloping (1-3%) to gentle sloping (3-5%).

The extent of area and distribution of these management units are marked with boundary on Pannur North-3 cadastral map. The high intensity survey (at 1:8,000 scale) was carried out in 640.78 ha area of the Pannur North-3 during 2016.

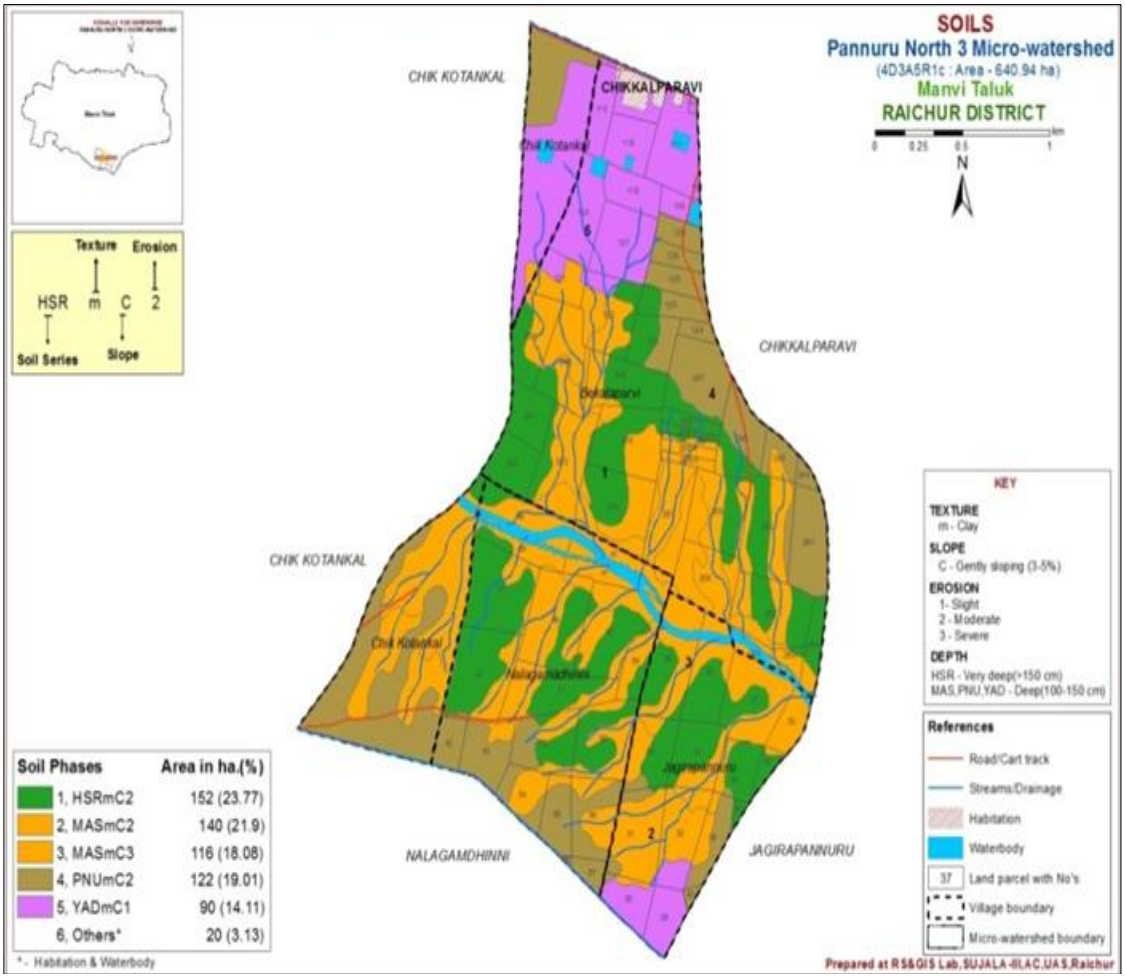

Fig 3: Soil mapping units of Pannur North-3 MWS

Results and Discussion

Morphological characteristics

The results of the morphological, physical and chemical characteristics of soils of Pannur North-3 micro-watershed, Manvi taluk, are presented (Tables 1). Soil depth varied from 95 cm to more than 160 cm indicating that they were moderately deep to very deep, soil colour of the study area varied from 10YR 2/1 (dark brown) to 10YR 4/2 (dark gray). Texture was found to be clay, surface structure was moderate, medium, subangular blocky, whereas in subsurface, the structure ranged from moderate, medium, angular blocky to strong, coarse, angular blocky. The dominant structure observed was moderate, medium, and angular blocky. Consistency varied from slightly hard to hard, very hard, friable to firm, slightly sticky to very sticky and slightly plastic to very plastic under dry, moist and wet condition in all the mapping units. Slickensides were common feature in all the soil pedons because of argillo-pedoturbation. Abundance and intensity of slickensides were more in middle of solum, because of maximum swelling pressure. Similar results were also reported by Dasog and Hadimani (1980) [3].

