ORIGINAL RESEARCH ARTICLE

Characterization and classification of soil resources of hittinahalli sub-watershed derived from basalt in Northern dry zone of Karnataka

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Abstract

Eighteen Typical pedons representing upland, midland, and lowland forms in a Hittinahalli sub-watershed of Vijayapur district were studied for their morphological characteristics and physico-chemical properties. The soils were shallow to very deep (25 to >150 cm), very dark brown to black (Munsell color chart) and moderately well to poorly drained. The soil structure changes from weak, medium sub-angular blocky on the surface to moderate, coarse sub-angular blocky in the sub-surface horizons. The soils are moderately alkaline to strongly alkaline (7.59–9.41), low to high in organic carbon (0.08–0.75 g/kg). The pedons on uplands exhibit the development of an argillic horizon (Bt). The pedons on the midlands and lowlands have cambic horizons (Bw), classified as Verisols and Inceptisols, respectively. The lowlands (P6, P10, P16, and P18) and midlands (P7, P8, P12, P15, and P17) are classified as fine, mixed, Iso-hyperthermic, and Typic Haplustalfs.

Key words: Vertisols, Inceptisols, characterization, and classification

1.0 Introduction:

Soils have diverse morphological, physical, and chemical properties. As a result, they differ in their responses to management practices, their inherent ability to deliver ecosystem services, as well as their resilience to disturbance and vulnerability to degradation (FAO, 2017). The characterization and classification of soils are therefore of paramount importance in using those resources based on their capabilities and managing them in a sustainable manner. Soil information obtained through systematic identification and grouping is useful for effective planning of different land uses as it provides information related to the potentials and constraints of the land (Lufega and Msanya, 2017). Soil characterization studies are a major building block for understanding the soil, classifying it, and getting the best understanding of the environment (Onyekanne *et al*., 2012). Soil characterization provides information for our understanding of the physical, chemical, and mineralogical properties of soil. Considering the above points, therefore, the present investigation

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was undertaken to assess the land resources inventory of the Hiitinahalli sub-watershed using RS and GIS.

2.0 Materials and methods

The study area is in the Hittinahalli sub-watershed in Vijayapur district, Karnataka, and falls under the North Dry Zone (zone no. 03) of Karnataka and the Agro-Ecological Sub-Region (AESR) of India, which receives its major annual rainfall during *Kharif* season (June–September). It covers an area of 10424.04ha and lies between 16^0 52' and 16^0 55' N latitude and 75° 20' and 75° 22' E longitude. The dominant geology of the study area is basalt. The sub-watershed area mainly comprises very gently sloping land. The soils are medium- and deep-black clay in major areas. The climate of the area is semi-arid, of the hot tropical monsoonal type. The average annual rainfall is 585.6 mm. The length of the growing period is <140 days.

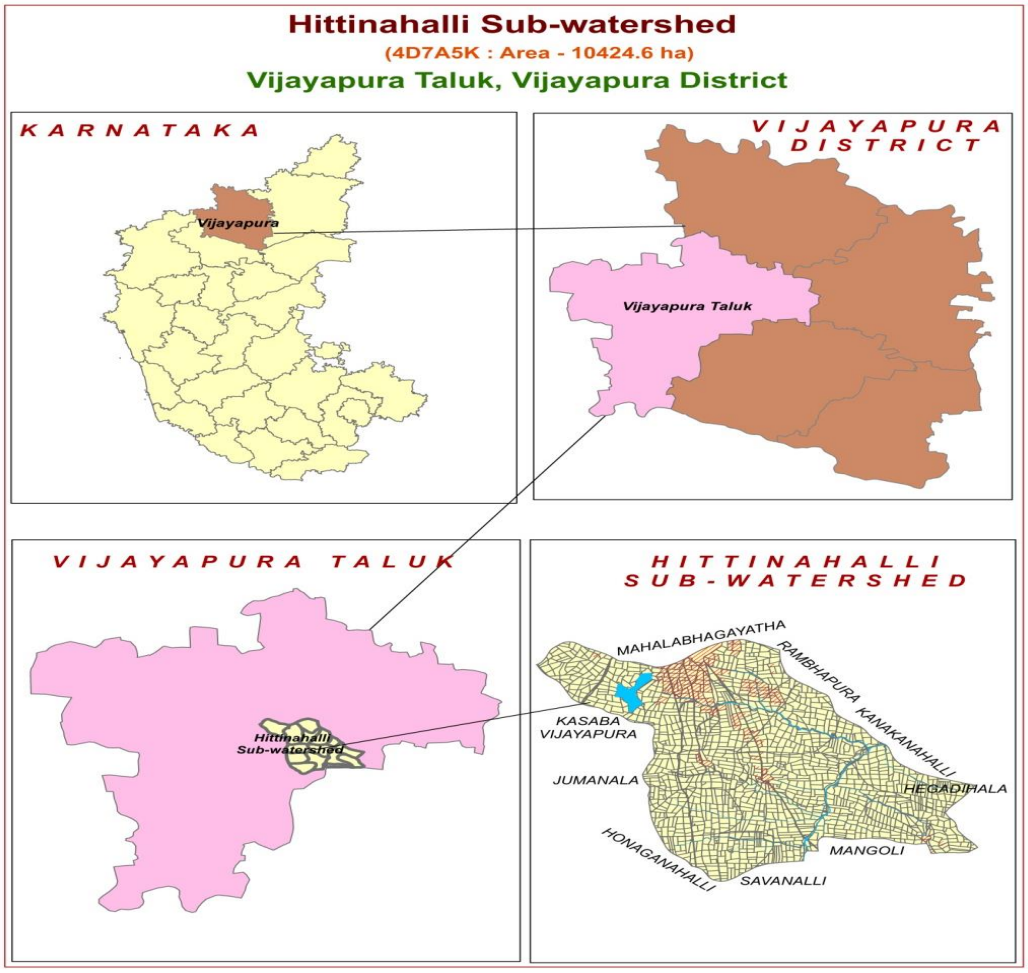

Fig.1. Location of Hittinahalli sub-watershed in Vijayapur taluka, Vijayapur district

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The database was generated by using a cadastral map of the sub-watershed and quick bird imagery as a base map for satellite. A total of 23 pedons were studied on transact, covering all the landforms for describing morphological characteristics (Soil Survey Staff, USDA 2014). Horizontal soil samples were collected, air dried, processed, and analysed for particle-size distribution, pH, EC, organic carbon, cation exchange capacity (CEC), and exchangeable cations as described by Jackson (1973). The soils were classified following the USDA system of soil classification (Soil Survey Staff, USDA 2014). Out of 23 pedons studied, 18 were selected to represent each identified series for the interpretation of results.

3.0 Results and discussion

3.1 Soil morphology

Brief morphological features of the pedons are presented in Table 1. The soils were dark grayish brown (10 YR 4/2) to very dark grayish brown (10 YR 3/2) in pedons except Nandyal pedon, which is reddish brown (5 YR 3/4) to dark reddish brown (5 YR 4/4). There was not much variation in the soil color with depth. All the pedons exhibited a hue of 10 YR throughout the profile, and the dominant color was dark grayish brown to very dark grayish brown due to the clay-humus complex in the presence of lime. The soils exhibited sub-angular blocky structure in all the pedons in the surface horizon except Jamanal pedon, which is angular blocky both at the surface and subsurface layers. The structure designates the mode of arrangement of the particles and their aggregation; therefore, the structural variation in soils was useful to differentiate the horizon (Landey *et al.*, 1982). The structure of all the pedons was predominantly angular to medium-sub-angular blocky in the surface horizons.

The dry consistency of the surface horizon ranged from slightly hard to hard in all pedons. A very hard consistency was observed in the surface horizon (Ap) and sub-surface horizon (Bss2) of the Sarwad pedon. The moist consistency was firm to friable in almost all pedons. A slightly sticky and very plastic consistency was observed in almost all pedons except Ap horizon. All the horizons of Yakkundi pedon were found to be very sticky and very plastic in consistency (wet). An increase in stickiness and plasticity may be due to a high clay content. Similar observations were made by Sarkar *et al.* (2001) in the soils of the lower outer Chotanagapur plateau.

