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Study on morphological properties and classification of Kanaginhal sub-watershed in northern dry zone of Karnataka

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Abstract
Total Twenty one soil profiles representing larger heterogeneity were studied for the morphological features. The sub-watershed was nearly level with moderate to severe erosion and drainage conditions. The results revealed that the Soil solum depth varied from 23 cm to more than 200 cm across pedons indicating that they are very shallow to very deep. All the pedons have A, B and C horizons. The A horizon is a ploughed layer indicated by horizon designation, Ap. The B horizon in the Vertisols indicate both structural (Bw) as well as slickensided (Bss) horizons. Clay texture and weak to moderate sub-angular blocky structure with many fine roots distributed in sub-surface horizons. The soil consistency was predominantly hard when dry, friable when moist, very stick and very plastic when wet. Pedons exhibited hue of 10YR, 7.5YR and 2.5Y throughout the profile and the dominant colour is black to very dark grey. Slickensides were observed in pedons 1, 3, 4, 5, 11, 12, 14, 16, 17 and 18 due to high clay content Soils were classified up to Family level. Taxonomically, the soils of the study area are classified under the orders Entisol, Inceptisol and Vertisol.

Keywords: Soil survey manual, Entisols, Inceptisols and vertisols

Introduction
Soil characterization is basically an inference process based on Jenny's model. According to this model, climate, parent material, relief or topography, vegetation and time are the soil forming factors that influence the soil characteristics. The climate acting over parent material for pedogenic time on different physiographic unit is the most dominant factor responsible for development of different types of soil to support different vegetation. Vegetation types are also actively influence soil formation by adding organic matter, providing pores for translocation and accumulation of minerals and clay. During soil development many morphological, physical, chemical, bio-chemical and, macro and microbiological reactions and processes occur simultaneously as also interactively in soils. These reaction and processes that affect the properties of soils and its development are in turn influenced by several natural factors *viz*., climate, organism, parent material and modified to a great extent by the relief features. Surface configuration is the chief factor in soil development and close relation exists between soils and their morphological setting. Since the productive potential of the soils is limited by intrinsic characteristics, understanding of the soils as influenced by landscape features is of great significance. Classification is the grouping of objects in some orderly and logical manner. It is based on the properties of objects for the purpose of their identification and study. The individual soils are grouped into classes of lower category (*i.e*., soil series), which are further grouped into classes of higher categories (*i.e*., soil orders). The USDA Soil Taxonomy is property based and concepts are discussed as guidelines, but not as criteria. Properties include horizons and soil morphological properties. The use of definitions for horizons and characteristic diagnostic properties limit descriptions of diagnostic criteria and enhance communication. This supports an accurate natural and concise classification of the pedon. The USDA Soil Taxonomy has six levels, with 12 Orders at the highest level. It defines nine topsoil horizons, 19 subsoil horizons, and 26 and 33 diagnostic properties for organic and inorganic soils, respectively (Soil survey staff, 2003) [2]. Therefore, soil classification is helpful in identifying their potential uses, estimating their productivity and transferring agro-technology from research farms to cultivators' fields.

Materials and Methods
The detailed 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 as per Soil Survey Manual (Anon., 2014) [1]. The horizons were identified and designated according to revised keys to Soil Taxonomy (Anon., 2014) [1].

Fig 1: Location of the study area

Table 1: Different morphological features were assessed in the field by following methods:

Sl. No	Parameter	Method
1	Texture	Feel method
2	Colour	Munsell colour chart
3	Structure	Based on shape and distinctness of the aggregates
4	Consistence	Based on resistance of soil material to rupture
5	$CaCO_3$	Based on effervescence with dil. HCl

(Soil Survey Staff, 2014) [1-2]

Result and Discussion

Morphological characteristics of soil pedons

The study of soil morphology provides a scope to know more about the external features and structures of soil body in a profile such as colour, texture, structure, horizonation, consistence, mottles, roots, coarser fragments and other features like concretions, depth and width of cracks, presence of slickensides and reaction with dilute HCl to show effervescence, confirming the presence of carbonates. The morphological features are often related with the physical, chemical and mineralogical properties of soils. This essentially shows the interactions of various soil forming factors on some soil characteristics important to maintain the soil health.