Physical characteristics

A perusal of the data on particle size distribution in soils revealed that all the soil pedons are clayey in texture according to the USDA textural triangle (Table 2). In all the mapping units the clay content increased with depth and could be attributed to several processes like illuviation of the finer fraction to the lower depth (Dasog, 1975 and Krishnamurthy and Govindarajan, 1977) [5, 8]. Similar trend was also noticed by Parvatappa (1981) and Doddamani *et al.* (1994) [6] in vertisols of the upper Krishna command area of Karnataka.

Silt content of all the five mapping units ranged from 11.70 to 31.29 percent. In all the mapping units the silt content increased with depth. MASmC3 mapping unit exhibited high amount of silt content due to accumulation of more silt in stream bank pedon from the midland and upland. These results were in agreement with the findings of Satish Kumar and Naidu (2012) [14]. Sand content varied from 19.80 to 29.16 percent. In all the mapping units, surface horizons exhibited higher sand content than the subsurface horizons due to enrichment of sand fraction in the surface horizons might be related to the clay eluviations and removal of clay by surface runoff similar results were quoted by (Dasog and Patil, 2011; Gangopadhyay *et al*., 2012 and Pulakeshi *et al*., 2014) [4, 7, 13].

The bulk density in all the five mapping units, ranged from 1.24 to 1.38 Mg m^{-3}. Bulk density of MASmC2 and MASmC3 mapping units were more than YADmC (A)1, PNUmC2 and HSRmB2 mapping units (Table 2) and this might be due to high amount of sand content and low amount of clay content and organic carbon. The porosity in all the mapping units varied from 46.87 to 54.62 percent. Highest porosity (54.62%) was noticed in HSRmB2 mapping unit due to higher clay content and lower porosity (46.87%) was observed in MASmC3 mapping unit due to low clay content. The maximum water holding capacity of various mapping units ranged from 40.89 to 51.08 percent. Higher water holding capacity (51.08%) was observed in HSRmB2 mapping unit because of high (%) clay content. Low water holding capacity (48.89%) was observed in MASmC3 mapping unit in due to high silt and less clay content. The similar results were also reported by Singh *et al.* (1999) [18] in soils of Rangappa catchment in Uttar Pradesh.

Physico-chemical properties

The soil reaction (pH) was moderately alkaline to alkaline which ranged from 7.95 to 8.30. Highest soil pH (8.30) value was observed in HSRmB2 mapping unit (Table 3) due to their calcareous nature and the accumulation of bases in the solum as they were poorly leached (Satyanarayana and Biswas, 1970) [15]. All the mapping units showed low to medium EC values ranging from 0.20 to 0.65 dS m^{-1} indicating the non-saline nature of the soils. The low electrical conductivity was noticed in MASmC2 and MASmC3 mapping units. The upper solum relatively less EC values which might be due to free drainage conditions which favored the removal of released bases by percolating water. The results were in accordance with the study conducted by Pillai and Natarajan (2004) [12] Garakahalli watershed.

The organic carbon content was found to be low to medium which ranged between 4.3 to 5.8 g kg^{-1}. The highest organic carbon content (5.80 g kg^{-1}) in HSRmB2 mapping unit and lowest organic content (4.3 g kg^{-1}) in MASmC3 mapping unit were observed (Table 3). This was due to high temperature which might have induced its rapid oxidation leading to low organic carbon content. These observations are in the line with the finding of Basavaraju *et al.* (2005) [1] in Chandragiri mandal of Chittoor district, Andhra Pradesh. The free calcium carbonate ($CaCO_3$) was moderately calcareous which ranged from 10.7 to 13.2 percent due to accumulation of bases, especially Ca^{2+} and Mg^{2+} in semi-arid climates is known to favour calcification process leading to accumulation of free lime in soil.

