

Original Research Article

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Forms and Distribution of Carbon in Soils of Dambal Sub-Watershed of Mundargi Taluk, Gadag District, Karnataka, India

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ABSTRACT

A study on forms and distribution of carbon in the soils of Dambal sub-watershed of Mundargi taluk of Gadag district, Karnataka was undertaken during 2018-19. One representative soil profile for each soil series was selected to represent twenty two soil series identified under Sujala-III project. Depth wise soil samples were collected and analysed for forms of carbon. Soils were generally sandy clay loam to clay in texture, bulk density and particle density increased with depth and on contrary porosity was decreased with depth. The pH and EC values ranged from neutral to strongly alkaline and normal to strongly saline respectively. Organic carbon content followed decreasing trend with depth and irregular distribution was observed in free CaCO_3 . CEC of soil series was average with Ca^{2+} found as dominant exchangeable cation followed by Mg^{2+} , Na^+ and K^+ . Majority of soils possessed medium to high per cent base saturation. Organic, water soluble and active carbon fractions were decreased with depth in all the soil series, whereas inorganic and total carbon did not follow a particular trend. Water soluble and active carbon showed significant positive correlation with organic carbon, whereas inorganic and total carbon showed significant and positive correlation with CaCO_3 . Organic, water soluble and active carbon were significantly and positively correlated with each other, whereas inorganic and total carbon was significantly and positively correlated with each other.

Keywords

Carbon fractions, Soil profile, Sub-watershed, Soil series, Exchangeable cations

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Introduction

Soil indeed alive and dynamic system consisting of minerals and microorganisms, the top-most layer of soil is comparatively richer in nutrients and supports maximum bio-resource. The profile character varies distinctly from place to place, particularly with respect to their depth, colour and composition. The mineral composition of the soil, organic matter within it and

environment, all these are resolute by chemical, physical and biological properties of soil.

Soil organic carbon is necessary for improving soil quality, sustaining food production and sinking CO_2 in the atmosphere, whereas its inorganic counterpart (free CaCO_3) is the cause of organic carbon decomposition, restricting root proliferation, developing salinity (Eswaran and Van den

berge, 1992) and immobilizing soil plasma. Moreover, average annual precipitation, period of canopy cover, tillage, available moisture content, silt and clays have noticeable effects on dynamics of soil carbon. Periodical evaluation of OC is important in semi-arid and arid regions. Attenuation of water resources, periodic drought, severe erosion and summer fallowing has a detrimental effect on SOC level.

As the interface between the atmosphere, lithosphere and biosphere, soil undergoes an intense vertical interchange of materials causing in sharp physical and chemical gradients from surface to bedrock. Stratification of soil is the most noticeable outcome of this interchange and its extensive reflection and synthesis form the basis of pedogenetic and taxonomical study. The type, thickness, and arrangement of horizons can give information about soil forming factors such as climate, time, topography and vegetation type. Similarly, the vertical distribution of nutrients in soil should yield related insights into nutrient cycling processes (Smeck, 1973; Kirby, 1985).

Watershed is a natural geo-hydrologic entity that encompasses a specific area stretch of land surface, where water from rainfall or run off flows to a specific defined drain it may be a channel, naala and small stream or river. The term Sub-watershed indicates hierarchical division considered appropriate unit for both survey, assessment of soil and land resources as well as for planning and implementation of watershed management practices.

Materials and Methods

Dambal sub-watershed (Mundargi taluk, Gadag district) is selected as study area is located in Northern dry zone of Karnataka between 15° 15' 07" to 15° 19' 30" North

latitudes and 75° 41' 15" to 75° 48' 26" East longitudes, covering an area of about 4749.89 ha (Fig. 1) and subjected to the detail of LRI using IRS P6 LISS IV data at 1:50,000 scale in Sujala-III project. Soil resources are mapped at soil phase level and identified 22 soil series (Anon., 2017). The major parent material in the sub-watershed is weathered schist and granite gneiss, climate of the area is semi-arid or hot tropical and monsoonic type. The entire sub-watershed has diversified crop, climate and soils comprises of both red gravelly clay and deep clay soils differing in their physical and chemical characteristics. The soil depth was very shallow to very deep and gradient of land was nearly level to very gently sloping. The soil is moderately eroded and some portion of the soil comes under slight eroded class.

One representative soil profile was selected from each soil series and horizon-wise soil samples were analyzed for vertical distribution of forms of carbon. Processed soil samples (<2 mm) were analyzed for different physico-chemical properties using following standard procedures.

The soil samples were analyzed for particle size distribution (Piper, 2002), bulk and particle density by Black (1965). pH (1:2.5), EC (1:2.5) and OC by Walkley and Black's wet oxidation method (Sparks, 1996). Free CaCO₃ (Piper, 2002), CEC and Exchangeable bases by (Jackson, 1973). The organic carbon content of finely ground (0.2 mm) soil samples was determined by using Walkley and Black's wet oxidation method (Sparks, 1996). The water soluble carbon was determined using the method as described by Mc Gill *et al.*, (1986). In brief, 10 g of soil was shaken for 1 hour with 20 ml of soil, followed by centrifugation (6000 rpm), filtration and titration against standard ferrous sulphate. The active carbon was determined by the modified method of Blair *et al.*, (1995)

as outlined by Weil *et al.*, (2003). In brief, active carbon was determined by shaking 5 g air dried soil with 20 ml of 0.02 M KMnO₄ for 2 minutes (horizontal shaker-120 rpm), followed by centrifugation and measuring the light absorbance at 550 nm by colorimeter. The inorganic carbon (free calcium carbonate) content of soil samples was determined by rapid acid titration method as described by Piper (2002) and expressed in g kg⁻¹. Total carbon was determined by using CHNS analyzer (Vario EL cube model) by Dhaliwal *et al.*, (2011). The experimental results were subjected to statistical analysis adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). Testing of significance was done by SPSS 16.0 version and values are given at 5 per cent and 1 per cent level of significance.