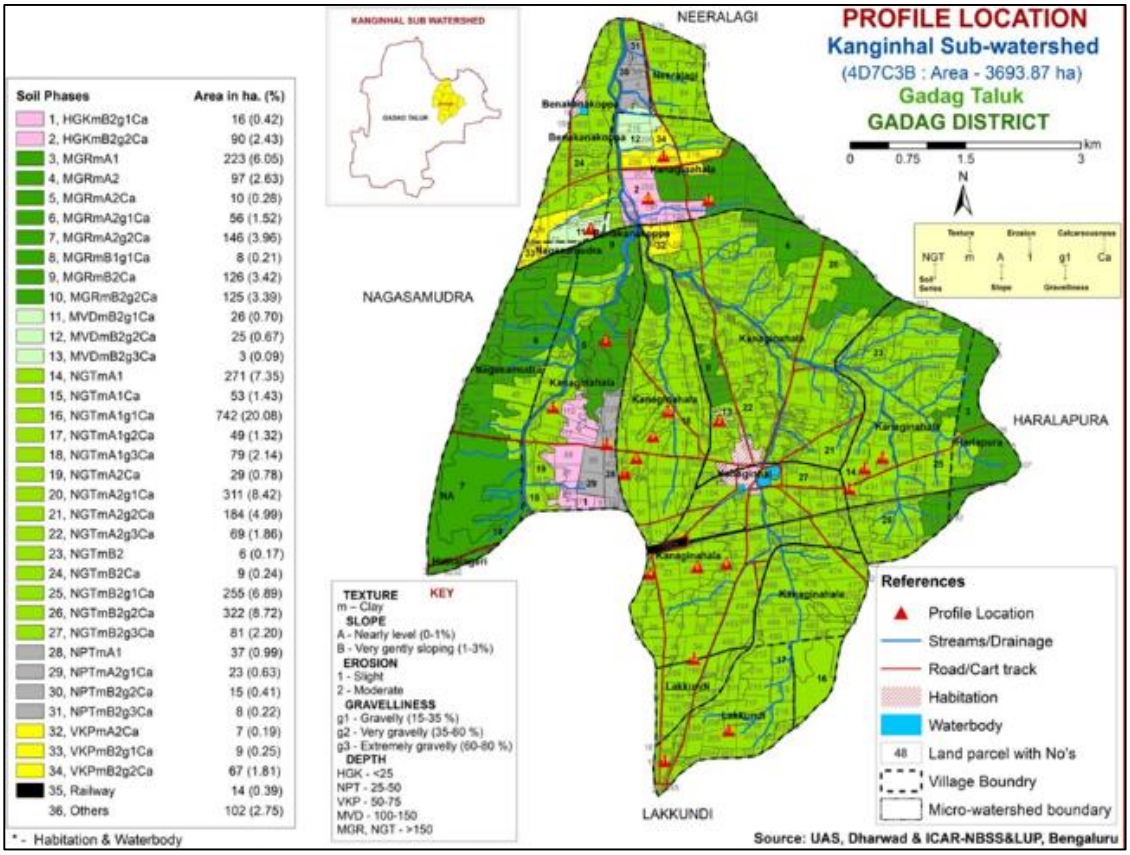

Fig 2: Profile Location

Horizon Differentiation

All the pedons have A, B and C horizons. The A horizon is a ploughed layer indicated by horizon designation, Ap. The B horizon in the Vertisols indicate both structural (Bw) as well as slickensided (Bss) horizons. The associated Inceptisols, however, show only Bw horizons. The C horizons are either calcareous or dominated by $CaCO_3$ as indicated by the Ck horizon (Soil Survey Staff, 2014) [1-2].

In the present study, horizon boundaries were clear in distinctness and smooth to wavy in topography. Horizon differentiation is relatively weak. Horizon identification in the pedons is made based on presence or Obsence of slickensides and the nature of cracks (Bhattacharjee *et al*., 1977) [4]. Similar observation of relatively weak horizon differentiation is reported by Pramod and Patil (2015) [10] for the soils of Balapur micro-watershed of Koppal district.