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Table1. Morphological characteristics of Hittinahalli sub-watershed pedon

Horizon	Depth	Moist Color	Texture	Structure		Consistence		
Atharga series (Fine, smectitic, iso-hyperthermic, Lithic Ustorthents)								
Ap	0-8	10 YR 4/4	Clay	2 m sbk	H	fr	ms	mp
AC	19-Aug	10 YR 4/4	Clay	2 m sbk	H	fr	ms	mp
Babaleshwara series (fine, Smectitic, iso-hyperthermicTypic Calciusterts)								
AP	0-15	10 YR 2/1	Clay	2 m sbk	sh	f	vs	vp
BW	15-40	10 YR 2/1	Clay	2 m sbk	sh	f	vs	vp
Bss	40-60	10 YR 2/1	Clay	2 m sbk	sh	f	ms	mp
Bssk1	60-100	10 YR 2/1	Clay	2 m abk	h	f	vs	vp
Bssk2	100-140	10 YR 3/3	Clay	2 m abk	h	f	ms	mp
Bssk3	140-170	10 YR 3/4	Clay	2 m abk	h	f	ss	sp
Dadamatti series (Fine loamy,smectitic, iso-hyperthermic, Lithic Haplustepts)								
Ap	0-12	10 YR 3/2	Clay	2 m sbk	sh	Fr	ss	sp
Bw	12-39	10 YR 3/2	Clay	2 m sbk	l	Fr	ss	sp
Halagani series (Fine, smectitic, iso-hyperthermic, VerticHaplustepts)								
AP	0-35	10 YR 3/2	Clay	2 m c	sh	f	ms	mp
Bw1	35-70	10 YR 3/2	Clay	2 m sbk	h	f	ms	mp
Bw2	70-100	10 YR 3/2	Clay	2 m sbk	h	f	ms	mp
Bw3	100-125	10 YR 3/4	Clay	2 m sbk	h	f	ms	mp
Cr	125+							
Honnutagi series (Fine, loamy, smectitic, iso-hyperthermic, FlurenticHaplustepts)								
AP	0-20	10 YR 3/3	Clay	2 m sbk	h	f	vs	vp
Bw1	20-40	10 YR 3/3	Clay	2 m sbk	-	f	vs	vp
Bw2	40-82	10 YR 3/3	Clay	2 m sbk	-	f	vs	vp
Bw3	82-135	10 YR 3/3	Clay	2 m sbk	-	f	ms	mp
BCk1	135-160	10 YR 2/2	Clay	2 m sbk	-	f	ms	mp
Bss	160-190	10 YR 2/1	Clay	2 m abk	-	f	vs	vp
Jamanal series (Fine, smectitic, iso-hyperthermic, Typic Haplusterts)								
AP	0-31	10 YR 2/2	Clay	2 m sbk	sh	f	ms	mp
Bss1	31-60	10 YR 2/2	Clay	2 m abk	h	f	vs	vp
Bss2	60-71	10 YR 3/2	Clay	2 m abk	h	f	Vs	vp
BCk1	71-80	10 YR 3/2	Clay	2 m abk	sh	f	ms	mp
Bss3	80-97	10 YR 3/2	Clay	2 m abk	sh	f	ms	mp
BCk2	97-112	10 YR 3/2	Clay	2 m abk	sh	f	ms	mp
Cr	112	Weathered basalt						
Kalgurki series (Fine, smectitic, iso-hyperthermic,TypicHaplustepts)								
Ap	0-19	10 YR ¾	Clay	2 m sbk	sh	Fr	ms	mp

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Bw1	19-32	10 YR 3/3	Clay	2 m sbk	sh	Fr	ms	mp
BCk1	32-70	10 YR 3/3	Clay	2 m sbk	sh	Fr	ms	mp
Karjol series (Fine, smectitic, iso-hyperthermic,Typic Haplusterts)								
Ap	0-17	10 YR 4/3	Clay	2 m sbk	sh	f	ms	mp
Bss1	17-49	10 YR 3/3	Clay	2 m sbk	sh	fi	vs	vp
Bss2	49-65	10 YR 3/3	Clay	2 m sbk	h	fi	vs	vp
Bss3	65-83	10 YR 3/3	Clay	2 m sbk	h	fi	vs	vp
Bss4	83-122	10 YR 3/3	Clay	2 m sbk	h	fi	vs	vp
Bss5	122-152	10 YR 3/3	Clay	2 m sbk	h	fi	vs	vp
Bss6	152-180	10 YR 3/3	Clay	2 m sbk	h	fi	ms	vp
Nandyal series (Fine, loamy, smectitic, iso-hyperthermic, Flurentic Haplustepts)								
Ap	0-25	5 YR 3/4	Clay	2 m sbk	sh	f	ms	mp
Bw1	25-55	5 YR 3/4	Clay	2 m sbk	sh	f	ms	mp
Bw2	55-70	5 YR 3/4	Clay	2 m sbk	sh	f	ms	mp
Bw3	70-95	5 YR 3/4	Clay	2 m sbk	sh	f	ms	mp
OCs	95-110	5 YR 4/4	Sand	1 f gr	l	l	ss	sp
BC2	110-150	5 YR 3/3	Clay	2 m sbk	sh	sh	ms	mp
BCk1	150-180	5 YR 3/3	Clay	1 f gr	l	l	sp	sp
Nidoni series (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)								
Ap	0-20	5 YR ¾	Clay	2 m sbk	sh	fr	ms	mp
Bw	20-50	5 YR 3/3	Clay	2 m sbk	h	fr	ms	mp
Bwk1	50-72	5 YR 3/3	Clay	2 m sbk	h	fr	ms	mp
Bwk2	72-114	5 YR 3/3	Clay	2 m sbk	h	fr	ms	mp
Bwk3	114-155	5 YR 3/3	Clay	2 m sbk	h	fr	ms	mp
Bwk4	155-197	5 YR 3/3	Clay	2 m sbk	h	fr		mp
Naihalla series (Very fine, smectitic, iso-hyperthermic, Leptic Haplusterts)								
Ap	0-12	10 YR 2/2	Clay	1 w sbk	sh	vf	ms	mp
Bw	12-38	10 YR 2/2	Clay	2 m sbk	sh	f	ms	mp
Bss	38-69	10 YR 2/2	Clay	2 m sbk	h	f	ms	mp
Rambhapur series (Fine, smectitic, iso-hyperthermic, Calcic Haplustepts)								
Ap	0-25	10 YR 4/2	Clay	2 m sbk	sh	f	ms	mp
BCk1	25-72	10 YR 3/3	Clay	2 m sbk	sh	f	ms	mp
BCk2	72-110	10 YR 4/3	Clay	2 m sbk	sh	f	ms	mp
BCk3	110-147	10 YR 3/3	Clay	2 m sbk	sh	f	ms	mp
Cr				Weathered basalt				
Rampur series (Very fine, smectitic, iso-hyperthermic, Typic Haplusterts)								
Ap	0-9	10 YR 3/3	Clay	2 m sbk	sh	f	ms	mp
Bw	9-44	10 YR 3/2	Clay	2 m sbk	Sh	f	ms	mp

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Bss1	44-83	10 YR 3/2	Clay	2 m sbk	sh	f	ms	mp
Bss2	83-130	10 YR 3/2	Clay	2 m sbk	sh	f	ms	mp
Bw2	130-148	10 YR 3/2	Clay	2 m sbk	sh	f	ms	mp
Cr	148			Weathered basalt				
Sarwad series (Fine, smectitic, iso-hyperthermic,Typic Haplustepts)								
Ap	0-20	10 YR 3/1	Clay	2 m sbk	s	fi	vs	vp
Bss1	20-50	10 YR 2/2	Clay	2 m sbk	vh	fi	vs	vp
Bss2	50-80	10 YR 2/2	Clay	3 m sbk	vh	fi	vs	vp
Bwk1	80-100	10 YR 3/3	Clay	3 m sbk	h	fr	ms	mp
Bwk2	100-140	10 YR 4/4	Clay	2 m sbk	h	fr	ms	mp
Bwk2	140-175	10 YR 4/4	Clay	2 m sbk	h	fr	ms	mp
Savanahalli series(Fine, smectitic, iso-hyperthermic, Typic Haplustepts)								
Ap	0-20	10 YR 4/2	Clay	2 m c	sh	f	ms	mp
Bw1	20-60	10 YR 4/2	Clay	2 m sbk	sh	f	ms	mp
Bw2	60-100	10 YR 4/2	Clay	2 f sbk	sh	f	ms	mp
Bw3	100-130	10 YR 4/3	Clay	2 f sbk	sh	f	ms	mp
Bw4	130-180	10 YR 4/3	Clay	2 f sbk	sh	f	ms	mp
Tenihalli series (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)								
AP	0-20	10 YR 4/3	Clay	2 m sbk	sh	fr	ms	mp
BCk1	20-40	10 YR 4/3	Clay	2 m sbk	sh	fr	ms	sp
BCk2	40-78	10 YR 4/2	Clay	1 f abk	l	l	ss	sp
CBk2	78-109	10 YR 3/3	Clay	1 f abk	l	l	ss	
Tonsyal Series (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)								
Ap	0-30	10 YR 3/2	Clay	2 m sbk	sh	f	ms	mp
Bw1	30-71	10 YR 4/2	Clay	2 m sbk	sh	f	ms	mp
BCk1	71-105	10 YR 4/3	Clay	2 m sbk	sh	f	ms	mp
BCk2	105-144	10 YR 4/3	Clay	2 m sbk	sh	f	ms	mp
BCk3	144-173	10 YR 4/3	Clay	2 m sbk	sh	f	ms	mp
Yakkundi series (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)								
Ap	0-14	10 YR 3/2	Clay	2 m sbk	sh	f	vs	vp
Bw_1	14-30	10 YR 3/2	Clay	2 m sbk		h	vs	vp
Bw_2	30-64	10 YR 3/2	Clay	2 m sbk		h	vs	vp
Bw_3	64-80	10 YR 4/3	Clay	2 m sbk		h	vs	vp
CB	89-94	10 YR 4/2	Clay	2 m sbk		h	vs	vp
Cr	94^+			Weathered basalt				

