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Altitudinal distribution of soil organic carbon stock and its relation to aspect and vegetation in the mountainous forest of Bagrot Valley, North Karakoram, Gilgit-Baltistan

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Abstract

Soil organic carbon (SOC) stock in mountain ecosystems is highly heterogeneous because of differences in soil parent material, climate, vegetation and topography. The area is unexplored with respect to distribution of SOC stock. Furthermore, SOC distribution factors like altitude, slope aspect, vegetation, deforestation and depth of soil remain unclear. In the present study SOC stock and bulk density in three depths were determined in 10-sites of forest under different altitude (2787-3600 m), slope aspect (north and south facing slope) and vegetation types on the mountainous forest of Bagrot valley, North Karakorum, Gilgit-Baltistan. The results showed that SOC stock and bulk density varied significantly with respect to altitude, aspect, vegetation and depths ($p < 0.05$). SOC stocks correlated positively with the altitude but negatively with bulk density, depth and pH. Mean SOC at north facing slope was comparatively higher than the south facing slope. The highest SOC stock was observed in Rakhan forest site at altitude 3460 m located at north facing slope and dominated by dense *Betula utilis* (Birch) vegetation. Similarly, the lowest SOC stock was found at the Gasonar forest site covered by *Juniperous excels* vegetation, where severely deforested was observed. The variation in SOC stocks were mainly due to the increasing precipitation and decreasing temperature and pH with altitude, which resulted in decreased litter decomposition. In addition to altitude the vegetation, soil depth and deforestation also significantly effect on SOC stock. Soil bulk density followed the above pattern but in inversed order.

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Introduction

Soils are the most important global carbon cycle reservoirs. They represent 75% of the total terrestrial organic carbon pool, and twice the atmospheric carbon content (Farquhar *et al.*, 2001). Most soil carbon is stored as soil organic matter (Lal, 2008). Forest and grassland soils are therefore of utmost importance as their organic matter content is much higher than that of agricultural soils (IPCC, 2000, 2007; Lal, 2004). Studies indicated that the forest ecosystem store almost 60% of the world's terrestrial carbon, so it represents a significant carbon pool to global carbon budget (Winjum *et al.,* 1992; Chhabra *et al.*, 2003). It is estimated that forest ecosystem has stored more than 80% of the above ground terrestrial carbon and more than 70% of soil organic carbon (Six *et al.*, 2002). Vegetation and soils are viable sinks of atmospheric carbon (C) and may significantly contribute to mitigation of global climate change and sustainable agriculture (Bajracharyaet *et al.,*1998; Phillips *et al.* 1998; Lal 2004; Smith 2004).

There are various factors which can influenced the soil organic carbon (SOC) stock such as altitude and climate (Garcia-Pausas *et al.,* 2007; Djukic *et al.,* 2010), aspect and slope position (Homann *et al.,* 1995; Perruchoud *et al.,* 2000), parent material and texture (Banfield *et al.,* 2002; Hoffmann *et al.,* 2009), pH (Falloon and Smith, 2009), topography (Yoo *et al.*, 2006), vegetation and stand age of the forest (Pregitzer and Euskirchen, 2004; Luyssaert *et al.*, 2008), and both human and natural disturbances (Czimczik *et al.,* 2005; Morgan *et al.,* 2010).

The most relevant factors that controlling SOC are altitude, climate, vegetation, and topography and profile depth (Baldock and Nelson, 2000). Altitudinal gradient induces microclimate which impacts directly on SOC content and rate of mineralization primarily through the effects of temperature and moisture. Temperature is a key factor controlling the rate of decomposition of biomass. For example, reaction rates double for each increase of 8–9°C in the mean annual air temperature (Bot and Benites, 2005). As a consequence, soils in cooler climates usually contain more organic matter due to slower mineralization rates. Similarly, SOC content increases as average annual rainfall increases (Meier and Leutschner, 2010). Variation in SOC concentration also correlate with changes in vegetation. For instance, herbaceous vegetation produces a big root mass compared with the above-ground component whereas, in forests, most organic matter is produced above ground and residues are more resistant to decomposition (Melillo *et al.*, 1993).