Soil depth

Soil solum depth varied from 23 cm to more than 200 cm across pedons indicating that they are very shallow to very deep. Pedons 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18 and 21 are very deep (> 150 cm), pedon 1 is deep (100-150 cm), pedon 17 is shallow (50-100 cm) and pedon 20 is very shallow (<50 cm) in depth. Solum depth reflected the relation between soil formation and soil loss by erosion in any area. The depth variability in relation to physiography is mainly ascribed to 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 (Ramprakash and Rao, 2002) [12]. This has resulted in shallow soils in uplands and deeper soils in lowland physiographic units.

Soil properties are directly or indirectly dependent on the slope. The depth of low land pedons are comparatively more than that of midland and upland pedons. The results of the present study are in accordance with findings of Basavaraju *et al*. (2005) [3].

Soil colour

Pedons exhibited hue of 10YR, 7.5YR and 2.5Y throughout the profile and the dominant colour is black to very dark grey (Fig. 2). The dark matrix colour is attributed to presence of high organic matter content in the surface horizons (Chandra Sekhar *et al.*, 2019) [6] and due to the clay-humus complex in the presence of lime (Tripathi *et al.*, 2006) [15]. Khan and Kamalakar (2012) [8] attributed the dark matrix colour in the soil profiles to presence of high organic carbon content in surface horizons. In the pedons the chroma did not change with depth. This might be due to higher degree of argillic pedoturbation as the soils are shrink swell type. Normally, the content of soil organic carbon (SOC) determines the relative darkness of soil colour especially in the surface. Light grey or grey with or without mottles indicates reduced SOC content prevailing in the soil environment.

Soil texture

Texture of soils refers to the relative proportion of the various soil separates of different size limits in the fine earth fractions (<2 mm) of soil mass. The particles larger than 2 mm size are recognized by modifiers of various textural class names, *viz*, gravelly, cobbly, *etc.* During profile examination the tentative textural class of the fine earth fraction of the soil was determined by hand "feel" method. The actual composition of soil was determined in the laboratory by particle-size analysis to cross check the field observation. Laboratory data of particle-size distribution in terms of sand, silt and clay are utilized to arrive at the exact textural class using the triangular chart of USDA System.

Texture of all the pedons are clay in both surface and subsurface, the increase in clay content through the soil depth

are observed. It could be attributed to processes like illuviation of the finer fraction to the lower depth. Similar results are also recorded by Sumithra *et al.* (2013) [13] in soils of Timanhal micro-watershed, Kushtagi taluk of Karnataka and Pulakeshi *et al.* (2014) [11] in Northern transition zone of Karnataka.

Soil Structure

Structure was predominantly moderate, medium, sub-angular blocky in the surface and subsurfaces. Sub-angular to angular blocky structure in the sub horizons is due to formation of slickensides in these soils. The dominant structure observed is moderate, medium, sub-angular blocky in soils of Timanhal micro-watershed, Kushtagi taluk of Karnataka by Sumithra *et al.* (2013) [13]. Soils in field are studied when the profile is dry. De Vos and Virgo (1969) [7] indicate that the occurrence of wedge-shaped structural aggregates and angular blocky structure are the most characteristic aspects of Vertisols. Soil structure is studied in the field in the form of class or size, type or shape, and grade or distinctness.

Soil Consistency

Soil consistence is the function of soil-water relationship. It is one of the important morphological properties, which indicates the degree of cohesion among the soil particles and the degree of adhesion to other objects. Soil consistence also indicates resistance to the deformation of cast prepared under applied stress.