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Table 2. Physico chemical properties of Hittinahalli sub-watershed pedons

PROFILE	PHYSICAL PARAMETERS									CHEMICAL PROPERTIES								
	Gravel	C. Sand	F. Sand	Sand	Silt	Clay	BD	F.C.	PWP	pH	EC	OC	CaCO3	EX Ca	EX Mg	EX K	EX Na	CEC
	%						Mg m^{-3}				dS m^{-1}	%		C mol (p^+) kg^{-1}				
Atharga Series (ARG) (0-28) (Fine, smectitic, iso-hyperthermic, Lithic Ustorthents)																		
Ap (0-8)	2	18	10	28	28	44	1.49	23.7	18.3	7.59	0.09	0.43	27.0	34.0	4.2	0.11	0.65	38.96
Bw1 (8-21)	8	19	13	32	24	44	1.40	24.6	17.0	8.23	0.10	0.31	24.2	36.6	5.2	0.23	0.77	42.80
Babaleshwar series (BBL) (>150 cm) (fine, Smectitic, iso-hyperthermic Typic Calciusterts)																		
AP (0-15)	11	15	11	26	24	50	1.29	32.5	15.7	8.13	0.25	0.63	5.9	13.4	6.1	0.5	0.25	20.25
Bw (15-40)	7	14	8	22	24	54	1.35	35.4	17.1	8.52	0.18	0.46	6.8	12.5	5.3	0.65	0.33	18.78
Bss (40-60)	20	17	13	30	20	50	1.38	30.2	14.2	8.58	0.17	0.41	9.6	15.8	5.8	0.47	0.2	22.27
Bssk1 (60-100)	6	16	14	30	20	50	1.38	30.2	14.2	8.58	0.17	0.41	9.6	15.8	5.8	0.47	0.2	22.27
Bssk2 (100-140)	11	25	16	41	32	27	1.42	23.4	12.8	8.64	0.45	0.15	16.3	16.5	6.3	0.69	0.25	23.74
Bssk3 (140-170)	12	26	19	45	32	23	1.47	18.5	10.3	8.75	0.35	0.08	17.9	17.7	5.6	0.39	0.2	23.89
Dadamatti Series (DMT) (25-50) (Fine loamy, smectitic, iso-hyperthermic, Lithic Haplustepts)																		
Ap (0-12)	21	18	13	31	20	49	1.31	23.3	12.4	8.16	0.02	0.56	15.1	30.5	4.2	0.36	0.81	35.87
Bw (12-39)	13	27	16	43	20	37	1.40	20.2	10.8	8.37	0.20	0.53	12.9	29.0	4.8	0.48	1.20	35.48
Halagani Series (HLG) (100-150 cm) series (Fine, smectitic, iso-hyperthermic, Vertic Haplustepts)																		
Ap (0-35)	8	24	10	34	20	46	1.21	20.8	11.3	8.08	0.06	0.43	13.0	14.2	6.5	0.80	0.66	22.16
Bw1(35-70)	8	24	14	38	14	48	1.24	22.6	12.5	8.34	0.07	0.41	11.4	18.6	6.8	0.70	0.54	26.64
Bw2(70-100)	2	20	14	34	16	50	1.31	25.8	14.9	8.35	0.08	0.27	12.0	20.3	8.5	0.40	0.42	29.62
Bw3(100-125)	7	20	10	30	20	50	1.34	26.1	16.2	8.67	0.08	0.29	10.4	22.4	8.2	0.71	0.51	31.82
Honnutagi Series (HNT) (>150 cm) (Fine, loamy, smectitic, iso-hyperthermic, FlurenticHaplustepts)																		
Ap (0-20)	2	23	18	41	12	47	1.27	-	-	8.76	0.11	0.72	12.7	20.9	8.5	0.36	0.61	30.37
Bw1 (20-55)	3	26	15	41	16	43	1.31	-	-	8.56	0.14	0.56	14.2	22.5	4.1	0.3	0.59	27.49
Bw2 (55-90)	5	29	16	45	24	31	1.42	-	-	8.89	0.09	0.41	14	23	4.8	0.3	0.61	28.71

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Bw3 (90-115)	11	24	17	41	28	31	1.47	-		8.64	0.12	0.33	13.8	23.2	4.1	0.27	0.62	28.19
BC3 (125-140)	32	28	26	54	16	30	1.48	24.8	12.3	8.48	0.10	0.16	3.9	18.6	6.2	0.34	0.74	25.88
Jamunal series (Fine, smectitic, iso-hyperthermic, Typic Haplusterts)																		
Ap (0-31)	1	26	16	42	18	40	1.21	29.3	14.8	8.24	0.31	0.66	19.8	20.8	4.2	0.36	0.84	26.2
Bss1 (31-60)	4	31	15	46	20	34	1.23	26.6	10.6	8.37	0.36	0.53	21.7	21.5	5.2	0.28	0.74	27.72
Bss2 (60-71)	2	24	18	42	20	38	1.26	26.8	11.5	8.56	0.3	0.41	14.3	20.3	3.6	0.2	0.91	25.01
BCk1 (71-80)	2	26	16	42	16	42	1.27	30.4	16.4	8.61	0.37	0.33	16.5	24.2	4.5	0.24	0.63	29.57
Bss3 (80-97)	2	18	12	30	24	46	1.34	35.8	19.3	8.42	0.23	0.23	16	16.6	3.2	0.18	0.91	20.89
Kalgurki Series (KGR) (50-75) (Fine, smectitic, iso-hyperthermic,Typic Haplustepts)																		
Ap (0-19)	1	16	10	26	28	46	1.23	29.2	13.2	8.21	0.08	0.45	2.0	22.1	7.5	0.50	0.96	31.06
Bw1 (19-32)	5	20	14	34	24	42	1.35	27.8	11.9	8.23	0.10	0.41	1.8	29.8	6.8	0.41	0.93	37.94
BCk1 (32-70)	9	16	10	26	24	50	1.32	30.2	13.6	8.32	0.13	0.12	0.7	24.3	8.2	0.49	0.94	33.93
Karjol Series (KRJ) (>150 cm) (Fine, smectitic, iso-hyperthermic,Typic Haplusterts)																		
Ap (0-17)	3	17	9	26	24	50	1.27	32.6	19.4	8.81	0.22	0.53	11.3	23.2	6.3	0.18	0.68	30.36
Bss1 (17-49)	6	14	8	22	28	50	1.28	34.5	18.7	8.87	0.23	0.33	14.3	18.0	4.8	0.21	0.62	23.63
Bss2 (49-65)	6	6	8	14	32	54	1.34	36.8	18.9	8.56	0.26	0.27	21.0	24.6	6.9	0.20	0.66	32.36
Bss3 (65-83)	7	11	7	18	28	54	1.36	38.2	14.3	8.28	0.23	0.29	20.0	23.0	5.6	0.16	0.61	29.37
Bss4 (83-122)	10	8	6	14	32	54	1.45	39.1	15.1	9.07	0.12	0.23	22.4	25.0	6.6	0.15	0.57	32.32
Bss5 (122-152)	4	10	4	14	28	58	1.47	41.7	19.3	9.39	0.11	0.14	23.0	21.7	3.5	0.24	0.64	26.08
Bss6 (152-180)	5	11	7	18	24	58	1.48	44.8	19.1	9.41	0.15	0.11	25.3	21.7	3.4	0.03	0.61	25.74
Nandhyal Series (NDL) (>150 cm) (Fine, loamy, smectitic, iso-hyperthermic, Flurentic Haplustepts)																		
Ap (0-25)	2	22	12	34	30	38	1.28	26.5	14.3	8.58	0.06	0.33	8.1	38.9	10.7	0.39	0.67	50.66
Bw1 (25-55)	2	20	16	36	30	34	1.29	21.3	10.5	8.61	0.06	0.25	6.0	42.3	12.5	0.30	0.63	55.73
BW2 (55-70)	4	20	14	34	28	38	1.34	25.5	15.5	8.79	0.08	0.21	8.2	43.6	10.8	0.15	0.74	55.29
Bw3 (70-95)	17	24	14	38	32	30	1.36	20.7	12.4	8.54	0.07	0.12	8.5	50.6	11.4	0.15	0.68	62.83
C-S (95-110)	10	73	18	92	4	4	1.39	14.6	9.4	8.77	0.09	0.10	8.9	52.9	14.4	0.13	0.66	68.09
BC2 (110-150)	19	24	18	42	24	34	1.40	17.2	11.3	8.71	0.10	0.10	9.7	51.8	12.0	0.14	0.75	64.69
BCK1 (150-180)	18	36	16	52	12	36	1.44	20.8	13.1	8.75	0.09	0.08	10.1	52.6	12.4	0.12	0.84	65.96