The highest calcium and magnesium was found in YADmC (A)1, PNUmC2 and HSRmB2 mapping units compared to MASmC2 and MASmC3 mapping units. The exchangeable bases in all the soil mapping unit were in order of Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} on the exchange complex. From the distribution of Ca^{2+} and Mg^{2+}, it is evident that Ca^{2+} shows the strongest relationship with all the species, comparing these ions (Mg^{2+}, Na^{+} and K^{+}) it was clear that Mg^{2+} was present in low amount than Ca^{2+} because of its higher mobility. The cation exchange capacity (CEC) of all the mapping units was ranged from 45.1 to 62.4 (cmol (P^{+}) kg^{1}). The highest CEC (62.4 cmol (p^{+}) kg^{-1}) value was observed in HSRmB2 mapping unit (Table 4).

The values of CEC increased with profile depths and followed the trend of clay. This is due to accumulation of clay and presence of higher extent of expanding type of clay (Landey *et al.*, 1982 and Das 1999) [9, 2]. The ESP of all the five mapping units ranged from 7.88 to 8.93 percent, the ESP was observed in HSRmB2 mapping unit (8.93) and lowest (7.88) in MASmC2 mapping unit (Table 3). This could due to higher sodium content in the parent materials of black soils, Thangasamy *et al.* (2005) [21]. The base saturation (BS) of different mapping units ranged from 91.86 to 94.69 percent. Lowest base saturation was found in MASmC2 (91.86) mapping units and highest was noticed in HSRmB2 (94.69) mapping units. This might be due to higher amount of Ca^{+2} ions occupying the exchange sites on the colloidal sites (Table 4).

Soil classification

Soils of the study area were classified upto family level based on morphological and physico-chemical properties (Table 5) according to Keys to Soil Taxonomy (Soil Survey Staff, 2014). All the soil series *viz.*, Yadvalli, Pannur, Maskihalla and Hosur were classified as Vertisols at order level, as these pedons did not have lithic or paralithic contact within 50 cm of soil surface and had a weighted average of >30 percent clay in all the horizons down to a depth of 1 m and had cracks that open and close periodically. These pedons have a layer of 25 cm or thicker, with an upper boundary within 100 cm of mineral soil surface, that has slickensides.

These series key out as Ustert at suborder level as they have cracks in normal year that are 5 mm or more (if not irrigated) through a thickness of 25 cm or more within 50 cm of mineral soil surface, for 90 or more cumulative days per year. Mapping units YADmC (A)1, PNUmC2, MASmC2, MASmC3 and HSRmB2 at great group level they are classified as the Haplusterts. At sub-group level they are classified as YADmC (A)1 was *Udic* Haplusterts and remaining mapping units are *Typic* Haplusterts as they do not have *densic, lithic, paralithic* contact, duripan, hallic and sodic horizon within 100 cm from mineral soil surface and Montmorillonitic type of clay mineralogy.

At the family level classification, particle size, mineralogical class, temperature and CEC were considered. Vertisols had fine to very fine clay movement over depth of the pedons in all the mapping units. MAST (Mean annual soil temperature) was computed from the MAAT (Mean annual air temperature 24 ºC) by adding 7.95 ºC. Based on this, the study area was classified under hyperthermic (MAST 27.5 ºC) (Sehgal, 1996) [17] and the difference between mean summer and winter temperature was more than 6 ºC. Therefore, the temperature regime of the Pannur North-3 microwatershed was classified as hyperthermic. The series such as Yadvalli having a sub group of *Udic* haplusterts and Pannur, maskihalla and Hosur soil series comes under *Typic* haplusterts.

Table 1: Morphological features of the soils of Pannur North -3 MWS

Name of Soil series	Mapping unit	Geology	Colour		Soil depth (cm)		Slope (%)	Landform	Texture		Structure		Consistency	
			Surface	Subsurface	Surface	Sub surface			Surface	Sub surface	Surface	Sub surface	Surface	Sub-surface
Yadavalli	YADmC(A)1	Schist	10YR 3/2 (D) & 3/1(M)	10YR 3/1(D) & 3/1(M)	0-11	95-130	3-5	Upland	C	C	2 msbk	3 mabk	sh, fr, ss, sp	vh, fi, vs, vp
Pannur	PNUmC2	Granite	10YR 3/2(D) & 3/1(M)	10 YR 3/1 (D) & 3/1 (M)	0-12	120-140	3-5	Upland	C	C	2 msbk	3 mabk	sh, fr, ss, sp	h, fr, vs, vp
Hosur	HSRmB2	Granite	10YR 3/1(D) & 3/1(M)	10 YR 2/1 (D) & 2/1(M)	0-11	120-160	1-3	Midland	C	C	2 msbk	3 mabk	sh, fr, ss, sp	vh, fr, vs, vp
Maskihalla	MASmC2	Granite	10YR 4/2(D) & 4/1(M)	10 YR 3/2(D) & 3/1M)	0-12	105-130	3-5	Stream bank	C	C	2 msbk	2 cabk	sh, fr, ss, sp	h, fr, vs, vp
	MASmC3	Granite	10YR 4/2(D) & 4/1(M)	10 YR 3/2(D) & 3/1(M)	0-18	95-120	3-5	Stream bank	C	C	2 msbk	2 cabk	sh, fr, ss, sp	h, fr, s, vp