Topographic aspect (referred to as 'aspect') is a potentially significant factor in generating differences in ecosystem characteristics (Bale and Charley, 1994; Bale *et al.,* 1998). The hydrological and solar energy regimes of mountainous topography differ according to aspect, and such differences may lead to divergence in composition and distribution patterns of vegetation (Hartman and Lloyd, 1969; Ganuza and Almendros, 2003), soil formation and organic matter decomposition (Hicks and Frank, 1984). Aspect also induces local variation in temperature and precipitation, which along with chemical and physical composition of the substrate, are the main regulators of decomposition rates of soil organic matter (Hutchins *et al.,* 1976; Brubaker *et al.,* 1993; Chen *et al.,* 1997; Dahlgren *et al.,* 1997; Lisiki and Westman, 1997; Trumbore, 1997; Casanova *et al.,* 2000; Mendoza- Vega, 2002).

Mountain ecosystems are highly sensitive and vulnerable to climate change due to the system complexity and multi-faceted interacting drivers. However, it is substantial reservoir of organic Carbon due to lower temperatures and higher precipitation favor slow organic matter decomposition (Riedo *et al.,* 2001; Djukic *et al.,* 2010). Hence, small changes in precipitation and temperature may release large amounts of CO_2, due to increased microbial activity in a warmer and wetter climate compared to recent conditions (Theurillat *et al.,* 1998).

Last few decades the mountainous areas are severely influenced by both natural and anthropogenic pressure and encompass, among other factors, climate change, land use cover change, industrialization, urbanization, and changes in atmospheric chemistry (IPCC 2007a; Beniston 2000, 2006; Goudie and Cuff 2002). The rapid economic and population growth has major impact on forest in mountain ecosystem. This may lead to environmental deterioration by losses of soil organic carbon and greenhouse gases due to deforestation, over-grazing and the intensive cultivation of marginal soils (Beniston 2000, 2003).

Bagrot valley, north Karakorum have both the bottoms of artificial irrigation terraces in the semi-arid valley floor in 2,500 m, and the floors of the grazing areas, extending from the Artemisia steppe on the forest belt to the mat stage upto 4200 m which are economic importance. Furthermore, the slopes of mountain are steep, even precipitous, making fragile watershed areas and associated forest vegetation. The increasingly commercial and domestic use of sub-humid forests, pasture, shelter and food the natural land covers are being deforested at an alarming rate. This entails the risk increased soil erosion and increase gravitational mass transfer processes which destroy roads, fields and settlements. Consequently, there is extensive loss of topsoil, especially in the irregular steep slopes, hilltops, and ridges. Under such conditions, the role of plant cover in protecting soil against erosion is crucial, because removal of vegetation strongly increases surface runoff and sediment yield and as a consequence increase the emission rate of greenhouse gases emission which directly and indirectly effect on agricultural productivity and climate which may lead to permanent soil degradation, which in turn could become the greatest environmental problem to the mountain agro-ecosystem. Literature revealed that no study has been done on distribution of SOC stock and its relation to various influential factors. So, the present study was undertaken with the objectives;

(i) distribution organic carbon stock along the altitudinal gradients in the forest soil of the study area (ii) and also effect of slope-aspect, vegetation type, depth and intensity of deforestation on SOC concentration.

The outcome of this study might be useful for global carbon budget and also for sustainable environment management.

Material and methods

Description of Study area

Bagrote valley (42350 hectare) forms part of the Central Karakorum National Park, Gilgit-Baltistan, Pakistan. Globally, it is located at latitude 36° 01′ and longitude 74° 33′ and situated approximately 17 km from southeast of Gilgit Town. The valley is inhabited by approximately 14,700 people in10 villages. The lower section of the valley is narrow, with barren slopes and a few settlements. The central part is characterized by large flat plains, and is more densely populated and cultivated. Past the Hinarchi glacier, the upper reaches of Bagrot valley are also wide enough that can be used for seasonal cultivation. The valley floor ranges in altitude from 1,500m to 2,900 m. Forests located on the valley slopes from 2700 m up to 3700m. Outstanding physical features in the vicinity include the Rakaposhi peak (7,788m) and Diran (7,269m) peaks in the northwest and northeast respectively, and Dubani peak (6,143m) in the east. The study map was represented in figure 6.