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Nidoni Series (NDN) (> 150cm) (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)																	
Ap (0-20)	20	23	15	38	16	46	1.21	30.4	12.2	8.48	0.05	0.72	16.9	26.6	5.9	0.17	0.33	33.00
Bw1 (20-51)	3	28	14	42	16	42	1.22	24.3	10.6	8.51	0.08	0.39	16.2	21.5	6.3	0.31	0.44	28.55
Bw2 (51-70)	5	20	14	34	20	46	1.27	26.8	11.5	8.63	0.07	0.35	13.7	22.8	4.5	0.32	0.70	28.32
BCk1 (70-81)	26	24	18	42	12	46	1.26	28.7	12.8	8.58	0.08	0.31	13.3	24.5	4.9	0.31	0.67	30.38
BCk2 (81-110)	22	19	15	34	12	54	1.25	32.4	16.7	8.59	0.09	0.10	12.6	21.3	8.5	0.20	0.73	30.73
BCk3(110155)	28	17	13	30	16	54	1.30	34.5	17.8	8.72	0.10	0.06	12.0	21.7	9.4	0.19	0.53	31.82
BC (155-185)	8	22	16	38	12	50	1.29	32.1	16.3	8.78	0.10	0.02	11.4	27.6	9.8	0.18	0.58	38.16
Naihalla Series (NHL) (50-75) (Very fine, smectitic, iso-hyperthermic, Leptic Haplusterts)																	
Ap (0-12)	1	10	8	18	20	62	1.22	37.4	21.1	8.26	0.15	0.52	10.4	32.6	4.8	0.36	0.58	38.3
Bw (12-38)	3	11	7	18	24	58	1.26	29.2	13.2	8.30	0.20	0.49	13.8	35.6	5.2	0.31	0.61	41.7
Bss (38-69)	13	8	6	14	24	62	1.39			8.46	0.24	0.39	11.0	32.0	4.4	0.35	0.69	37.4
Rambhapur Series (RMB) (100-150 cm) (Fine, smectitic, iso-hyperthermic, Calcic Haplustepts)																	
Ap (0-25)	19	20	18	38	20	42	1.34	29.1	23.3	8.18	0.10	0.43	23.9	25.0	4.1	0.28	0.89	30.27
BCk1(25-72)	13	18	16	34	24	42	1.33	28.9	21.4	8.23	0.12	0.19	31.6	29.5	6.8	0.36	0.90	37.56
BCk2 (72-110)	27	22	18	40	22	38	1.42	27.2	18.3	8.36	0.10	0.12	32.5	23.0	6.4	0.34	1.13	30.87
BCk3 (110-147)	27	21	17	38	24	38	1.50	26.8	17.1	8.49	0.22	0.02	37.3	19.0	5.6	0.25	1.14	25.99
Rampur Series (RPR) (100-150 cm) (Very fine, smectitic, iso-hyperthermic, Typic Haplusterts)																	
Ap (0-9)	8	6	10	16	24	60	1.30	34.5	17.2	8.37	0.13	0.29	11.2	23.5	6.1	0.33	0.49	30.42
Bw (9-44)	3	8	6	14	20	66	1.36	36.6	20.1	8.23	0.16	0.19	11.1	22.1	6.5	0.65	0.66	29.91
Bss1 (44-83)	3	6	8	14	16	70	1.43	38.6	22.6	8.47	0.17	0.16	8.8	18.7	7.1	0.49	0.40	26.69
Bss2 (83-130)	3	4	6	10	20	70	1.40	39.2	24.5	8.59	0.18	0.14	7.9	13.1	5.6	0.35	0.74	19.79
Sarwad Series (SRD) (>150 cm) (Fine, smectitic, iso-hyperthermic, Vertic Calciustepts)																	
Ap (0-20)	1	22	15	38	16	46	1.26	32.4	16.4	8.20	0.92	0.43	19.9	22.8	7.4	0.24	1.05	31.49
Bw1 (20-45)	1	17	13	30	20	50	1.27	36.1	20.3	8.29	0.86	0.41	22.0	22.9	6.3	0.22	1.17	30.59
Bss1 (45-76)	2	16	14	30	16	54	1.33	39.1	19.6	8.41	0.91	0.36	22.4	35.6	9.4	0.19	1.13	46.32
BCk1 (76-106)	7	18	12	30	24	46	1.38	31.2	15.4	8.45	0.94	0.16	21.5	35.4	4.7	0.36	0.70	41.16
BCk2 (106-139)	14	15	11	26	24	50	1.47	35.5	18.3	8.69	1.27	0.14	27.1	29.6	5.2	0.29	0.96	36.05

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BCk3(139-170)	5	16	14	30	16	54	1.54	40.3	22.4	8.72	1.24	0.08	28.6	30.3	5.8	0.11	1.06	37.27
Savanahalli Series (SVL) (>150 cm) (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)																		
Ap (0-20)	2	10	14	24	28	48	1.40	19.3	8.6	8.06	0.09	0.72	3.5	31.3	4.4	0.48	0.58	36.76
Bw1 (20-60)	1	16	13	29	24	47	1.42	19.0	10.1	8.19	0.11	0.21	6.0	31.7	4.1	0.51	0.78	37.09
Bw2 (60-100)	2	12	14	26	26	48	1.46	18.3	8.6	8.27	0.13	0.14	6.6	24.0	5.1	0.32	0.80	30.22
Bw3 (100-130)	3	13	12	25	24	51	1.44	16.1	11.0	8.42	0.15	0.04	2.5	34.6	4.6	0.29	1.03	40.52
Bw4 (130-180)	3	10	14	24	24	52	1.59	21.2	10.3	8.56	0.10	0.06	7.4	26.0	3.4	0.32	0.98	30.70
Thenihalli series (THL) (75-100 cm) (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)																		
Ap (0-20)	20	18	12	30	24	46	1.41	32.3	15.3	8.57	0.22	0.54	17.6	27.1	6.0	0.34	0.92	34.36
BCk1 (20-40)	18	16	14	30	20	50	1.52	37.5	18.3	8.64	0.23	0.35	16.5	29.7	5.4	0.16	0.99	36.25
BCk2 (40-78)	25	19	15	34	24	42	1.54	33.5	14.7	8.66	0.15	0.21	15.3	36.5	7.2	0.32	0.74	44.76
CBk1 (78-109)	27	20	14	34	20	46	1.50	34.8	16.2	8.82	0.17	0.11	14.4	24.8	6.5	0.33	0.73	32.36
CB (109-140)	22	17	13	30	24	46	1.49	33.6	15.2	9.06	0.17	0.08	14.8	47.6	7.9	0.35	0.80	56.65
Tonshyal series (TSL) (>150 cm) (Fine, smectitic, iso-hyperthermic, Typic Calcicustepts)																		
Ap (0-30)	4	22	12	34	32	34	1.36	25.6	18.3	9.14	0.35	0.60	17.5	29.3	6.5	0.32	1.00	37.12
Bw1 (30-71)	14	19	11	30	32	38	1.38	29.1	19.2	8.39	0.22	0.31	21.4	31.2	8.6	0.31	1.05	41.16
BCK1 (71-105)	12	20	10	30	28	42	1.41	34.3	23.3	8.45	0.36	0.21	21.8	30.7	6.1	0.26	0.96	38.02
BCK2 (105-144)	12	16	10	26	28	46	1.42	36.6	25.1	8.66	0.27	0.02	23.6	25.3	4.8	0.28	1.04	31.42
BCK3 (144-173)	8	15	11	26	28	46	1.42	37.2	26.7	8.84	0.46	0.04	25.3	18.7	3.4	0.22	0.64	22.96
Yakkundi Series (YKD) (75-100) (Fine, smectitic, iso-hyperthermic, Typic Haplustepts)																		
Ap (0-14)	12	16	10	26	20	54	1.25	26.4	12.1	8.29	0.20	0.53	10.9	18.3	5.5	0.08	0.33	24.21
Bw1 (14-30)	11	15	11	26	16	58	1.27	29.8	14.5	8.63	0.17	0.31	13.3	18.6	4.6	0.13	0.29	23.62
Bw2 (30-64)	5	18	12	30	16	54	1.34	25.1	12.6	8.99	0.20	0.21	14.4	17.8	5.7	0.18	0.35	24.03
Bw3 (64-80)	4	18	12	30	24	46	1.37	20.4	10.2	9.22	0.40	0.16	9.8	19.7	4.2	0.24	0.50	24.64
CB (80-94)	9	28	18	46	16	38	1.43	18.8	9.2	9.03	0.50	0.08	16.6	20.1	5.0	0.09	0.23	25.42

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3.1.1 Physical characteristics:

The physical characteristics of the soil are presented in Table 2. 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. The particle size data indicated that clay content varied from 4 to 70 percent, silt content from 4 to 32 percent, and sand content from 4 to 92 percent. These soil separates were irregularly distributed in all the pedons. However, Rambhapur pedon clay content increased with depth. The increase in clay content through the soil depth observed in the study could be attributed to several processes, like the illuviation of the finer fraction to the lower depth. A similar trend was also noticed by Dasog (1975) in the vertisols of the Upper Krishna of Karnataka and Balpande *et al.* (1996) in the degraded Vertisols of the Purna valley of Maharashtra. The clay content remained uniformly high (>35%) throughout pedons (except Atharga, Nandhyal, and Babaleshwara pedons) in soils belonging to the order Vertisols or vertic subgroup.