Note: sh – slighly hard, ss – slightly sticky, sp – slightly plastic, fr – friable, fi – firm, vs – very sticky, v p – very plastic, h – hard, m – medium, sbk – subangular blocky, abk-angular bloky, c – coarse

Table 2: Physical properties of the mapping unit of Pannur North -3 MWS

Soil series (Mapping unit)	Depth (cm)	Horizon	Coarse sand	Fine sand	Total sand	Silt	Clay	Textural class	Bulk density (Mg m^{-3})	Porosity	MWHC
			%							%	
Yadavalli (YADmC(A)1)	0-11	Ap	12.68	21.56	34.24	8.88	56.88	Clay	1.23	52.69	45.51
	11 - 40	Bw	12.09	20.54	32.63	9.26	58.11	Clay	1.24	52.31	46.62
	40-63	Bss1	11.03	18.75	29.78	10.21	60.01	Clay	1.26	51.54	48.06
	63-81	Bss2	10.49	17.83	28.32	11.31	60.37	Clay	1.27	51.15	48.86
	81-95	Bss3	9.91	16.84	25.75	12.01	62.24	Clay	1.31	49.62	49.21
	95-125	Bss4	8.97	15.26	24.23	12.63	63.14	Clay	1.32	49.23	49.32
Solum weighted average	0-125	Ap-Bss	10.86	18.46	29.16	10.72	60.13		1.27	51.1	47.93
Pannur (PNUmC2)	0-12	Ap	11.48	20.93	32.40	9.8	57.80	Clay	1.22	53.08	44.98
	12 - 28	Bw	11.74	19.64	31.39	10.3	58.31	Clay	1.26	51.54	46.32
	43-97	Bss1	10.01	18.72	28.73	10.87	60.40	Clay	1.29	50.38	47.75
	55-82	Bss2	9.66	15.42	26.08	11.75	62.17	Clay	1.3	50.00	49.82
	82-120	Bss3	9.08	15.43	24.51	12.04	63.45	Clay	1.32	49.23	50.12
	120-140	Bss4	8.93	15.19	23.12	12.24	64.64	Clay	1.33	48.85	51.00
Solum weighted average	0-140	Ap-Bss	10.15	17.55	27.71	11.17	61.03		1.29	50.51	48.33
Hosur (HSRmB2)	0-11	Ap	8.99	15.28	24.27	10.36	65.37	Clay	1.17	55.00	48.57
	11-40	Bw	8.59	14.60	23.19	10.89	65.92	Clay	1.18	54.62	49.76
	40-60	Bss1	8.33	14.17	22.50	11.02	66.48	Clay	1.18	54.62	49.83
	60-83	Bss2	7.80	13.26	21.06	11.59	67.35	Clay	1.19	54.23	50.93
	83-95	Bss3	7.27	12.36	19.63	12.35	68.02	Clay	1.22	53.08	51.87
	95-120	Bss4	5.26	8.95	14.21	12.81	72.98	Clay	1.23	52.69	51.93
	120-160	Bss5	5.09	8.66	13.75	12.9	73.35	Clay	1.24	52.31	52.13
Solum weighted average	0-160	Ap-Bss	7.33	12.47	19.80	11.70	68.50		1.24	54.62	51.08
Maskihalla (MASmC2)	0-12	Ap	18.75	11.03	27.78	24.31	47.91	Clay	1.28	50.77	44.37
	2-24	Bw	17.50	10.29	24.79	26.33	48.88	Clay	1.29	50.38	44.26
	24-42	Bss1	15.69	9.23	22.92	27.15	49.93	Clay	1.31	49.62	45.43
	42-75	Bss2	15.14	8.90	21.04	28.64	50.32	Clay	1.35	48.08	46.29
	75-105	Bss3	13.02	7.66	18.68	29.86	51.46	Clay	1.36	47.69	49.87
	105-140	Bss4	12.23	7.20	16.43	31.54	52.03	Clay	1.38	46.92	51.69
Solum weighted average	0-140	Ap-Bss	15.39	9.05	21.94	27.97	50.09		1.33	48.91	46.98
Maskihalla (MASmC3)	0-18	Ap	18.54	10.91	29.45	28.67	44.88	Clay	1.30	50.00	42.35
	18-30	Bw	17.49	10.29	27.78	29.40	45.82	Clay	1.31	49.62	42.54
	30-45	Bss1	15.86	9.32	25.18	29.95	47.87	Clay	1.37	47.31	44.16
	45-58	Bss2	16.96	9.97	26.93	31.29	44.78	Clay	1.39	46.54	44.98
	58-75	Bss3	15.65	9.21	24.86	31.66	46.48	Clay	1.42	45.38	46.09
	77-95	Bss4	12.93	7.60	20.53	33.29	49.18	Clay	1.43	45.00	46.44
	95-135	Bss5	11.28	6.63	17.91	34.76	50.33	Clay	1.45	44.23	47.69
Solum weighted average	0-135	Ap-Bss	15.53	9.13	24.66	31.29	47.05		1.38	46.87	44.89