Results and Discussion

Physical properties of soil

The particle size analysis showed that the texture of the different soil profile of the different soil series was sandy clay loam to clay in nature. The sand, silt and clay content in soil profiles varied from 12 to 62, 10 to 32 and 24 to 73 per cent, respectively. The highest values of sand silt and clay per cent observed in JLG, NGT and BLD series respectively. This is might be due to topography, in-situ weathering and translocation of clay (Thangasamy *et al.*, 2005). It was further observed that the particle size analysis did not follow any pattern with soil depth. While, lowest values showed in KPR, MJR and JLG series respectively. The mean value of sand (33.27 %), silt (19.97 %) and clay (46.77 %) was recorded in different soil series. More amount of sand content (JLG series) was usually observed in upper horizons than sub-surface horizons, while clay content in majority of the soil series increasing with respect to depth. Highest

value of clay observed in BLD series and lowest in JLG series. The amount of clay increased with increasing profile depth was attributed due to illuviation of the finer fraction to the lower horizons. These conformities were also lined with observations recorded by Chari (2015) and Prathibha (2016).

Bulk density and particle density of the different soil profile of the different soil series were ranged from 1.19-1.51 Mg m⁻³ and 2.60-2.65 Mg m⁻³ respectively. The lowest and highest value of bulk and particle densities was observed in (MTL and DNI series) and (CKP and HHG series) respectively. The mean value of both the parameters was observed as 1.36 Mg m⁻³ and 2.62 Mg m⁻³, showed increasing trend with increase in depth in all soil series. Soils possessed higher values of bulk density observed in lower horizons of soil profile compared to surface horizons in all soil series. It might be due to high smectite clay leading to compaction and formation of slicken sides, leading to strong structural aggregate formation and more compaction of finer (clay) particles in lower layers caused by over-head weight of the surface layers. The low bulk density values of surface horizons could be accredited due to higher organic matter. The increased bulk density with depth was attributed to increased compaction due to the load of overlying horizons (Nagendra and Patil, 2015) and (Thangasamy *et al.*, 2005). Porosity values varied from 42.37 (CKP series) to 54.58 (MTL series) in per cent and followed a decreasing trend along the depth in all the profiles. Porosity of the soil series varied with one profile to another, due to variation in bulk and particle density of the soil profile. This was mainly influenced due to organic matter and clay content of soil. Higher per cent porosity was observed in surface horizons as compared to sub surface horizons. As organic matter content increases the soil pore space

increases. These outcomes were also matched with the result of Meenkshi Bai *et al.*, (2018).

Chemical properties of soil

Soil reaction values ranged from 6.72 to 9.27, which representing that the soils were neutral to strongly alkaline in nature with mean value of 8.11. Among twenty two profiles, BLD and VRV series showed minimum and maximum value of pH respectively. It didn't showed definite trend along with depth. The alkaline pH of soil was due to semi-arid climate characterized by high evapotranspiration and less precipitation leading to accumulation of higher amount of basic cations in the soil. Similar results and inferences were also drawn by Vinay (2007) in the soils of Bhanapur micro-watershed of Karnataka. EC (Salinity) of the soils varied from 0.08 to 1.84 dS m⁻¹ indicating the soils were normal to strongly saline in nature; this might be due to excess salt contained in irrigation water. The least value of EC was observed in MJR series and highest in NGT series, 0.51 dS m⁻¹ was an average value of EC. Soluble salt content in the soil profiles not followed a definite trend with the depth. Irregular variation in EC could presently due to movement of salt from surface to down level through the percolation of water and subsequent accumulation at places during evapotranspiration resulting in differential salt accumulation along the pedons. Similar observations were recorded by Anjali and Hebbara (2017). The OC content varied from 1.8 to 6.8 g kg⁻¹ and decreased with depth in all soil series. On an average of OC content was observed in all the series was 4.16 g kg⁻¹ and SGT had a minimum value of OC, while MTL recorded maximum value. The organic carbon content of different soil series was under low to medium category. It was further observed that the OC content was more at surface layers than lower layers of the soil profiles, as the depth increases organic carbon also decreases

in Dambal study area. The lower value of OC might be due to semi-arid climate which leads to faster decomposition of organic matter and this fact observed in SGT series. Similar trend was reported by Patil and Patil (2018) for soils of Kanagihal sub-watershed.

Free calcium carbonate content in soil had a mean value of 136.66 g kg⁻¹ and ranged from 36.2 (SGT series) to 472.5 (VKP series) g kg⁻¹. Majority of the profiles comes under calcareous behaviour and increased with depth in HHG, BLD, MJR, VKP, NPT, AKT, DNI and MVD series, while KPR series was showed decreasing trend with respect to profile depth and remaining soil series, not followed any definite trend. This might be due to illuviation along with clay and predominance of free calcium carbonate in lower horizons as compared to the surface horizons attributed to the leaching of soluble salts, free calcium and semi-arid climate favors calcification process leading to accumulation of free CaCO₃ in these soils. The CEC of soil series ranged from 12.29 to 49.78 cmol (p⁺) kg⁻¹ and mean value was 29.20 cmol (p⁺) kg⁻¹. The highest and lowest content was recorded in MVD and KLK series respectively and values were not in consistency with depth. The magnitude of CEC was an indicative of presence of mixed type of clay minerals in the pedons. Variation in clay content and type, OC and presence of free iron oxides were responsible for variation in CEC in different pedons at varying physiographic positions. This was in concordance with the observations made by Pramod and Patil (2015) and Sitanggang *et al.*, (2006).