The bulk density varied from 1.12 to 1.54 Mg per m^3. In general, the bulk density of the lower solum was higher than that of the upper solum. This could be attributed to the clogging of pores by dispersed clays in sub-soil layers (Mathur and Mahendra, 1994) and the reduction of organic carbon with depth. Similar findings were reported by Ravikumar *et al. (2007)* and Dasog and Patil (2011) in the black soils of north Karnataka.

3.1.2 Chemical characteristics:

The pH of the pedons ranged from moderately alkaline (7.59) to strongly alkaline (9.41). High pH in black pedons due to their calcareous nature and the accumulation of bases in the solum as they were poorly leached (Satyanarayana and Biswas, 1970). In the case of the soil, pH with depth was evident in some of the pedons, which may be ascribed to the increasing content of exchangeable and soluble sodium and calcium. PH increased with depth, which could be due to the leaching of exchangeable bases from the surface horizon. Higher pH values were also recorded by Balpande *et al.* (1996) in degraded Vertisols in Purna Valley. This increase in soil reaction down the slope could be due to the leaching of bases from higher topography and getting deposited at lower elevations (Sitanggang *et al.*, 2006).

The EC values of the soils ranged from 0.02 to 1.27 dS per m. In the soils studied, the electrical conductivity generally increased with depth. The upper solum was relatively lower in salt than the lower solum. This might be due to the leaching of salts from the soil surface to lower depths due to irrigation and their accumulation in lower depths. Even at the time when irrigation was introduced, the distribution of salts showed a concentration of salts in the lower solum (Dasog and Hadimani, 1980) in the Malaprabha project area.

The free calcium carbonates in pedons varied from 3.5 to 37.3 percent. Krishnamurthy and Govindarajan (1977) reported the abundance of $CaCO_3$ in black soils. Vertisols in India have a $CaCO_3$ content generally ranging from 7.0 to 12 percent (Dudal, 1965). Similar results were also reported for Vertisols in north Karnataka (Ravikumar *et al., 2007).*

The organic carbon content of pedons ranged from 0.08 to 0.75 percent, which in general accumulated in surface layers. The lower contents of organic carbon apparently resulted from high temperatures, which induced a rapid rate of organic matter oxidation, while the declining trend towards the

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accumulation of crop residues every year, without substantial downward movement, Observations in line with the present findings have been reported in salt-affected soils of the Purna Command Area of Maharashtra by Balpande *et al.* (1996). Medirate *et al.* (1985) in Harshi Command Area of Madhya Pradesh, and Basavaraju *et al.* (2005) in the soils of Chandragiri Mandal of Chittor district of Andhra Pradesh. The organic carbon content of the surface soil was greater than the sub-surface soils in most of the pedons due to the high amount of litter and crop residues at the surface. Organic carbon content of the soils, followed by a decreasing trend with depth in all the pedons. It reflects the rapid rate of organic matter mineralization in these soils. Similar findings were reported by Mruthynjaya and Kenchanagowda (1993) in the Vanivilas Command Area, Shadaksharappa *et al.* (1995), and Ravikumar *et al.* in the Malaprabha Command Area of Karnataka.

Among the extractable bases, the exchangeable calcium content of the soils ranged from 13.1 to 52.6 cmol (p+)kg^{-1}. Exchangeable magnesium ranged from 3.4 to 14.4 cmol (p+)kg^{-1}, soil. Exchangeable sodium ranged from 0.23 to 1.20 cmol (p+)kg^{-1}, in soil. Exchangeable potassium ranged from 0.11 to 0.49 cmol (p+)kg^{-1}, in the soil. Exchangeable cations followed in the following order: Ca>Mg>Na>K (Table 1). Indicating the presence of calcium-bearing minerals in parent rocks. Similar results were reported by Sarkar *et al.* (2001), Tripathi *et al.* (2006), and Thangasamy *et al.* (2005).

3.2 Soil classification

Based on the morphological characteristics and physical and chemical properties of the typifying pedons, the soils are classified under Entisols, Inceptisols, and Vertisols by following the Keys to Soil Taxonomy (Soil Survey Staff, 2014). Totally, 18 soil series were identified and mapped into seventy-four phases of soil series. Among the different mapping units, the KRJmB2 soil mapping unit occupied a maximum area of 1902 hectares, accounting for 18.24 percent of the total watershed area (TWA), followed by SRDmB2 (6.28%), NDNmB2 (4.87%), and NDNmB2g1Ca (4.2%), together covering an area of 3502 ha. The remaining seventy mapping units covered an area ranging from 3 to 365 ha, constituting 56.34 percent of the area (Fig. 2).

Table 3: Major soil mapping units and their extent in Hittinahalli sub-watershed

Soil map units	Description	Area (ha)	Percentage
ARGcB2g2	Very shallow, very gravelly (35-60%) sandy loam soils of Atharga series occurring on very gently sloping (1-3%), moderately eroded lands.	14	0.13
ARGfB2g1	Very shallow, gravelly (15-35%) clay loam soils of Atharga series occurring on very gently sloping (1-3%), moderately eroded lands.	89	0.85
ARGfB3g1	Very shallow, gravelly (15-35%) clay loam soils of Atharga series occurring on very gently sloping (1-3%), severely eroded lands.	12	0.11
ARGfC3g1	Very shallow, gravelly (15-35%) clay loam soils of Atharga series occurring on gently sloping (3-5%), severely eroded lands.	87	0.83

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ARGhB2g2	Very shallow, very gravelly (35-60%) sandy clay loam soils of Atharga series occurring on very gently sloping (1-3%), moderately eroded lands.	67	0.64
ARGmB2g1	Very shallow, gravelly (15-35%) clay soils of Atharga series occurring on very gently sloping (1-3%), moderately eroded lands.	94	0.90
ARGmB2g1Ca	Very shallow, gravelly (15-35%) clay soils of Atharga series occurring on very gently sloping (1-3%), moderately eroded lands.	21	0.20
ARGmB2g3Ca	Very shallow, extremely gravelly (60-80%) clay soils of Atharga series occurring on very gently sloping (1-3%), moderately eroded lands.	86	0.82
BBLmB2	Very deep, clay soils of Babaleshwar series occurring on very gently sloping (1-3%), moderately eroded lands.	101	0.97
BBLmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Babaleshwar series occurring on very gently sloping (1-3%), moderate eroded lands.	39	0.37
DMTfB2	Shallow, clay loam soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	10	0.10
DMTfB2g1	Shallow, gravelly (15-35%) clay loam soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	246	2.36
DMTfB2g2	Shallow, very gravelly (35-60%) clay loam soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	16	0.16
DMTfB3g1	Shallow, gravelly (15-35%) clay loam soils of Dadamatti series occurring on very gently sloping (1-3%), severely eroded lands.	21	0.20
DMTfC3g1	Shallow, gravelly (15-35%) clay loam soils of Dadamatti series occurring on gently sloping (3-5%), severely eroded lands.	9	0.09
DMThB2g1	Shallow, gravelly (15-35%) sandy clay loam soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	32	0.31
DMTmB2	Shallow, clay soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	112	1.07
DMTmB2g1	Shallow, gravelly (15-35%) clay soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	73	0.70
DMTmB2g1Ca	Shallow, gravelly (15-35%) clay soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	315	3.02