Table 3: Chemical properties of the mapping units of Pannur North -3 micro watershed

S. No.	Soil series (Mapping Unit)	Depth (cm)	pH	EC (dS m^{-1})	OC (g kg^{-1})	$CaCO_3$ (%)
1	Yadavalli (YADmC(A)1)	0-11	7.81	0.21	6.8	11.2
		11 - 40	7.93	0.29	6.5	12.0
		40-63	8.02	0.37	6.3	13.5
		63-81	8.26	0.33	5.8	12.4
		81-95	8.29	0.42	3.5	14.2
		95-125	8.33	0.43	3.1	14.4
Solum weighted average		0-125	8.11	0.34	5.5	13.0
2	Pannur (PNUmC2)	0-12	7.63	0.28	6.9	10.3
		12 - 28	7.88	0.32	6.9	11.3
		43-97	8.13	0.44	6.7	12.8
		55-82	8.21	0.43	5.9	13.1
		82-120	8.29	0.66	3.8	14.7
		120-140	8.3	0.67	3.3	14.5
Solum weighted average		0-140	8.07	0.47	5.6	12.8
3	Hosur (HSRmB2)	0-11	8.19	0.46	7.2	11.5
		11-40	8.24	0.49	6.9	11.9
		40-60	8.26	0.61	6.6	13.6
		60-83	8.29	0.59	6.5	12.9
		83-95	8.33	0.63	5.9	13.8
		95-120	8.38	0.68	3.8	14.6
		120-160	8.42	0.71	3.5	14.3
Solum weighted average		0-160	8.30	0.61	5.8	13.2
4	Maskihalla (MASmC2)	0-12	7.88	0.19	6.2	9.8
		2-24	7.91	0.22	5.8	10.0
		24-42	8.06	0.28	5.5	10.6
		42-75	8.09	0.31	4.8	11.3
		75-105	8.15	0.29	3.1	12.0
		105-140	8.21	0.36	2.3	12.4
Solum weighted average		0-140	8.05	0.28	4.6	11.0
5	Maskihalla (MASmC3)	0-18	7.56	0.12	5.5	9.3
		18-30	7.69	0.18	5.1	10.0
		30-45	7.83	0.17	4.7	10.6
		45-58	8.06	0.21	4.5	10.3
		58-75	8.12	0.24	3.9	11.5
		77-95	8.18	0.23	3.6	11.3
		95-135	8.20	0.22	3.0	12.0
Solum weighted average		0-135	7.95	0.20	4.3	10.7

Table 4: Vertical distribution of exchangeable cations and cation exchange capacity (CEC) in the mapping units of Pannur North -3 MWS