Exchangeable calcium and magnesium content in the soils ranged from 5.6 (KLK) to 37.5 (MVD) cmol (p⁺) kg⁻¹ and 1.6 (AKT) to 11.7 (NGT) cmol (p⁺) kg⁻¹, respectively. The exchangeable sodium ranged from 0.12 (KLK) to 2.07 (KPR) cmol (p⁺) kg⁻¹, while

exchangeable potassium varied from 0.18 (SGT & MJR) to 0.90 (VRV) $\text{cmol (p}^+) \text{ kg}^{-1}$. On an average value of Ca^{2+} , Mg^{2+} , Na^+ and K^+ was 19.29, 5.92, 0.78 and 0.32 in $\text{cmol (p}^+) \text{ kg}^{-1}$ respectively. The predominance of exchangeable cations in majority of soil series was followed an order: $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ and not showed any particular trend with depth. This order of dominance was in accordance with Pinki *et al.*, (2017), viewed that leaching causes preferential losses of Na^+ and K^+ . Due to preferential leaching of monovalent, this leads to lower value of exchangeable monovalent compared to divalent. Similar results were reported by Anjali and Hebbara (2017). This was apparently due to the difference in the parent material from which the soils were formed and also the free drainage conditions. Base saturation of the profile soils varied from 72.15 to 99.02 per cent and mean value was 89.68 per cent. Highest base saturation was observed in HBL series and lowest in YSJ series. This mainly depends on CEC and total exchangeable bases. So, didn't exhibit definite trend in their distribution to profile depth and observed moderate to high base saturation in the study area. The higher base saturation in soil series was due to the prevailing semi-arid climate facilitating less leaching and more accumulation of bases. Thangasamy *et al.*, (2005) also observed direct relation between base saturation and accumulation of bases due to less leaching.

Vertical distribution of forms of carbon

Organic carbon

The organic carbon varied from 1,800 (SGT series) to 6,800 (MTL series) in mg kg^{-1} and its declined with depth in all the soil series. Among Ap horizon the highest organic carbon content was recorded in MTL (6,800 mg kg^{-1}) series and lowest in SGT (2,800 mg kg^{-1}) series. The mean value of organic carbon of all the profile was 4,162 mg kg^{-1} It

might be due to accumulation of organic materials in the surface horizons through crop residue, external applications, *etc.* which generally occurs at the surface. This fractions includes both water soluble and active carbon, hence contributions towards total pool was comparatively more *i.e.* 20.22 per cent. Similar outcomes were also observed by Sharma *et al.*, (2014) and Jogan *et al.*, (2017).

Water soluble carbon

The water soluble carbon is easily degraded by microorganisms and plays key role in soil formation. The water soluble carbon distribution is similar to the soil organic carbon in all the soil series of study area, and decreased with depth and this varied from 7.4 to 37.5 mg kg^{-1} . The maximum value was found in MTL series and minimum in NGT series, average value of water soluble carbon content was 19.4 mg kg^{-1} . Among Ap horizon the highest water soluble carbon content was recorded in MTL series (37.5 mg kg^{-1}) and lowest in of SGT series (13.6 mg kg^{-1}). Contribution towards total content was very minute *i.e.* 0.09 percent.

This might be due to decrease in organic carbon content down the depth and this form of carbon mainly depends up on soil organic matter, which influenced the distribution in soil profiles. Similar observations were also mentioned by Majumdar (2014) and Patil and Patil (2018).

Active carbon

The active carbon also called as KMnO_4 oxidizable carbon or reactive carbon is readily degradable by microorganisms and used as an indicator of change produced by cropping and soil management practices that manipulates SOM content. The active carbon content was ranged from 174.31 to 1335.95 mg kg^{-1} . The mean value of active carbon was 599.26 mg kg^{-1}

kg⁻¹ and highest content was observed in HGK series, while lowest in NPT series. Among Ap horizon the active carbon content was highest (1335.95 mg kg⁻¹) in HGK series and lowest (175.36 mg kg⁻¹) in of JLG series. 2.91 per cent of this fraction accounted towards total-C content in study area. Its content decreased with respect to profile depth in all the profiles of different soil series which is in accordance with OC content of the soil. Surface soil had maximum quantity of active carbon then sub-surface soil and its gradually decreased with respect to OC content in soil. The present findings were in line with those of Benbi *et al.*, (2015) and Madhu (2016).

Inorganic carbon

The inorganic carbon values ranged from 4,344 (SGT series) to 56,700 (VKP series) in mg kg⁻¹ and mean value was 16,418 mg kg⁻¹. The inorganic carbon content increased with depth in HHG, BLD, MJR, VKP, NPT, AKT, DNI and MVD series, while KPR series was showed decreasing pattern with profile depth and remaining soil series, did not follow definite trend. Among the Ap horizons, it was lowest (4,728 mg kg⁻¹) in SGT series and highest (45,744 mg kg⁻¹) in VKP series. The higher inorganic carbon content highest in sub-surface horizon compare to surface horizon, which indicates that parent material was alkaline in nature. The similar outcomes were also cited by Patil and Patil (2018). This form of carbon includes other than organic carbon forms and shared maximum per cent (79.78) to total content. This fraction contributed the highest per cent among all other fractions.

Total carbon

The total carbon content ranged from 6,244 to 61,000 mg kg⁻¹. The total carbon content decreased with depth HHG, YSJ, MTL and

KPR series, while BLD, VKP, NPT, AKT, DNI and SGT series were showed inclining trend with depth and remaining soil series did not follow definite trend. This variation was mainly due to contribution of organic and inorganic carbon pool towards total-C. However, inorganic carbon contribution was more than organic carbon. These findings were in agreement with earlier report of Madhu (2016) and Patil and Patil (2018). The highest total carbon content was observed in VKP and lowest in SGT series. The average value was 20,579 mg kg⁻¹ from all the soil series of study area.

The results pertaining to different forms of C in soils of Dambal sub-watershed is depicted graphically in Fig. 2.