Consistency of soil pedons varied from slightly hard to hard when dry, friable to firm when moist, slightly sticky to very sticky and slightly plastic to very plastic when wet. The clay content of soil is known to play a major role in the expression of consistency. This physical behaviour of soils influenced by dry, moist and wet conditions are not only due to the textural makeup but also due to type of clay minerals present in these soils. The hardness, firmness, stickiness and plasticity increased with depth up to BC horizon in most of the pedon. This trend can be attributed to the increase in clay content with depth due to illuviation. Similar observation was made by Nagendra and Patil (2015) [9]. Soil consistency is reported to be dependent not only on the textural make up but also on type of clay minerals present in soils (Dasog and Patil, 2011) [11]. Evidence of loose, friable and slightly sticky and slightly plastic consistence is attributed to low amount of expanding clay minerals (Thangasamy *et al*., 2004; Sarkar *et al*., 2001) [14].

Special Features

Special features include slickensides, cracks and effervescence. Presence of slickensides or wedge-shaped peds with an upper boundary within 100 cm of the soil surface is mandatory to qualify a soil to Vertisols (Soil Survey Staff, 1999) [2]. This is a common feature of the Vertisols rich in smectite type clays. Slickensides were observed in pedons 1, 3, 4, 5, 11, 12, 14, 16, 17 and 18 due to high clay content. These pedons exhibited very sticky and very plastic consistency which leads to development of slickensides. Pressure faces are considered as weak expressions of slickensides. In most occasions this morphological feature is identified in the soil horizons immediately above the slickenside horizons. Pressure faces were observed in pedons 6, 7, 8, 9, 10, 13 and 19. The results of the present study are in accordance with findings of Bhattacharyya *et al*. (2007) [5]. A crack has been defined as a separation between gross polyhedrons. If the surface is strongly self mulching or if the soil is cultivated while cracks are open, the cracks may be filled mainly by granular material from the surface. A crack is regarded as open, if it controls the infiltration and percolation of water in a dry, clayey soil (Soil Survey Staff, 2014) [1-2].

Special features like effervescence with dil. HCl was observed in pedons. All pedons showed slight to strong effervescence with dil. HCl which increased with depth, in pedon 4 and 6 strong effervescence throughout the solum were observed. The differences in reaction to dil. HCl were due to variation in lime content of these soils.

Soil classification

In Kanaginhal sub-watershed, the soils were classified up to family level. The soils were classified based on morphological, physical and chemical properties according to Soil Taxonomy (Anon., 2014) [1]. At higher categories (order), the presence or absence of diagnostic horizons which are indications of pedogenic processes were considered. At the sub-order level, the moisture and temperature regimes were used. At lower categories (great group, sub-group and family); diagnostic subsurface horizons, soil depth, mineralogy, texture, soil chemical properties and drainage conditions were considered. Taxonomically, the soils of the study area were classified under the orders Entisol, Inceptisol and Vertisol. The taxonomic classification of soil pedons up to family level in Kanaginhal sub-watershed is presented in Table 2. The details of guidelines used in soil classification as per Soil Taxonomy are given in Appendix XIII.

Table 2: Classification of soil pedons

Sl no	Pedon	Soil classification	Order
1	1, 3, 5, 7, 10 13, 15, 16 & 18	Fine, Smectitic, Super Active, iso-hyperthermic, Typic Haplusterts	Vertisol
2	4, 6, 8, 9, 11, 12 & 14	Fine, Smectitic, Super Active, iso-hyperthermic, calcic Haplusterts	
3	2 &21	Fine smectitic, Super Active, iso-hyperthermic, Vertic Haplustepts.	Inceptisol
4	17	Very fine, smetitic, super active, iso-hyperthermic Vertic Haplustepts.	
5	19	Clayey, smectitic, Super Active iso-hyperthermic, Lithic Haplustepts.	
6	20	Clayey, smectite, superactive, isohyperthermic, Lithic Ustorthents	Entisols