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DMTmB2g2Ca	Shallow, very gravelly (35-60%) clay soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	109	1.05
DMTmB2g3Ca	Shallow, extremely gravelly (60-80%) clay soils of Dadamatti series occurring on very gently sloping (1-3%), moderately eroded lands.	69	0.67
DMTmB3	Shallow, clay soils of Dadamatti series occurring on very gently sloping (1-3%), severely eroded lands.	33	0.32
HLGmB2	Deep, clay soils of Halagani series occurring on very gently sloping (1-3%), moderately eroded lands.	16	0.16
HLGmB2g1	Deep, gravelly (15-35%) clay soils of Halagani series occurring on very gently sloping (1-3%), moderately eroded lands.	27	0.26
HLGmB2g1Ca	Deep, gravelly (15-35%) clay soils of Halagani series occurring on very gently sloping (1-3%), moderately eroded lands.	48	0.46
HNTmB2g1Ca	Very deep, gravelly (15-35%) clay soils occurring on very gently sloping (1-3%), moderately eroded lands.	45	0.44
JMLmB2	Deep clay soils of Jamnal series occurring on very gently sloping (1-3%), moderately eroded lands.	28	0.27
JMLmB2g1	Deep clay soils of Jamnal series occurring on very gently sloping (1-3%), gravelly with 15-35% gravels, moderately eroded lands.	26	0.25
JMLmB2g1Ca	Deep, gravelly (15-35%) clay soils of Jamnal series occurring on very gently sloping (1-3%), moderately eroded lands.	35	0.33
JMLmB2g2Ca	Deep, very gravelly (35-60%) clay soils of Jamnal series occurring on very gently sloping (1-3%), moderately eroded lands.	41	0.40
KGRmB2	Moderately shallow, clay soils of Kalgurki series occurring on very gently sloping (1-3%), moderately eroded lands.	66	0.63
KGRmB2g1	Moderately shallow, gravelly (15-35%) clay soils of Kalgurki series occurring on very gently sloping (1-3%), moderately eroded lands.	62	0.59
KGRmB2g1Ca	Moderately shallow, gravelly (15-35%) clay soils occurring on very gently sloping (1-3%), moderately eroded lands.	7	0.07
KRJmB2	Very deep, clay soils of Karjol series occurring on very gently sloping (1-3%), moderate eroded lands.	1902	18.24

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KRJmB2g1	Very deep, gravelly (15-35%) clay soils of Karjol series occurring on very gently sloping (1-3%), moderate eroded lands.	108	1.04
KRJmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Karjol series occurring on very gently sloping (1-3%), moderately eroded lands.	67	0.65
KRJmB3	Very deep, clay soils of Karjol series occurring on very gently sloping (1-3%), severely eroded lands.	203	0.91
KRJmB3g1Ca	Very deep, gravelly (15-35%) clay soils of Karjol series occurring on very gently sloping (1-3%), severely eroded lands.	2	0.01
NDLmB2	Very deep, clay soils of Nandyal series occurring on very gently sloping (1-3%), moderate eroded lands.	62	0.59
NDLmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Nandyal series occurring on very gently sloping (1-3%), moderately eroded lands.	21	0.20
NDNmB2	Very deep, clay soils of Nidoni series occurring on very gently sloping (1-3%), moderate eroded lands.	507	4.87
NDNmB2g1	Very deep, gravelly (15-35%) clay soils of Nidoni series occurring on very gently sloping (1-3%), moderate eroded lands.	217	2.08
NDNmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Nidoni series occurring on very gently sloping (1-3%), moderately eroded lands.	438	4.20
NDNmB2g2Ca	Very deep, very gravelly (35-60%) clay soils of Nidoni series occurring on very gently sloping (1-3%), moderately eroded lands..	111	1.06
NDNmB2g3Ca	Very deep, clay soils of Nidoni series occurring on very gently sloping (1-3%), moderately eroded lands.	17	0.16
NDNmB3g1Ca	Very deep, gravelly (15-35%) clay soils of Nidoni series occurring on very gently sloping (1-3%), severely eroded lands.	16	0.16
NHLmB2g1Ca	Moderately shallow, clay soils of Naihalla series occurring on very gently sloping (1-3%), moderately eroded lands.	79	0.75
NHLmB2g2Ca	Moderately shallow, very gravelly (35-60%) clay soils of Naihalla series occurring on very gently sloping (1-3%), moderately eroded lands.	54	0.52
NHLmB2g3Ca	Moderately shallow, extremely gravelly (60-80%) clay soils of Naihalla series occurring on very gently sloping (1-3%), moderately eroded lands.	126	1.21

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NHLmC3g2Ca	Moderately shallow, very gravelly (35-60%) clay soils of Naihalla series occurring on gently sloping (3-5%), severely eroded lands.	12	0.12
RMBhB2g1	Deep, gravelly (15-35%) sandy clay loam soils of Rambhapur series occurring on very gently sloping (1-3%), moderately eroded lands.	14	0.14
RMBmB2	Deep, clay soils of Rambhapur series occurring on very gently sloping (1-3%), moderately eroded lands.	407	3.90
RMBmB2g1	Deep, gravelly (15-35%) clay soils of Rambhapur series occurring on very gently sloping (1-3%), moderately eroded lands.	49	0.47
RMBmB2g1Ca	Deep, gravelly (15-35%) clay soils of Rambhapur series occurring on very gently sloping (1-3%), moderately eroded lands.	321	3.08
RMBmB2g2Ca	Deep, very gravelly (35-60%) clay soils occurring on very gently sloping (1-3%), moderately eroded lands.	190	3.92
RPRmB2	Deep clay soils of Rampur series occurring on very gently sloping (1-3%), moderately eroded lands.	143	1.37
RPRmB2g1	Deep, gravelly (15-35%) clay soils of Rampur series occurring on very gently sloping (1-3%), moderately eroded lands.	11	0.10
SRDmB2	Very deep, clay soils of Sarwad series occurring on very gently sloping (1-3%), moderately eroded lands..	655	6.28
SRDmB2g1	Very deep, gravelly (15-35%) clay soils of Sarwad series occurring on very gently sloping (1-3%), moderate eroded lands.	49	0.47
SRDmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Sarwad series occurring on very gently sloping (1-3%), moderately eroded lands.	208	1.99
SRDmB2g2Ca	Very deep, very gravelly (35-60%) clay soils of Sarwad series occurring on very gently sloping (1-3%), moderately eroded lands.	6	0.06
SVLmB2	Very deep, clay soils of Savanahalli series occurring on very gently sloping (1-3%), moderately eroded lands.	101	0.97
SVLmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Savanahalli series occurring on very gently sloping (1-3%), moderate eroded lands.	37	0.36
THLmB2	Moderately deep, clay soils of Tenihalli series occurring on very gently sloping (1-3%), moderately eroded lands.	88	0.34

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THLmB2g1	Moderately deep, gravelly (15-35%) clay soils of Tenihalli series occurring on very gently sloping (1-3%), moderately eroded lands.	128	1.22
THLmB2g1Ca	Moderately deep, gravelly (15-35%) clay soils of Tenihalli series occurring on very gently sloping (1-3%), moderately eroded lands.	343	3.29
THLmB2g2Ca	Moderately deep, very gravelly (35-60%) clay soils of Tenihalli series occurring on very gently sloping (1-3%), moderately eroded lands.	365	3.50
THLmB2g3Ca	Moderately deep, extremely gravelly (60-80%) clay soils occurring on very gently sloping (1-3%), moderately eroded lands.	22	0.21
TSLmB2	Very deep, clay soils of Tonshyal series occurring on very gently sloping (1-3%), moderately eroded lands.	53	0.51
TSLmB2g1Ca	Very deep, gravelly (15-35%) clay soils of Tonshyal series occurring on very gently sloping (1-3%), moderate eroded lands.	102	0.97
TSLmB2g2Ca	Very deep, very gravelly (35-60%) clay soils of Tonshyal series occurring on very gently sloping (1-3%), moderately eroded lands.	3	0.03
YKDhB2g1	Moderately deep, gravelly (15-35%) sandy clay loam soils of Yakkundi series occurring on very gently sloping (1-3%), moderately eroded lands.	14	0.13
YKDmB2g1	Moderately deep, gravelly (15-35%) clay soils of Yakkundi series occurring on very gently sloping (1-3%), moderately eroded lands.	39	0.38
YKDmB2g1Ca	Moderately deep, gravelly (15-35%) clay soils of Yakkundi series occurring on very gently sloping (1-3%), moderately eroded lands.	28	0.27
Railway	Railway	12	0.11
Others	Habitation & Water body	1038	9.96
10424.60	100		