Correlation between forms of carbon with soil properties Dambal sub-watershed

Water soluble, organic and active carbon recorded negative correlation with free CaCO₃ and pH and positive correlation with clay, OC and CEC. This clearly indicated that OC content, water soluble and active carbon content were in positive relation. Organic carbon showed significant negative correlation with pH ($r = -0.128^{**}$) and free CaCO₃ ($r = -0.290^{**}$). Water soluble carbon had significant positive correlation with clay and CEC ($r = 0.156^{*}$) and ($r = 0.462^{*}$) respectively, significant negative correlation with free CaCO₃ ($r = -0.225^{**}$). Active carbon shows significantly and negatively correlated with pH ($r = -0.398^{**}$) and free CaCO₃ ($r = -0.612^{*}$). Inorganic and total carbon has significant positive correlation with free CaCO₃ ($r = 1.000^{**}$ and $r = 0.978^{**}$, respectively), suggests that inorganic carbon contributed more to the total carbon. While, significant negative correlation with OC ($r = -0.387^{**}$ and $r = -0.255^{*}$, respectively). Similar results were also described by Sharma *et al.*, (2014) and Madhu (2016).

Table.1 Physical properties in soils of Dambal sub-watershed of Mundagri taluk of Gadag district

Sl. No.	Name of the soil series	Horizon	Depth (cm)	Sand	Silt (%)	Clay	Textural Class	BD		Porosity (%)
								(Mg m ⁻³)		
1	BGT	Ap	0-21	22	16	62	Clay	1.24	2.60	52.31
2	HGK	Ap	0-16	18	24	58	Clay	1.23	2.60	52.69
3	KLK	Ap	0-16	51	20	29	Sandy clay loam	1.43	2.63	45.63
4	AKT	Ap	0-14	38	20	42	Clay	1.33	2.62	49.24
		Bw	14-36	32	16	52	Clay	1.40	2.63	46.77
5	BLD	Ap	0-9	21	18	61	Clay	1.28	2.60	50.77
		Bw	9-33	15	12	73	Clay	1.34	2.61	48.66
6	JLG	Ap	0-28	62	14	24	Sandy clay loam	1.33	2.64	49.62
7	MTL	Ap	0-16	33	28	39	Clay loamy	1.19	2.62	54.58
		Bw	16-34	34	20	46	Clay	1.22	2.63	53.61
8	NPT	Ap	0-12	30	24	46	Clay	1.29	2.61	50.57
		Bwk	12-29	26	16	58	Clay	1.42	2.62	45.80
9	YSJ	Ap	0-12	23	28	49	Clay	1.23	2.60	52.69
		Bw ₁	12-30	27	28	45	Clay	1.36	2.62	48.09
		Bw ₂	30-45	27	20	53	Clay	1.48	2.62	43.51
10	BDT	Ap	0-16	50	13	37	Sandy clay	1.36	2.63	48.29
		Bw ₁	16-38	46	15	39	Sandy clay	1.41	2.64	46.59
		Bw ₂	38-60	37	23	40	Clay loamy	1.47	2.64	44.32
11	MJR	Ap	0-14	57	10	33	Sandy clay loam	1.27	2.63	51.71
		Bt ₁	14-38	50	16	34	Sandy clay loam	1.31	2.64	50.38
		Bt ₂	38-65	47	16	37	Sandy clay	1.38	2.64	47.73
12	VKP	Ap	0-14	17	24	59	Clay	1.42	2.61	45.59
		Bwk	14-59	50	16	34	Sandy clay loam	1.44	2.63	45.25
13	CKP	Ap	0-18	40	16	44	Clay	1.21	2.61	53.64
		Bwk ₁	18-58	25	24	51	Clay	1.39	2.62	46.95
		Bwk ₂	58-96	24	16	60	Clay	1.51	2.62	42.37
14	KPR	Ap	0-25	16	28	56	Clay	1.34	2.60	48.46
		Bw ₁	25-58	12	30	58	Clay	1.37	2.62	47.71
		Bw ₂	58-99	20	21	59	Clay	1.41	2.63	46.39
15	HBL	Ap	0-19	25	24	51	Clay	1.30	2.61	50.19
		Bw	19-53	24	26	50	Clay	1.36	2.61	47.89
		Bss	53-87	22	27	51	Clay	1.43	2.62	45.42
		Bssk	87-124	21	23	56	Clay	1.47	2.63	44.11

Table.1 Contd.....

Sl. No.	Name of the soil series	Horizon	Depth (cm)	Sand	Silt	Clay	Textural Class	BD	PD	Porosity (%)
				(%)				(Mg m ⁻³)		
16	HHG	Ap	0-17	57	15	28	Sandy clay loam	1.28	2.62	51.15
		Bw ₁	17-48	55	16	29	Sandy clay loam	1.32	2.62	49.62
		Bw ₂	48-90	51	17	32	Sandy clay loam	1.40	2.64	46.97
		Bw ₃	90-128	48	18	34	Sandy clay loam	1.43	2.65	46.04
17	MPT	Ap	0-29	20	24	56	Clay	1.33	2.61	49.04
		Bt ₁	29-77	26	16	58	Clay	1.36	2.62	48.09
		Bt ₂	77-130	21	17	62	Clay	1.41	2.62	46.18
18	MVD	Ap	0-21	28	19	53	Clay	1.32	2.60	49.23
		Bt ₁	21-49	22	21	57	Clay	1.36	2.61	47.89
		Bt ₂	49-81	18	20	62	Clay	1.39	2.61	46.74
		Bc	81-102	24	21	55	Clay	1.44	2.63	45.25
19	NGT	Ap	0-10	28	24	48	Clay	1.29	2.60	50.38
		Bw	10-40	16	28	56	Clay	1.34	2.61	48.66
		Bw _{ss}	40-80	13	29	58	Clay	1.39	2.61	47.13
		Bc	80-130	24	32	44	Clay	1.42	2.62	46.95
20	SGT	Ap	0-17	57	15	28	Scl	1.28	2.62	51.15
		Bw ₁	17-58	48	16	36	Sandy clay	1.34	2.62	48.85
		Bw ₂	58-89	46	12	42	Sandy clay	1.39	2.63	47.15
		Bw ₃	89-141	45	16	39	Sandy clay	1.45	2.64	45.08
21	VRV	Ap	0-17	30	20	50	Clay	1.31	2.60	49.62
		Bw	17-48	34	21	45	Clay	1.37	2.62	47.71
		Bc	48-95	22	24	54	Clay	1.40	2.62	46.56
		Bwk	95-150	23	25	52	Clay	1.45	2.63	44.87
22	DNI	Ap	0-15	55	13	32	Sandy clay loam	1.33	2.63	49.43
		Bw	15-35	52	18	30	Sandy clay loam	1.35	2.63	48.67
		Bt ₁	35-110	45	16	39	Sandy clay	1.38	2.64	47.73
		Bt ₂	110-160	46	13	41	Sandy clay	1.42	2.65	46.42
Range				12-62	10-32	24-73	Sandy clay loam - Clay	1.19-1.51	2.60-2.65	42.37-54.58
Mean				33.27	19.97	46.77		1.36	2.62	48.17
SD				13.98	5.26	11.21		0.07	0.01	2.63