Soil pedons 1, 3, 5, 7, 10 13, 15, 16 and 18 were grouped under the order; Vertisol, suborder; Usterts, great group; Haplusterts subgroup; Typic Haplusterts and family; Fine, Smectitic, super active, iso-hyperthermic. Soil pedons 4, 6, 8, 9, 11, 12 and 14 were grouped under the order; Vertisol, suborder; Usterts, great group; Haplusterts, subgroup; Calcic Haplusterts and family; Fine, Smectitic, Super Active, iso-hyperthermic. Soil pedon 2 and 21, were grouped under the order; Inceptisol, suborder; Ustepts, great group; Haplustepts, subgroup; Vertic Haplustepts and family; Fine Smectitic, Super Active, iso-hyperthermic. Soil pedon 17 was grouped under the order; Inceptisol, suborder; Ustepts, Vertic Haplustepts and family; Very fine Smectitic, Super Active, iso-hyperthermic. Soil pedon 19 was grouped under the order; Inceptisol, suborder; Ustepts, great group; Haplustepts, subgroup; Lithic Haplustepts and family; Clayey, Smectitic, Super Active iso-hyperthermic. Soil pedon 20 was grouped under the order; Entisol, suborder; Orthents, great group; Ustorthents, subgroup; Lithic Ustorthents and family Clayey, Smectitic, Super Active iso-hyperthermic.

Table 3: Morphological characteristics of soil pedons in Kanaginhal sub –watershed

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boun-dary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 1	Ap	0 – 17	10 YR 3/2	10 YR 3/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	No surface crackes were observed, Prominent slicken sides were observed from 41-75 cm. slight to strong effervescence with dilute HCl.
	Bw	17-41	10 YR 3/2	10 YR 3/1	c	2 m sbk	h	fr	vs & vp	mfp	cs	
	Bss	41-75	10 YR 3/2	10 YR 3/1	c	2 m sbk	h	fi	vs & vp	ffp	cw	
	BCk	75-145	10 YR 4/3	10 YR 4/2	c	2 m sbk	h	fi	vs & vp	ffp	cs	
Pedon 2	Ap	0-19	10YR 3/2	10 YR 4/2	c	1 m sbk	sh	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 45 cm. slight to strong effervescence with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 46 to 140 cm.
	Bw1	19-41	10YR 3/1	10 YR 2/1	c	2 m sbk	h	fr	vs & vp	mfp	cs	
	Bw2	41-68	10YR 3/1	10 YR 3/1	c	2 m sbk	h	fr	vs & vp	mfp	cs	
	Bw3	68-118	10YR 3/2	10 YR 3/2	c	2 m sbk	h	fr	vs & vp	mfp	cs	
	Crk	118-170	Weathered Granite gneiss									
Pedon 3	Ap	0-18	7.5 YR 3/3	7.5 YR 2.5/3	c	2 m sbk	h	fr	ms & mp	mfp	cs	No surface cracke were observed, buried sand horizon was found at 50 cm. Slight effervesces with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 50 to 160cm.
	Bw_1	18-47	7.5 YR 3/3	7.5 YR 2.5/3	c	2 m sbk	h	fr	ms & mp	mfp	cs	
	Bw_2	47-90	7.5 YR 2.5/3	7.5 YR 3/3	c	1 m abk	h	fr	ms & mp	mfp	cs	
	Bss	90-145	7.5 YR 3/3	7.5 YR 2.5/3	c	1 m abk	vh	fr	ms & mp	mfp	cs	
	BC	145-180	7.5 YR 3/4	7.5 YR 3/4	c	1 m abk	vh	fr	ms & mp	mfp	cs	
Pedon 4	Ap	0-18	10 YR 3/1	10 YR 3/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Surface cracks were observed up to 39. Prominent slicken sides were observed from 39-70 cm. Slight to strong effervesces with dilute HCl. Fine sized CaCO3 concretions were observed throught the profile.
	Bw	18-39	2.5 Y 5/1	2.5 Y 3/1	c	2 m sbk	h	fi	vs & vp	mfp	cs	
	Bss	39-70	10 YR 2/1	10 YR 3/1	s	1 m sbk	h	fi	ms & mp	ffp	cs	
	Bwk1	70-122	2.5 Y 3/2	2.5 Y 3/1	c	2 m sbk	h	fi	vs & vp	mfp	cs	
	Bwk2	122-200	2.5 Y 4/2	2.5 Y 3/2	c	2 m sbk	h	fi	vs & vp	mfp	cs	