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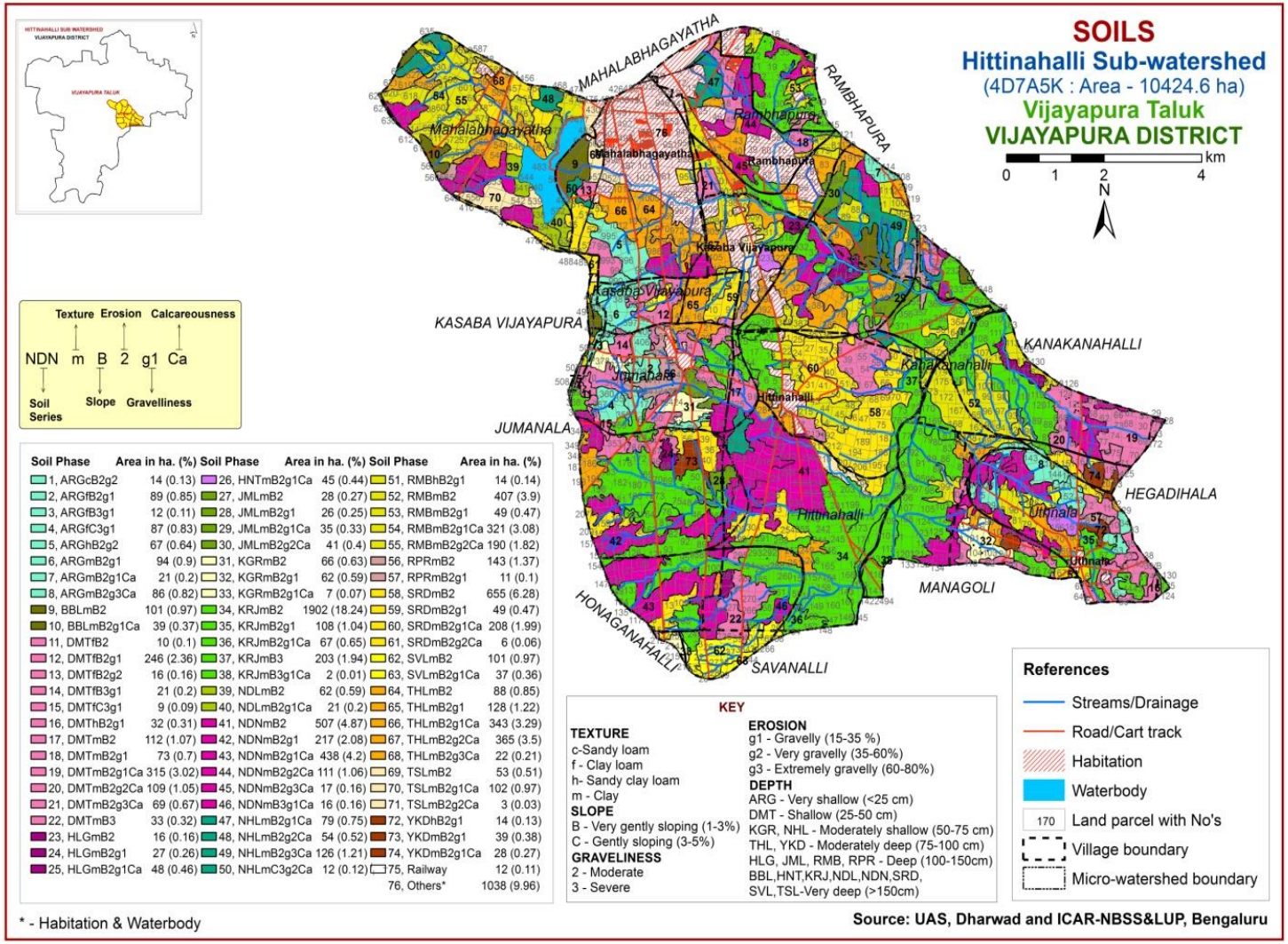

Fig 2: Soil map of Hittinahalli sub-watershed

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3.3 Status of land resources

3.3.1 Atharga series:

The soils of the Atharga series are formed from weathered Basalt. They are classified at family level as Fine loamy, smectitic, and iso-hyperthermic Lithic Ustorthents. The gravel percentage ranged from 0 to 5 percent, following an increasing trend with an increase in soil depth. The texture is sandy loam. Bulk density varied from 1.30 to 1.33 Mgm^{-3} which increased with soil depth. The horizon sequence is Ap- AC

3.3.2 Babaleshwara series:

Soils of the Babaleshwara series are classified at family level as Fine, Smectitic, iso-hyperthermic, and typic calciusterts. The gravel percentage is 6 to 20 percent. The texture is clay-like loam. Bulk density varied from 1.29 to 1.47 Mgm^{-3} which increased with soil depth. The horizon sequence is Ap- Bw- Bss- Bssk.

3.3.3 Dadamatti series:

The soils of the Dadamatti series belonging to the fine loamy, smectitic, iso-hyperthermic, and lithic haplustepts are shallow, moderately well drained, and have a non-gravelly clay texture. The clay content varied from 37 to 49 percent in the subsoil. The pH of the surface layer is 8.16, and it increases with depth. The EC of surface soil is 0.02dSm^{-1}. The horizon sequence is Ap - Bw .

3.3.4 Halagani series:

The soils of the Halagani series are formed from weathered Basalt. They are classified at family level as fine, smectitic, iso-hyperthermic, and vertical haplustepts." The depth of the soil ranges from 100–150 cm. The colour varied from a very dark greyish brown to a very dark brown. The soil texture is clay. The gravel content was found to be <15 percent. The horizon sequence is Ap-BBw_1 - Bw_2 - Bw_3- Cr.

3.3.5 Honnutagi series:

They are classified at family level as fine, loamy, smectitic, iso-hyperthermic, flurentic haplustepts. The gravel percentage ranged from 1 to 13 percent. The texture is clay. Bulk density varied from 1.25 to 1.51 Mgm^{-3} which increased with soil depth. The horizon sequence is Ap- Bw_1 - Bw_2 - $Bssk_1$, Bw_3 - BCk_1, Bss.

Soil pH ranged from 8.13 to 8.58, suggesting that the soils are moderately alkaline in nature. The pH value increased with soil depth. The electrical conductivity of the soils ranged from 0.09 to 0.17 dSm^{-1} indicating the soil is non-saline. The organic carbon content ranged from 0.02 to 0.43 percent and decreased with depth. The horizon sequence is Ap- Bw_1 - Bw_2 - $Bssk_1$- Bw_3, BCk_1, Bss.

3.3.6 Jumanal series:

The Soils of the Jumanal series are formed from weathered Basalt. They are classified at family level as fine, smectitic, iso-hyperthermic, and they are classified at family level as "fine,"

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"smectitic," "iso-hyperthermic," and "typic" haplusterts. Soil pH ranged from 8.24 to 8.67, suggesting that the soils are moderately alkaline in nature. The pH value increased with soil depth. The electrical conductivity of the soils ranged from 0.22 to 0.40 dSm^{-1} indicating the soil is non-saline. The organic carbon content ranged from 0.08 to 0.66 percent and decreased with depth. The horizon sequence is Ap- Bss_1 - Bss_2 - Bck_1- Bss_3 - Bck_2-Cr.

3.3.7 Kalgurki series:

The soils of the Kalgurki series are formed from weathered basalt. They are classified at family level as fine, smectitic, iso-hyperthermic, Haplustepts A relatively higher clay content was observed in sub-surface soils than in surface soils. The surface soil had a pH of 8.21. Electrical conductivity was higher in the subsurface than in the surface layer. The organic carbon content of surface soils is 0.45 g kg^{-1}, and it decreases with depth. The horizon sequence is Ap- Bw_1 - Bck_1- Cr.

3.3.8 Karjol series:

Soils were classified as fine, smectitic, iso-hyperthermic, and typic haplusterts." The clay content of the surface soil was 50 per cent and it increased in subsequent layers. The pH of the surface soil was 8.81, and it was irregularly distributed in subsequent layers. The organic carbon content of surface soil was 0.53 g kg^{-1}, and it decreased with depth. The horizon sequence is Ap- Bss_1- Bss_2- Bss_3- Bss_4 - Bss_5 - Bss_6.

3.3.9 Nandhyhal series:

The soils of the Nandhyhal series are formed from weathered Basalt. They are classified at family level as fine, loamy, smectitic, iso-hyperthermic, Flurentic Haplustepts. The depth of the soil ranges from 100–150 cm. The colour varied from olive to dark brown. The soil texture is clay. The gravel content was found to be <15 percent. The horizon sequence is Ap- Bw_1 - Bw_2 - Bw_3- Cs- Bc_2- Bck_1.

3.3.10 Nidoni series:

Nidoni series, representing Fine, smectitic, iso-hyperthermic, and type I Haplustepts have a clay texture. Clay content varied from 59 to 65 percent, and the soil pH of surface and sub-surface layers ranged from 8.08 to 8.79. EC in the surface soil layer is 0.11 dSm^{-1}. The organic carbon content of surface soil is 0.53 g kg^{-1}; it decreased in adjustment layers. The horizon sequence is Ap – Bw1- Bck1-Bck2-Bck3-Bc.