Table.2 Chemical properties in soils of Dambal sub-watershed of Mundagri taluk of Gadag district

Sl. No.	Name of the soil series	Horizon	Depth (cm)	pH (1:2.5)	EC (dS m ⁻¹)	OC (g kg ⁻¹)	CaCO ₃ (g kg ⁻¹)	Exchangeable cations (cmol (p ⁺) kg ⁻¹)				TEB	CEC	BS (%)
								Ca	Mg	Na	K			
1	BGT	Ap	0-21	7.29	0.16	4.7	266.2	12.7	2.9	0.17	0.34	16.11	19.28	83.56
2	HGK	Ap	0-16	8.18	0.18	5.3	380.3	14.3	4.7	0.14	0.27	19.41	21.19	91.59
3	KLK	Ap	0-16	6.78	0.14	3.6	39.7	5.6	3.5	0.12	0.18	9.37	12.29	76.23
4	AKT	Ap	0-14	7.98	0.16	4.8	151.2	11.7	2.1	0.16	0.44	14.40	16.48	87.36
		Bw	14-36	8.09	0.21	3.7	337.5	15.8	1.6	0.21	0.19	17.80	19.94	89.27
5	BLD	Ap	0-9	6.72	0.24	3.8	41.2	16.1	4.2	0.30	0.24	20.64	25.62	80.56
		Bw	9-33	7.28	0.20	3.2	47.7	20.8	4.5	0.21	0.19	25.50	32.59	78.25
6	JLG	Ap	0-28	8.10	0.12	4.2	45.3	12.7	3.4	0.43	0.31	16.84	19.31	87.21
7	MTL	Ap	0-16	8.16	0.56	6.8	141.1	25.6	6.2	0.93	0.55	33.28	35.09	94.85
		Bw	16-34	8.57	0.45	4.7	118.7	26.3	6.8	0.86	0.35	34.31	36.03	95.23
8	NPT	Ap	0-12	8.15	0.19	4.0	41.5	26.2	6.3	1.01	0.42	33.93	38.08	89.11
		Bwk	12-29	8.11	0.21	3.6	52.5	28.5	4.8	0.61	0.59	34.50	36.64	94.15
9	YSJ	Ap	0-12	7.54	0.22	4.6	49.5	20.2	4.8	0.27	0.21	25.48	33.92	75.12
		Bw ₁	12-30	6.75	0.28	4.1	51.4	22.7	4.5	0.22	0.20	27.59	38.24	72.15
		Bw ₂	30-45	7.31	0.21	3.4	40.2	24.8	3.8	0.28	0.19	29.07	37.55	77.42
10	BDT	Ap	0-16	8.17	0.46	4.2	90.5	19.4	3.4	0.39	0.22	23.35	25.69	90.82
		Bw ₁	16-38	7.93	0.58	3.7	97.1	20.4	4.2	0.42	0.20	25.18	28.75	87.57
		Bw ₂	38-60	8.05	0.53	2.8	93.8	21.8	4.7	0.37	0.21	26.98	30.24	89.18
11	MJR	Ap	0-14	6.98	0.12	4.4	46.1	10.2	3.6	0.27	0.22	14.17	19.44	72.89
		Bt ₁	14-38	7.72	0.14	4.2	48.2	12.2	4.1	0.23	0.18	16.53	20.99	78.74
		Bt ₂	38-65	7.28	0.08	3.3	52.3	15.3	3.3	0.31	0.21	18.87	24.79	76.13
12	VKP	Ap	0-14	8.09	0.17	5.6	381.2	16.1	4.6	0.23	0.32	21.25	25.26	84.12
		Bwk	14-59	8.23	0.18	4.3	472.5	12.7	2.8	0.48	0.24	16.09	18.59	86.57
13	CKP	Ap	0-18	8.56	1.38	5.7	367.5	10.6	4.7	1.55	0.66	17.51	19.34	90.56
		Bwk ₁	18-58	8.72	0.99	4.0	445.7	13.7	3.1	1.82	0.26	18.88	20.40	92.56
		Bwk ₂	58-96	8.21	1.63	3.7	441.2	11.5	5.3	1.67	0.35	18.82	20.58	91.45
14	KPR	Ap	0-25	8.52	0.22	5.8	101.2	20.1	11.4	1.64	0.56	33.70	34.17	98.63
		Bw ₁	25-58	8.31	1.34	5.3	87.5	17.7	10.7	1.47	0.32	30.18	30.97	97.43
		Bw ₂	58-99	8.36	1.22	3.3	51.5	9.6	2.8	2.07	0.22	14.69	15.42	95.29
15	HBL	Ap	0-19	8.64	0.31	6.2	131.5	27.2	7.7	1.14	0.58	36.62	37.11	98.67
		Bw	19-53	8.82	0.54	4.9	121.8	18.5	9.9	1.31	0.31	30.02	30.67	97.89
		Bss	53-87	8.77	0.43	4.4	122.5	27.6	3.4	1.02	0.34	32.36	30.97	98.15
		Bssk	87-124	8.73	1.49	2.4	136.2	17.5	10.8	1.91	0.38	30.59	30.86	99.02

Table.2 Contd.....