Table 3: Continued…

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boun-dary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 5	Ap	0-22	2.5 Y 4/1	2.5 Y 3/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 50 cm. Prominent slicken sides were observed from 38-95 cm Slight to strong effervescence with dilute HCl. Fine sized prominent $CaCO_3$ concretions were observed from 55-160 cm.
	Bw	22-39	2.5 Y 4/1	2.5 Y 3/1	c	2 m sbk	sh	fi	vs & vp	mfp	cs	
	Bss	39-58	2.5 Y 3/1	2.5 Y 3/1	c	1m sbk	h	fi	vs & vp	mfp	cs	
	Bwk1	58-95	2.5 Y 5/2	2.5 Y 4/2	c	2 m sbk	h	fi	vs & vp	mfp	cs	
	Bwk2	95-175	2.5 Y 5/2	2.5 Y 4/2		2 m sbk	h	fi	vs & vp	mfp	cs	
Pedon 6	Ap	0-17	2.5 Y 4/1	2.5 Y 3/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	No surface cracks were observed, Slight to strong effervescence with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 50 to 180 cm.
	AB	17-38	2.5 Y 4/1	2.5 Y 3/1	c	2 m sbk	sh	fi	vs & vp	mfp	cs	
	Bss	38-81	2.5 Y 3/1	2.5 Y 3/1	c	2 m sbk	h	fi	vs & vp	mfp	cs	
	Bwk1	81-135	2.5 Y 4/1	2.5 Y 3/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	
	Bwk2	135-190	2.5 Y 4/1	2.5 Y 3/1	c	2 m sbk	sh	fi	vs & vp	mfp	cs	
Pedon 7	Ap	0-26	10 YR 3/1	10 YR 3/2	c	2 m sbk	h	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 40 cm. Slight to strong effervescence with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 75 to 175 cm.
	AB	26-62	10 YR 3/2	10 YR 3/2	c	2 m sbk	h	fr	ms & mp	ffp	cs	
	Bss	62-190	10 YR 3/2	10 YR 3.2	c	2 m sbk	h	fi	ms & mp	ffp	cs	
Pedon 8	Ap	0-20	10 YR 4/1	10 YR 4/2	c	2 m sbk	h	fr	vs & vp	cfp	cs	Wide and deep cracks observed up to 40 cm. Slight to strong effervescence with dilute HCl. Few and fine sized prominent $CaCO_3$ concretions were observed from 0-20 cm.
	AB	20-48	10 YR 4/1	10 YR 4/2	c	2 m sbk	h	fi	vs & vp	cfp	cw	
	Bss	48-110	10 YR 4/1	10 YR 4/2	c	2 m sbk	sh	fi	vs & vp		cs	
	BCk	110-190	10 YR 4/1	10 YR 4/2	c	2 m sbk	sh	fr	vs & vp		ds	

Table 3: Continued….

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boun-dary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 9	Ap	0-19	10 YR 3/1	10 YR 3/2	c	2 m sbk	h	fr	vs & vp	cfp	cs	Wide and deep cracks observed up to 55 cm. Violent to slight effervescence with
	Bw	19-68	10 YR 3/1	10 YR 3/2	c	2 m sbk	h	fr	vs & vp	cfp	cw	
	Bss	68-106	10 YR 3/3	10 YR 3/3	c	2 m sbk	h	fi	ms &mp		cw	
	Bwk	106-170	10 YR 4/2	10 YR 4/2	c	2 m sbk	sh	fi	ms &mp		cs	