The climate of the Gilgit-Baltistan fall the transitional between central Asian mid-latitude and Indian summer monsoon types. So, the area is placed in dry continental climate under the climatic regions of Pakistan. However, there are variable microclimates are exist due to influence of multi-scale topographic factors (Hewitt, 1989; Athar, 2005; Seong *et al.,* 2007, 2009). The study area Bagrote valley there is a huge contrast between the hot and dry valley bottoms and the cold ice desert in high altitude. In vertical profile from 3200 m to 3800 m the humid forest belt is located. The mean annual air temperature was recorded (- 4.3 to 8.1° C) from altitude range from 2450 m to 4150 m. While the mean precipitation was 142 mm/y at altitude 2210 m) and, 720 mm/y more humid conditions at higher elevations 4120 m. At the altitude 5000 m, more than 90% of the annual precipitation is deposited as snow monsoonal. The monsoonal influence is negligible in the region (Cramer, 1997: 266).

The geology of Bagrote valley is mainly composed of the rocks of the Chalt Group. It consists of alternating meta-sediments and volcanic. However, a small exposure of ultramafic rocks is also exposed. The terraces of glacio fluvial and fluvial sediments generally cover the chalt volcanic (Searle *et al.*, 1991). Landforms consist of colluviums and alluvial fans, glacier drift, and river terraces and moraine deposits. The colluvium soil mostly found in the area. However, at inceptisol and entisol were identified at north and south facing slopes respectively (Shamsher 2014 unpublished data).

The forest is located at alpine and sub alpine zones and scattered throughout the all valley in the form of small patches. All of the villages in Bagrot have equal access to high natural forests where from they meet their fuel-wood and timber requirements. The natural occurrence of vegetation at the Bagrot Valley, as well as in the other similar areas primarily depends on the amount and the exposure and climatic condition. In the valley, the areas below 2,000 m above sea level the Chenopodiaceous steppe and Artemisia steppe are dominant. From a height of approx. 2,300 m above sea level the vegetation mostly found Juniper (mainly *Juniperus excelsa*), whose population density decreased with increasing at high altitude. On the sunny slopes (south facing slope) up to an altitude of 3,800 m above sea level where find more or less closed Juniperus forests only. In north exposures at altitudes 2700-3600 m where wet–tempered Coniferous forests composed predominantly of *Pinus wallichiana* (tears pine) and *Picea smithiana* (Himalayan spruce). Furthermore the *Betula utilis* (birch) started from the elevation 3,200 m and its stocks increasingly which the tree stands dominate above the tree line of conifers up to 3600 m (Cramer 1997).

Soil sampling

So, the forest are scattered on north and south facing slope of the valley at different altitude. 10-sites were selected from altitude range from 2787 to 3600 m. The density and type of vegetation were varied with respect to altitude and slope aspect. The dominant vegetations were *Juniperus excelsa, Pinus wallichiana* (tears pine) and *Picea smithiana* (Himalayan spruce) and *Betula utilis* (birch). Further, anthropogenic interference i.e. deforestation intensity was also differed in different sites. At each sampling site, five randomly 40 m long and 5 m width transect was selected to ensure representative sampling for statistical analyses. Located each sampling point (30 * 30cm quardrat) in zigzag manner at the edge of 5 m wide strip along the transect and ten soil sub-samples in a" zigzag type pattern were collected from the depth of 0-20, 20-40 and 40-60cm layer by using a stainless steel cylinder and made a composite sample (Anderson and Ingram 1993). Exact location of sampling point, altitude and slope aspect was recorded by GPS and compass. One undisturbed core sample was also collected for bulk density from each site by using 100 cm^3 core ring. Roots, stones, and debris removed before sampling. The sample were packed in polyethen bag and labeled. About 1-kg mixed samples were returned to the laboratory and air dried for 2 to 3 days. Samples will be lightly ground, sieved through a 2-mm mesh. In this way total 150 sample (10-sites x 3-depth x 5-replicate= 150) were collected. The vegetation was also recorded. Morphological information of study area showed in table 1.