Sl. No.	Name of the soil series	Horizon	Depth (cm)	pH (1:2.5)	EC (dS m ⁻¹)	OC	CaCO ₃ (g kg ⁻¹)	Exchangeable cations				TEB	CEC	BS (%)
								Ca	Mg	Na	K			
						(cmol (p ⁺) kg ⁻¹)								
16	HHG	Ap	0-17	8.04	0.23	4.1	44.7	19.1	6.7	0.80	0.32	26.92	29.40	91.57
		Bw ₁	17-48	8.12	0.52	3.3	45.9	12.4	6.4	0.78	0.24	19.82	21.51	92.13
		Bw ₂	48-90	8.01	0.34	3.1	46.3	20.3	7.5	0.93	0.23	28.96	32.02	90.45
		Bw ₃	90-128	7.82	0.86	2.5	48.6	19.0	7.8	0.82	0.27	27.89	31.26	89.23
17	MPT	Ap	0-29	8.41	0.19	6.6	88.7	12.4	6.2	1.43	0.53	20.56	21.79	94.37
		Bt ₁	29-77	8.56	0.38	5.1	136.2	17.7	4.8	1.56	0.23	24.29	25.41	95.58
		Bt ₂	77-130	9.07	0.58	4.2	51.2	11.5	4.1	0.81	0.27	16.68	17.13	97.36
18	MVD	Ap	0-21	8.29	0.37	5.3	132.9	35.3	10.5	0.43	0.21	46.44	48.87	95.02
		Bt ₁	21-49	8.14	0.44	4.7	138.2	37.5	8.3	0.47	0.25	46.52	49.78	93.46
		Bt ₂	49-81	8.32	0.31	4.1	153.8	32.7	9.2	0.39	0.22	42.51	44.91	94.65
		Bc	81-102	8.23	0.51	3.5	165.1	29.8	7.1	0.55	0.37	37.82	40.52	93.33
19	NGT	Ap	0-10	8.74	0.24	5.8	94.5	23.9	11.3	1.54	0.61	37.35	37.91	98.52
		Bw	10-40	9.01	0.98	4.4	93.7	19.3	11.7	1.51	0.36	32.87	33.23	98.92
		Bw _{ss}	40-80	8.82	1.53	3.8	102.5	18.1	10.9	1.02	0.38	30.40	31.12	97.69
		Bc	80-130	8.87	1.84	2.3	96.0	16.2	8.1	1.45	0.32	26.07	26.84	97.13
20	SGT	Ap	0-17	7.36	0.09	2.8	39.4	21.6	6.2	0.67	0.29	28.76	35.52	80.97
		Bw ₁	17-58	7.58	0.15	2.2	43.8	24.1	6.7	0.85	0.18	31.83	38.59	82.48
		Bw ₂	58-89	8.24	0.28	1.9	36.2	22.9	5.8	0.63	0.24	29.48	30.78	95.79
		Bw ₃	89-141	7.81	0.18	1.8	39.5	22.4	7.4	0.42	0.26	30.48	34.80	87.58
21	VRV	Ap	0-17	9.18	1.07	4.8	121.2	15.2	4.8	0.83	0.59	21.42	22.90	93.52
		Bw	17-48	9.27	1.21	4.2	132.5	12.1	7.4	1.06	0.64	21.20	22.39	94.67
		Bc	48-95	8.83	1.14	3.7	433.7	16.5	6.8	1.49	0.36	25.15	28.05	89.82
		Bwk	95-150	8.04	1.02	3.1	403.4	19.1	7.3	0.94	0.90	28.24	32.62	86.57
22	DNI	Ap	0-15	8.29	0.16	5.7	85.2	23.9	4.1	0.49	0.30	28.79	29.92	96.23
		Bw	15-35	7.74	0.14	5.3	91.5	25.2	5.3	0.47	0.26	31.13	35.31	88.15
		Bt ₁	35-110	7.18	0.17	4.8	113.4	22.4	3.6	0.53	0.20	26.73	32.10	83.27
		Bt ₂	110-160	7.53	0.21	3.9	128.2	20.8	4.5	0.51	0.24	26.05	30.78	84.62
Range				6.72-9.27	0.08-1.84	1.8-6.8	36.2-472.5	5.6-37.5	1.6-11.7	0.12-2.07	0.18-0.90	9.37-46.52	12.29-49.78	72.15-99.02
Mean				8.11	0.51	4.16	136.66	19.29	5.92	0.78	0.32	26.31	29.20	89.68
SD				0.61	0.46	1.12	123.44	6.54	2.58	0.54	0.17	7.97	8.18	7.29

Table.3 Vertical distribution of carbon fractions in soils of Dambal sub-watershed of Mundargi taluk of Gadag district