												dilute HCl.
Pedon 10	Ap	0-16	10 YR 2/1	10 YR 2/1	c	2 m sbk	h	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 23 cm depth. Strong effervescence with dilute HC.
	Bss	26-62	10 YR 2/2	10 YR 3/2	c	2 m sbk	h	fr	vs & vp	cfp	cw	
	BCk	62-150	10 YR 4/2	10 YR 4/2	c	2 m sbk	sh	fi	ms & mp		cs	
Pedon 11	Ap	0-22	2.5 Y 3/1	2.5 Y 4/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	No cracks were observed Prominent slicken sides were observed from 84-128 cm depth. Slight to strong effervesces with dilute HCl.
	Bw1	22-46	2.5 Y 3/1	2.5 Y 3/1	c	2 m sbk	h	fi	vs & vp	cfp	gs	
	Bw2	46-84	10 YR 4/2	10 YR 4/2	c	2 m sbk	h	fi	vs & vp	ffp	gs	
	Bss	84-128	2.5Y 5/2	2.5Y 4/2	c	1 m sbk	h	fi	vs & vp		….	
	Bwk	128-160	10 YR 5/3	10 YR 4/3	c	1 m sbk	h	fi	vs & vp		….	
Pedon 12	Ap	0-22	10 Y 3/1	2.5 Y 4/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 50 cm. Prominent slicken sides were observed from 62 to 118 cm Slight effervesces with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 75 to 195 cm
	Bw	22-62	10 YR 4/1	2.5 Y 3/1	c	2 m sbk	h	fi	vs & vp	cfp	gs	
	Bss	62-118	10 Y 4/2	2.5 Y 4/2	c	1 m sbk	h	fi	vs & vp	ffp	gs	
	BC	118-154	10 Y 6/2	2.5 Y 5 /2	c	1 m sbk	h	fi	vs & vp		….	
	Crk	154-215	Weathered Granite gneiss									
Pedon 13	Ap	0-22	2.5Y 3/1	2.5Y 3/2	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Small cracks observed up to 25 cm depth. Slight to violent effervesces with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 75 to 171 cm.
	AB	22-45	2.5Y 3/1	2.5Y 3/2	c	2 m sbk	sh	fr	vs & vp	cfp	cs	
	Bw	45-79	2.5Y 3/2	2.5Y 3/2	c	3 m sbk	h	fi	vs & vp	ffp	ds	
	Bwk	79-175	2.5Y 4/2	2.5Y 4/2	c	3 m sbk	h	fi	vs & vp		ds	

Table 3: Continued…

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boundary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 14	Ap	0-20	10 YR 2/2	10 YR 3/1	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 50 cm. Prominent slicken sides were observed from 38 to 82 cm Slight effervesces with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 75 to 195 cm
	Bw	20-38	10 YR 2/2	10 YR 2/2	c	2 m sbk	sh	fi	vs & vp	cfp	gs	
	Bss	38-82	10 YR 2/1	10 YR 2/2	c	3 m sbk	h	fi	vs & vp	ffp	gs	
	BC1	82-145	10 YR 2/2	10 YR 2/2	c	3 m sbk	h	fi	ms & mp		….	
	BC2	145-200	10 YR 3/1	10 YR 3/1	c	2 m sbk	sh	fi	ms & mp		….	
Pedon 15												No cracks observed. Slight to strong effervesces with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 55 to 180 cm.
	Ap	0-21	10 YR 2/1	10 YR 2/2	c	2 m sbk	sh	fr	vs & vp	mfp	cs	
	AB	21-42	10 YR 2/1	10 YR 4/2	c	2 m sbk	h	fi	vs & vp	cfp	gs	
	Bwk1	42-128	10 YR 5/2	10 YR 4/2	c	2 m sbk	h	fi	ms & mp	ffp	gs	
	Bwk2	128-180	10 YR 4/3	10 YR 4/3	c	2 m sbk	h	fi	ms & mp	ffp	gs	
Pedon 16	Ap	0-25	10 YR 3/1	10 YR 3/2	c	2 m sbk	sh	fr	vs & vp	mfp	cs	Wide and deep cracks observed up to 60 cm. Prominent slicken sides were observed from 50-104 cm Slight effervesces with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 104 to 160 cm.
	AB	25-50	10 YR 3/2	10 YR 4/2	c	2 m sbk	sh	fr	vs & vp	mfp	cs	
	Bw	50-104	10 YR 4/2	10 YR 4/2	c	2 m sbk	sh	fr	vs & vp	mfp	cs	
	Bss	104-135	10 YR 4/2	10 YR 4/2	c	2 m sbk	sh	fr	vs & vp	mfp	cs	
	BCk	135-170	10 YR 5/4	10 YR 5/4	c	2 m sbk	sh	fr	vs & vp	mfp	cs	
Pedon 17	Ap	0-13	10 YR 4/2	10 YR 3/2	c	2 m sbk	h	vfr	vs & vp	cfp	cs	Wide and deep cracks observed up to 45 cm depth. Prominent slicken sides were observed from 42-128 cm Slight to strong effervesces with dilute HCl.
	Bw	13-35	10 YR 3/2	10 YR 3/1	c	3 m sbk	vh	fr	vs & vp		cw	
	Bw1	35-67	10 YR 3/2	10 YR 3/2	c	2 m sbk	sh	fi	vs & vp		ds	
	Cr	67-120	Weathered Granite gneiss									