Laboratory analysis

The soil bulk density was determined by using core sampling method (Blake and Harte 1986). Soil pH (1:2) soil to water ratio was measuring using glass electrode pH meter (McLean, 1982). SOC was measured by the dichromate oxidation method (Kalembasa and Jenkinson 1973). The total organic carbon stock (Mg/ha) was calculated by following formula;

SOC stock (Mg/ha) = soil depth (cm) × bulk density (g cm-3) × C conc. (%) × 2mm< rock fragments (%).

Data analysis.

Analysis of variance (ANOVA) was used to analyze the significant difference of means of SOC and bulk density with respect to altitude, aspect, vegetation, intensity of deforestation and depths. Post-hoc tests for each variable were made using LSD comparisons. Pearson correlation analysis was used to determine the correlation between all the measured parameters. Significant differences for all statistical tests were evaluated at the level of $p \leq 0.05$ unless noted. All data analyses were conducted with the SPSS software (SAS 2002) and graphs were made on excel. Spatially distribution map of SOC stock was developed by subjecting the GPS readings and SOC data to the Arc View GIS and value was categorized into 5 levels.

Results

Altitudinal distribution of Soil organic carbon stock

The analysis of variance showed that overall mean (sum of three layers) of SOC stock and bulk density significantly varied ($P < 0.05$) with altitudinal (Table 2-4). SOC stocks correlated positively with the altitude r = 0.663 and negatively with bulk density r = 0.886, depth r = 0.947 and pH r = 0.733 at ($P < 0.01$) (Figure 4). Furthermore pH had negative correlation with altitude and bulk density (figure 5). An increasing trend of SOC stock (2.43±0.48 to 12.49±0.39) were observed with the increased altitude range from 2,797 to 3,460 m. Above this altitude a slightly decreased of SOC stock was found upto 3,600 m altitude. The same patter was also observed in 0-20, 20-40 and 40-60 cm soil layers (Table 2). Similarly, soil bulk density (g/cm^3) values were showed a decreasing trend with increased altitude. A linear decreasing pattern of bulk density (1.04±0.03 to 0.66±0.06) was observed with increasing altitude range from 2787-3600 m, except at the altitudes 3220, 3550 and 3600 m a slight deviation in bulk density was found (Table 3). The SOC (Mg/ha) was also calculated by multiplying SOC (%) * BD * depth (cm). The results revealed that the SOC (Mg/ha) followed the pattern of SOC (%) mentioned earlier. The highest overall mean value 156.26±22.60 of SOC stock (Mg/ha) was observed at Rakhan forest with altitude 3,460 m while, lowest 48.42±8.48 was found at Gasonar forest having altitude 2,797 m (Table 4).

Table 1. Morphological information study sites.

Site	Altitude (m)	Latitude	Longitude	Aspect	Vegetation
Gasonar	2787	36.03541	74.59228	NFS	*Juniperous excelsa*
Dar	2980	36.03416	74.62861	SFS	*Juniperous excelsa*
Damai	3160	36.02633	74.57406	NFS	Pinus wallichiana; Picea smithiana
Barche	3220	36.04486	74.64158	SFS	*Juniperous excelsa*
Khoo	3325	36.04491	74.641833	NFS	Pinus wallichiana; Picea smithiana
Sling	3400	36.01463	74.65403	NFS	*Betula utilus*
Rakhan	3460	36.01647	74.65553	NFS	*Betula utilus*
Diran	3550	36.06228	74.58619	SFS	*Juniperous excelsa*
Proni	3572	36.01886	74.58106	NFS	*Betula utilus*
Chokisai	3600	36.05759	74.57902	SFS	Juniperous excelsa

NFS, SFS are north and south facing slope.