3.3.11 Naihalla series:

They are classified at family level as very fine, smectitic, iso-hyperthermic, and leptic haplusterts." The depth of the soil is 50–75 cm. The colour varied from very dark brown to black. The soil texture is clay. The gravel content is found to be <15 percent. The horizon sequence is Ap- Bw- Bss – Crk.

3.3.12 Rambhapur series:

The soils of the Rambhapur series are formed from weathered basalt. They are classified at family level as fine, smectitic, iso-hyperthermic, and Calcic Haplustepts. The gravel percentage ranged

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from 13 to 27 percent. The texture is clay. Bulk density varied from 1.33 to 1.50 Mgm^{-3} which increased with soil depth. The horizon sequence is Ap-BCk_1 - BCk_2 - BCk_3.

3.3.13 Rampur series:

The soils of the Rampur series are formed from weathered basalt. They are classified at family level as very fine, smectitic, iso-hyperthermic, and typic haplusterts." The depth of the soil ranges from 100–150 cm. The colour varied from Very dark greyish brown to dark brown. The soil texture is clay. The gravel content was found to be <15 percent. The horizon sequence is Ap- Bw- Bss_1- Bss_2 – Bw_1.

3.3.14 Sarwad series:

The soils of the Sarwad series are formed from weathered basalt. They are classified at family level as fine, smectitic, iso-hyperthermic, and typic haplustepts." The clay content was erratically distributed within the pedon. The surface soil had a pH of 8.21, and it increased with depth. Electrical conductivity was higher in the subsurface than in the surface layer. The organic carbon content of surface soils is 0.43 $g/kg^{-1}$and it decreases with depth. The horizon sequence is Ap- Bss_1 -Bss_2 -Bck_1 -Bck_2.

3.3.15 Savanahalli series:

At family level, the Savanahalli series is classified as fine, smectitic, iso-hyperthermic, and vertic calcistepts." Soil pH ranged from 8.06 to 8.56, suggesting that the soils are moderately alkaline in nature. The pH value increased with soil depth. The electrical conductivity of the soils ranged from 0.10 to 0.14 dSm^{-1} indicating the soil is non-saline. The organic carbon content ranged from 0.04 to 0.72 percent and decreased with depth. The horizon sequence is Ap - Bw_1 - Bw_2 - Bw_3 - Bw_4.

3.3.16 Thenihalli series:

In the soils of the Thonshyal series (Fine, smectitic, iso-hyperthermic, and Typic Haplustepts), clay content increased at all depths except 18–40 cm. The soil pH and EC increased with depth. The horizon sequence is Ap - Bck_1 - Bck_2 - CBk_1 - CBk_2 - Cr.

3.3.17 Thonsyal series:

Fine, smectitic, iso-hyperthermic, and typic haplustepts representing the Thonsyal series had a higher accumulation of clay content in the subsoil (46.0%) than the overlying horizon (34.0%). The pH of surface soil was 9.14, and it decreased with depth. The surface soil content of 0.36 dSm-1 was irregularly distributed in adjacent layers. The horizon sequence is Ap, Bw_1- Bck_1- Bck_2 and Bck_3.

3.3.18 Yakkundi series:

The soils of the Yakkundi series are formed from weathered basalt. They are classified at family level as fine, smectitic, and iso-hyperthermic type Haplustepts. The gravel percentage ranged from 4 to 12 percent, following an increasing trend with an increase in soil depth. The texture is clay to

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sandy clay. Bulk density varied from 1.25 to 1.43 Mgm^{-3} which increased with soil depth. The horizon sequence is Ap- Bw_1 -Bw_2 - Bw_3-CB-Cr.

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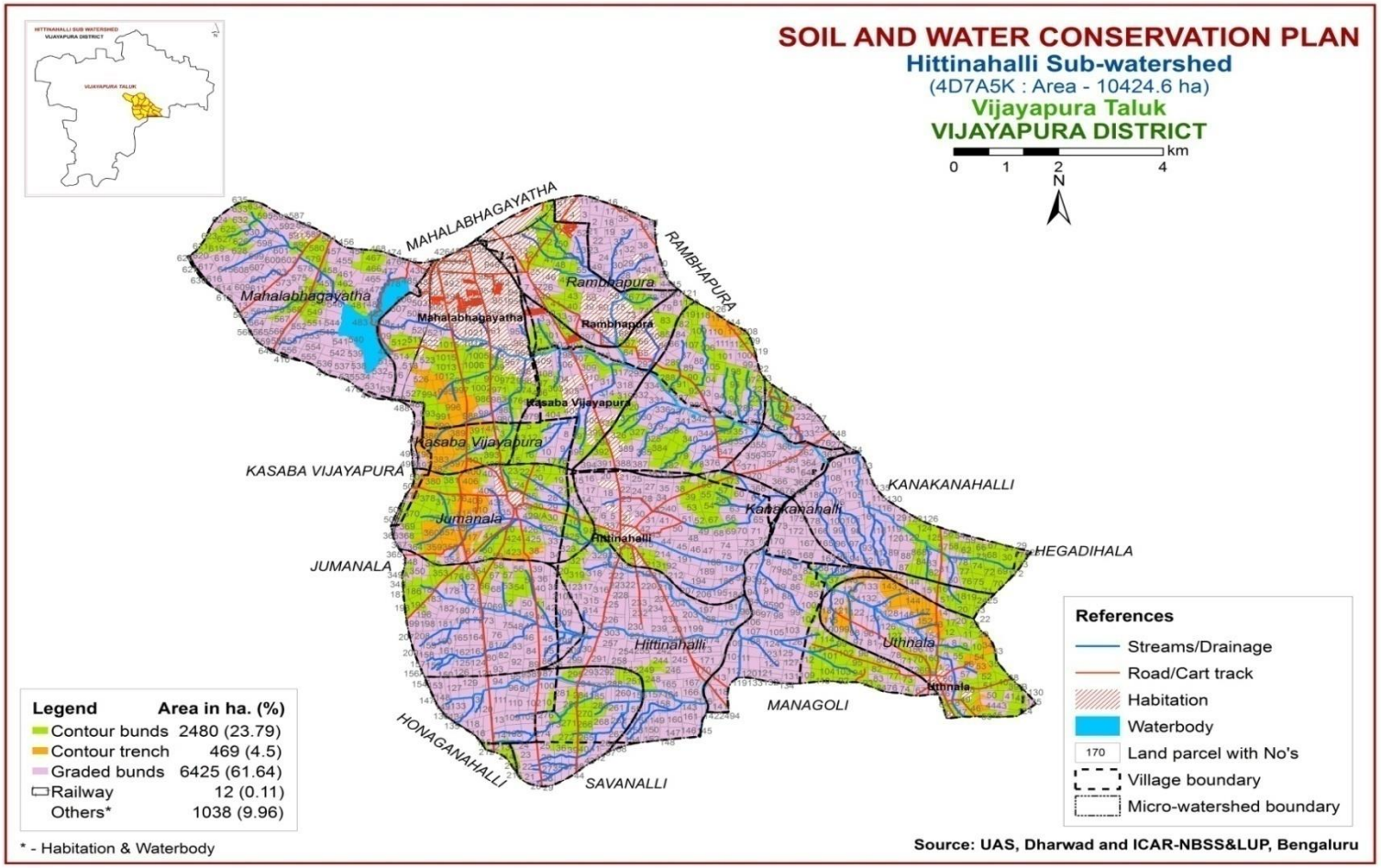

Fig 3: Soil and water conservation plan map of Hittinahalli sub-watershed

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3.3.19 Soil and water conservation:

Soil and water conservation practises vary with the depth and slope of the soil. In the Hittinahalli sub-watershed, eighteen soil series were identified, among which Atharga, Dadamatti, Honnutagi, Jamnal, Kalgurki, Naihalla, Yakkundi, and Tenihalli soil series are shallow to moderately deep. For these three series, the soil and water conservation plan is contour bunds and inter-bund management practises with compartment bunding before sowing and conservation furrow after sowing. For deep to very deep soils (Halagani, Rambhapur, Sarwad, Savanahalli, Rampur, Babaleshwasr, Karjol, Tenihalli, Nidoni, and Nandhyal series), graded bunds and inter-bund management practises with compartment bunding before sowing and conservation furrow were adopted.

4.0 Conclusion

The soils were classified up to family level according to revisions in soil taxonomy. A soil survey revealed that the soils of the Hittinahalli sub-watershed belonged to the orders Entisols, Inceptisols, and Vertisols. Soils were separated and distributed irregularly with depth. The pH was alkaline, and the EC increased with depth. Organic carbon and calcium carbonate content decreased with depth, except in Tonshyal pedon. Calcium and magnesium were the dominant exchangeable cations.

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5.3 Conflict of Interest

None.

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