Table 3: Continued….

Pedon No.	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Root	Boun -dary	Special features
			Dry	Moist			Dry	Moist	Wet			
Pedon 18	Ap	0-22	10 YR 4/1	10 YR 3/1	c	2 m sbk	l	l	vs & vp	mfp	cs	Wide and deep cracks observed up to 40 cm. Prominent slicken sides were observed from 64-115 cm Slight effervesces with dilute HCl.
	Bw	22-64	10 YR 4/3	10 YR 4/3	c	2 m sbk	sh	fr	vs & vp	cfp	ds	
	Bss	64-115	10 YR 5/3	10 YR 5/3	c	2 m sbk	sh	fr	vs & vp	ffp	dw	
	Bssk	115-180	10 YR 5/4	10 YR 5/4	c	2 m sbk	sh	fi	vs & vp	ffp	….	
Pedon 19	Ap	0-11	10 YR 4/2	10 YR 3/2	c	2 m sbk	h	vfr	vs & vp	cfp	cs	No surface cracks observed. Slight to strong effervesces observed with dilute HCl. Fine sized $CaCO_3$ concretions were observed from 40 cm.
	Bwk	11-40	10 YR 3/1	10 YR 3/2	c	3 m sbk	vh	fr	vs & vp		cw	
	Crk	40-110	Weathered Granite gneiss									
Pedon 20	Ap	0-23	10 YR 4/1	10 YR 3/1	c	2 m sbk	l	l	vs & vp	mfp	cs	Few and fine sized prominent $CaCO_3$ concretions were observed from 0-23 cm.
	Crk	23-100	Weathered Granite gneiss									
Pedon 21	Ap	0-19	10 YR 3/2	10 YR 3/3	c	2 m sbk	sh	fr	ms & mp	cfp	cs	Narrow and deep cracks observed up to 45 cm. 45 cm depth. Buried sand layers were seen from 40 to 80 cm. Voilent effervesces with dilute HCl.
	A1	19-41	10 YR 3/1	10 YR 3/3	c	2 m sbk	h	fr	vs & vp	ffp	cw	
	Cb	41-57	10 YR 7/1	10 YR 7/4	s	2 m sbk	l	l	ns & np	ffp	cs	
	A	57-78	10 YR 4/1	10 YR 4/2	c	2 m sbk	h	fr	ms & mp	fvfp	cs	
	ACb	78-148	10 YR 5/3	10 YR 3/4	s	2 m sbk	l	l	ns & np		….	

Conclusion

The soils were very shallow to very deep in depth and varied Yellowish brown to black in colour. Soils under the study were predominantly sub-angular blocky in structure, friable (wet) in consistency, the cracks were observed in the surface of most of the profile area and the pressure faces, slicken sides and concentration of calcium were observed in the lower depths of most of the profiles. The texture sandy clay loam to clay. Based on morphological, physical and chemical properties of soils, soils were classified as per "Keys to Soil Taxonomy" (Soil Survey Staff, 2014) [1-2] up to family level. The soils of Kanaginahal sub-watershed belonged to three soil orders namely Entisols, Inceptisol and Vertisol. The soil mapping will help in better planning and efficient use of natural resources towards achieving higher crop productivity and production.

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