Soil organic carbon stock in relation to slope aspect and vegetation

Statistical analysis showed that aspect significant effect on SOC stock ($p < 0.05$). The overall mean of SOC stock (8.20±0.81) at north facing slope was significantly higher than south facing slope (6.37±0.80). A similar, trend was observed in the individual depths (Figure 1b). The bulk density was not significant varied with respect to the slope aspect ($p > 0.05$). However, in south facing slope the overall mean of bulk density (0.84±0.03) was slightly higher then north facing slope (0.80±0.02). The same trend of bulk density was observed in each depth (Figure 1a).

Slope aspect effect on climate and vegetation distribution on mountain ecosystem. The analysis of variance showed that a significant different in SOC stock and bulk density were observed with respect to type of vegetation ($p <0.05$). Least significant difference (LSD) test showed *Juniperous excels* vegetation showed significantly lower SOC stock than coniferous vegetation (*Pinus wallichiana and Picea smithiana*) and *Betula utilis* vegetation ($p < 0.05$). A similar pattern of SOC stock was observed in the individual depths (Figure 2b). Similarly, bulk density values showed the same trend but in inverse order that *Juniperous excels* vegetation sites showed highest value while lowest value found in *Betula utilus* forest (Figure 2a).

Table 2. Altitudinal distribution of Soil organic carbon (%) in different depth of forest.

S.No	Altitude (m)	0 – 20cm	20 – 40cm	40 – 60 cm	Overall
1	2787	4.20 ± 0.06	2.20 ± 0.06	0.90 ± 0.06	2.43 ± 0.48^{a}
2	2980	4.30 ± 0.06	2.17 ± 0.06	1.43 ± 0.06	2.68 ± 0.44^{a}
3	3160	10.63 ± 0.12	4.50±0.06	3.60 ± 0.06	6.24 ± 1.12^{ab}
4	3220	9.61 ± 0.12	5.71 ± 0.07	2.43 ± 0.03	5.92 ± 1.04^{ac}
5	3325	13.43 ± 0.12	6.64 ± 0.18	3.70 ± 0.06	7.92 ± 1.44^{bcd}
6	3400	19.33 ± 0.29	9.63 ± 0.09	4.59 ± 0.05	11.18 ± 2.17^{de}
7	3460	21.60 ± 0.17	10.43 ± 0.15	5.43 ± 0.09	12.49 ± 2.39^{ef}
8	3550	16.87 ± 0.12	7.30 ± 0.06	4.20 ± 0.06	9.46 ± 1.91^{bcef}
9	3572	16.48 ± 0.30	7.11 ± 0.06	3.13 ± 0.03	8.91 ± 1.98^{bcef}
10	3600	14.27 ± 0.23	5.63 ± 0.23	2.63 ± 0.03	7.51 ± 1.74^{bce}
	overall	13.07 ± 1.04^{a}	6.12 ± 0.49^{b}	3.20 ± 0.25^{c}	7.47 ± 5.85

Overall (Means ± SE) followed by same letter (s) across columns and rows are not significantly different with respect to altitude and depth at $P \leq 0.05$.

Table 3. Altitudinal variation of Soil bulk density (g/cm3) in different depth of forest.

S.No	Altitude (m)	0 – 20 cm	20 – 40 cm	40 – 60 cm	Overall
1	2787	0.94 ± 0.01	1.04± 0.01	1.14± 0.01	1.04 ± 0.03^{a}
2	2980	0.93± 0.01	1.00± 0.01	1.08± 0.01	1.00 ± 0.02^{ab}
3	3160	0.85± 0.01	0.92± 0.01	0.96± 0.02	0.91 ± 0.02^{bc}
4	3220	0.87± 0.01	0.95± 0.02	1.00± 0.02	0.94 ± 0.02^{b}
5	3325	0.72± 0.01	0.82± 0.03	0.92± 0.02	0.82 ± 0.03^{bc}
6	3400	0.60± 0.01	0.69± 0.01	0.78± 0.01	0.69 ± 0.03^{d}
7	3460	0.56± 0.01	0.64 ± 0.01	0.86± 0.01	0.69 ± 0.04^{d}
8	3550	0.66± 0.01	0.71± 0.01	0.89± 0.02	0.75 ± 0.03^{cd}
9	3572	0.45± 0.01	0.66± 0.01	0.89± 0.02	0.66 ± 0.06^{d}
10	3600	0.56 ± 0.01	0.69± 0.01	0.79± 0.01	0.68 ± 0.03^{d}
	overall	0.71 ± 0.03^{a}	0.81 ± 0.03^{a}	0.93 ± 0.02^{b}	0.82 ± 0.12