Sl. No.	Name of the soil series	Horizon	Depth (cm)	Organic-C	Water soluble-C	Active-C	Inorganic-C	Total-C
				mg kg ⁻¹				
1	BGT	Ap	0-21	4,700	31.2	981.56	31,944	36,644
2	HGK	Ap	0-16	5,300	28.7	1,335.95	45,636	51,044
3	KLK	Ap	0-16	3,600	33.6	459.47	4,764	8,364
4	AKT	Ap	0-14	4,800	25.3	763.28	18,144	22,944
		Bw	14-36	3,700	17.5	697.31	40,500	44,200
5	BLD	Ap	0-9	3,800	21.3	465.79	4,944	8,744
		Bw	9-33	3,200	16.5	415.36	5,724	8,924
6	JLG	Ap	0-28	4,200	13.7	175.36	5,436	9,636
7	MTL	Ap	0-16	6,800	37.5	825.18	16,932	23,732
		Bw	16-34	4,700	32.9	781.62	14,244	18,944
8	NPT	Ap	0-12	4,000	27.8	198.63	4,980	8,980
		Bwk	12-29	3,600	21.6	174.31	6,300	9,900
9	YSJ	Ap	0-12	4,600	14.3	526.47	5,940	10,540
		Bw ₁	12-30	4,100	12.6	489.63	6,168	10,268
		Bw ₂	30-45	3,400	9.4	452.17	4,824	8,224
10	BDT	Ap	0-16	4,200	17.2	564.93	11,400	15,600
		Bw ₁	16-38	3,700	13.6	548.38	11,652	15,352
		Bw ₂	38-60	2,800	11.3	511.42	11,256	14,056
11	MJR	Ap	0-14	4,400	22.5	211.63	5,532	9,932
		Bt ₁	14-38	4,200	16.6	196.37	5,784	9,984
		Bt ₂	38-65	3,300	12.2	185.26	6,276	9,576
12	VKP	Ap	0-14	5,600	25.7	726.39	45,744	51,344
		Bwk	14-59	4,300	19.2	651.23	56,700	61,000
13	CKP	Ap	0-18	5,700	29.5	1,016.15	44,100	49,800
		Bwk1	18-58	4,000	24.8	984.51	53,400	57,400
		Bwk2	58-96	3,700	19.3	812.23	52,944	56,644
14	KPR	Ap	0-25	5,800	26.1	851.57	12,144	17,944
		Bw ₁	25-58	5,300	23.8	810.83	10,500	15,800
		Bw ₂	58-99	3,300	14.5	767.98	6,850	10,150
15	HBL	Ap	0-19	6,200	31.4	796.32	15,780	21,980
		Bw	19-53	4,900	29.5	723.54	14,616	19,516
		Bss	53-87	4,400	27.2	658.15	14,700	19,100
		Bssk	87-124	2,400	23.6	605.25	16,344	18,744

Table.3 Contd.....

Sl. No.	Name of the soil series	Horizon	Depth (cm)	Organic-C	Water soluble-C	Active-C	Inorganic-C	Total-C
				mg kg⁻¹				
16	HHG	Ap	0-17	4,100	17.2	322.56	5,364	9,464
		Bw ₁	17-48	3,300	15.1	302.75	5,508	8,808
		Bw ₂	48-90	3,100	14.3	289.32	5,556	8,656
		Bw ₃	90-128	2,500	11.7	271.85	5,832	8,332
17	MPT	Ap	0-29	6,600	19.2	691.38	10,644	17,244
		Bt ₁	29-77	5,100	15.4	623.21	16,344	21,444
		Bt ₂	77-130	4,200	10.8	579.51	6,144	10,344
18	MVD	Ap	0-21	5,300	31.5	862.04	15,948	21,248
		Bt ₁	21-49	4,700	27.4	841.58	16,584	21,284
		Bt ₂	49-81	4,100	25.2	838.91	18,456	22,556
		Bc	81-102	3,500	22.8	792.37	19,812	23,312
19	NGT	Ap	0-10	5,800	16.7	624.25	11,340	17,140
		Bw	10-40	4,400	12.3	611.47	11,244	15,644
		Bwss	40-80	3,800	9.8	591.56	12,300	16,100
		Bc	80-130	2,300	7.4	567.11	11,520	13,820
20	SGT	Ap	0-17	2,800	13.6	296.47	4,728	7,528
		Bw ₁	17-58	2,200	10.3	289.13	5,256	7,456
		Bw ₂	58-89	1,900	8.4	264.98	4,344	6,244
		Bw ₃	89-141	1,800	7.9	250.36	4,740	6,540
21	VRV	Ap	0-17	4,800	16.3	814.36	14,544	19,344
		Bw	17-48	4,200	13.9	747.58	15,900	20,100
		Bc	48-95	3,700	12.6	705.96	52,044	55,744
		Bwk	95-150	3,100	10.4	658.13	48,408	51,508
22	DNI	Ap	0-15	5,700	28.5	723.68	10,224	15,924
		Bw	15-35	5,300	23.9	704.82	10,980	16,280
		Bt ₁	35-110	4,800	16.2	674.85	13,608	18,408
		Bt ₂	110-160	3,900	14.1	651.20	15,384	19,284
Range				1,800-6,800	7.4-37.5	174.31-1335.95	4,344-56,700	6,244-61,000
Mean				4,162 (20.22)	19.4 (0.09)	599.26 (2.91)	16,418 (79.78)	20,579 (100.00)
SD				1,121.45	7.65	249.00	14,799	15,052

Note: Figures in the parentheses indicate per cent contribution towards total.

Table.4 Correlation between the forms of carbon and soil properties in different soil series of Dambal sub watershed

	Clay	pH	OC	Free CaCO ₃	CEC
Organic-C	0.163*	-0.218**	1.000**	-0.290**	0.538*
Water soluble-C	0.156*	-0.041	0.840**	-0.225*	0.462*
Active-C	0.487**	-0.398**	0.893**	-0.612*	0.343*
Inorganic-C	0.288	0.271*	-0.387**	1.000**	0.156
Total-C	0.305*	0.290	-0.255*	0.978**	0.245

** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level.

Table.5 Correlation amongst forms of carbon in different soil series of Dambal sub watershed

	Organic-C	Water soluble-C	Active-C	Inorganic-C	Total-C
Organic-C	1	0.842**	0.638**	-0.387**	-0.145*
Water soluble-C		1	0.753**	-0.320*	-0.260*
Active-C			1	-0.119*	-0.095
Inorganic-C				1	0.937**
Total-C					1

** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level.

Fig.1 Location map of Dambal sub-watershed

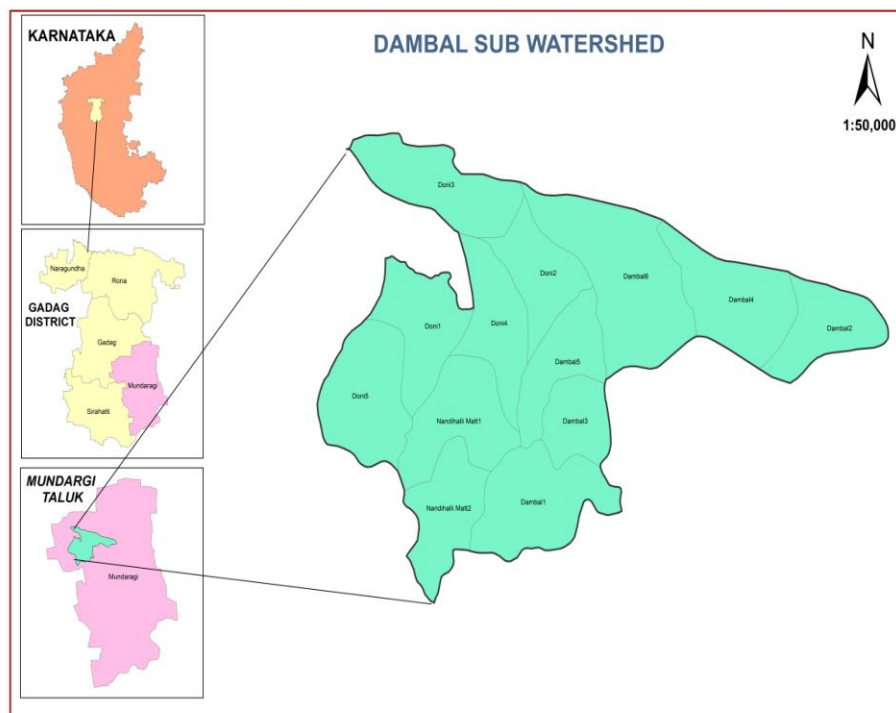
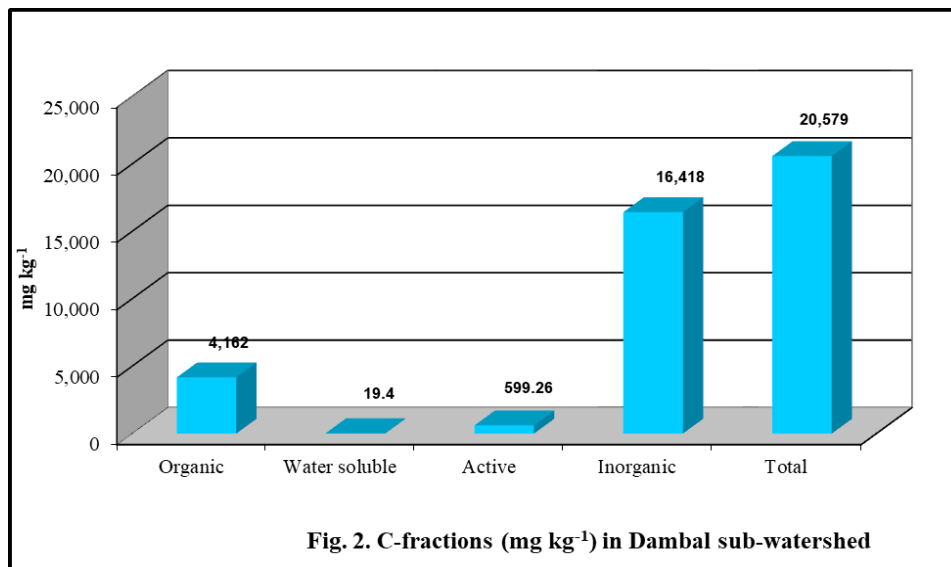


Fig.2



Correlation amongst forms of carbon in different soil series of Dambal sub-watershed

Organic carbon showed a significant and positive correlation with water carbon ($r = 0.842^{**}$) and active carbon ($r = 0.638^{**}$). Water soluble carbon was significantly and positively correlated with active carbon ($r = 0.753^{**}$). It clearly indicates that increase in organic carbon content leads to the increase in water soluble carbon and active carbon content. Inorganic carbon and total carbon showed negative correlation with water soluble, organic and active carbon, while inorganic carbon significantly and positively correlated with total carbon ($r = 0.937^{**}$), indicates that inorganic carbon contributed more to the total carbon. These results were also similar to the findings of Patil and Patil (2018) in Kanginahal sub-watershed of Northern dry zone of Karnataka and Majumdar and Patil (2017).

In conclusion the results of the present study on forms and distribution of carbon in the soils of Dambal sub-watershed of Mundargi taluk of Gadag district (Karnataka) concluded

that, soils were generally sandy clay loam to clay in texture, bulk density and particle density increased with depth and on contrary porosity was decreased with depth. The pH and EC values ranged from neutral to strongly alkaline and normal to strongly saline respectively. Organic carbon content followed decreasing trend with depth and irregular distribution was observed in free CaCO₃. CEC of soil series was average with Ca²⁺ found as dominant exchangeable cation followed by Mg²⁺, Na⁺ and K⁺. Majority of soils possessed medium to high per cent base saturation. Organic, water soluble and active carbon forms were decreased with depth in all the soil series, whereas inorganic and total carbon did not follow a particular trend. The distribution of carbon fractions in soils is mainly controlled by organic matter, which is the best indicator for assessing the carbon status of the soils. Knowledge about the vertical distribution of forms of carbon in soils was helpful in assessing the long-term carbon supplying capacity of soils. Water soluble and active carbon showed significant positive correlation with organic carbon, whereas inorganic and total carbon showed significant and positive correlation with

CaCO₃. Organic, water soluble and active carbon were significantly and positively correlated with each other, whereas inorganic and total carbon was significantly and positively correlated with each other.

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