S. No	Soil series (Mapping unit)	Depth (cm)	Exchangeable cations				CEC (cmol (P^+) kg^{-1})	ESP (%)	BS (%)
			Ca	Mg	Na	K			
			(cmol (P^+) kg^{-1})						
1	Yadavalli (YADmC(A)1)	0-11	32.30	9.60	2.77	0.53	48.0	5.77	94.17
		11 - 40	31.70	11.80	3.35	0.45	50.0	6.70	94.60
		40-63	39.40	10.60	4.68	0.64	58.0	8.07	95.38
		63-81	40.20	10.40	5.38	0.34	59.0	9.12	95.46
		81-95	32.83	13.30	6.19	0.48	59.0	10.49	89.49
		95-125	33.80	14.50	7.95	0.41	62.0	12.82	90.90
Solum weighted average		0-125	35.01	11.70	5.05	0.49	56.0	8.83	93.33
2	Pannur (PNUmC2)	0-12	31.70	10.30	2.80	0.54	48.0	5.83	94.46
		12 - 28	32.80	10.86	3.10	0.53	50.0	6.20	94.58
		43-97	30.10	11.30	4.36	0.56	50.0	8.72	92.74
		55-82	33.34	10.50	3.95	0.43	55.0	7.18	87.78
		82-120	39.10	13.20	5.20	0.36	61.0	8.52	94.77
		120-140	40.30	13.19	6.10	0.42	65.0	9.38	92.42
Solum weighted average		0-145	34.55	11.59	4.25	0.47	54.8	7.64	92.79
3	Hosur (HSRmB2)	0-11	36.05	9.60	4.10	0.56	52.3	7.84	96.20
		11-40	38.60	11.40	4.32	0.54	57.3	7.54	95.73
		40-60	41.50	13.30	4.91	0.61	62.0	7.92	97.29
		60-83	42.10	10.80	5.31	0.35	64.2	8.27	91.22
		83-95	40.40	12.10	6.15	0.41	65.5	9.39	90.17
		95-120	42.30	14.70	6.67	0.28	66.3	10.06	96.45
		120-160	43.20	14.50	7.95	0.41	69.0	11.52	95.74
Solum weighted average		0-160	40.59	12.34	5.63	0.45	62.4	8.93	94.69
4.	Maskihalla (MASmC2)	0-12	23.80	8.40	2.83	0.51	39.0	7.26	91.13
		2-24	26.80	8.60	2.91	0.50	43.0	6.77	90.26

		24-42	25.30	10.40	4.15	0.42	43.0	9.65	93.65
		42-75	24.60	12.20	3.50	0.46	45.0	7.78	90.26
		75-105	32.30	10.10	4.01	0.32	49.7	8.07	94.31
		105-140	35.20	11.30	4.20	0.37	54.3	7.73	94.05
		0-140	28.00	10.17	3.60	0.43	45.7	7.88	92.27
5.	Maskihalla (MASmC3)	0-18	22.30	7.90	2.20	0.56	35.8	6.15	92.07
		18-30	23.60	8.90	2.42	0.48	39.3	6.16	90.08
		30-45	27.20	11.60	3.21	0.53	43.7	7.35	97.34
		45-58	26.80	10.70	4.86	0.57	45.2	10.75	94.98
		58-75	23.10	11.50	3.75	0.37	46.6	8.05	83.09
		77-95	30.20	11.00	4.89	0.48	49.3	9.92	94.56
		95-135	33.10	10.50	6.68	0.47	55.9	11.95	90.91
Solum weighted average		0-135	26.63	10.30	4.00	0.48	45.1	8.62	91.86

Table 5: Soil classification of Pannur North -3 MWS as per USDA soil taxonomy, 1999

Order	Suborder	Great Group	Sub Group	Family	Series
Vertisols	Usterts	Haplusterts	*Udic* Haplusterts	Very fine montmorillonitic, hyperthermic	Yadvalli,
Vertisols	Usterts	Haplusterts	*Typic* Haplusterts	Very fine montmorillonitic, hyperthermic	Pannur and maskihalla
Vertisols	Usterts	Haplusterts	*Typic* Haplusterts	Very Fine montmorillonitic, hyperthermic	Hosur

Conclusion

Pannur North-3 watershed area have soil depth of moderately deep to very deep, colour varied from dark brown to dark gray. The texture was found to be clay, surface structure was moderate, medium, subangular blocky, whereas in subsurface, the structure ranged from moderate, medium, angular blocky to strong, coarse, angular blocky. The soil reaction (pH) was moderately alkaline to alkaline, low to medium EC, organic carbon content was found to be low to medium, free calcium carbonate ($CaCO_3$) was moderately calcareous. Thus this study reveals that there is a close relationship between physiography and soils.

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