Overall means (Means ± SE) followed by same letter (s) across same columns and rows are not significantly different with respect to altitude and depth at $P \leq 0.05$.

Deforestation intensity showed a significant effect on distribution of SOC and bulk density ($p < 0.05$). In our study lowest overall mean of SOC (3.65±0.50) was observed in severely deforested site followed by moderately deforested (7.87 ± 0.88) and non-deforestation (10.02 ± 1.05) sites ($p < 0.05$) (Figure 3b). Deforestation intensity also effect on the bulk density. A similar inverse pattern in distribution of bulk density was observed that non-deforested site had lowest value (0.68±0.02) of bulk density while highest value (0.99±0.02) was found in the severely deforested site (Figure 3a).

SOC stock and bulk density were also varied significantly with respect to the depth ($p < 0.05$). Table (2-4). Correlation analysis also showed that

SOC and depth had a negative correlation (r = 0.9474) (Figure 4d). The highest concentration of SOC stock was observed in upper layer 0-20 cm while, lowest in 40-60 cm. On other hand the bulk density was statistically increased with the increasing depth (Table 3). The overall mean values of bulk densities were 0.71± 0.03, 0.81 ± 0.03 and 0.93 ± 0.02 observed in 0-20, 20-40 and 40-60 cm depth respectively (Table 3).

Table 4. Altitudinal distribution of Soil organic carbon (Mg/ha) in different depth (Means ± SE).

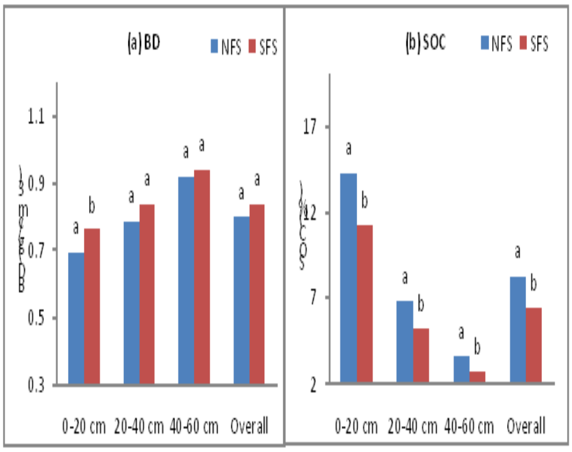
S.No	Altitude (m)	0-20 cm	20 – 40 cm	40 – 60 cm	Overall
1	2787	78.93 ± 0.01	45.79 ± 1.71	22.55 ± 1.52	48.42 ± 8.48
2	2980	79.93 ± 1.58	41.36 ± 1.21	30.32 ± 1.11	50.56 ± 7.56
3	3160	180.71 ± 0.77	82.78 ± 0.54	69.09 ± 0.35	110.86 ± 17.58
4	3220	167.16 ± 0.29	108.51 ± 0.75	48.48 ± 0.73	108.05 ± 17.13
5	3325	192.51 ± 0.42	109.09 ± 1.06	68.05 ± 0.39	123.22 ± 18.31
6	3400	230.61 ± 0.76	132.27 ± 0.50	71.55 ± 0.58	144.81 ± 23.18
7	3460	241.88 ± 0.56	133.48 ± 0.60	93.41 ± 0.35	156.26 ± 22.60
8	3550	222.61 ± 0.60	104.13 ± 0.50	74.72 ± 0.43	133.82 ± 22.60
9	3570	148.29 ± 0.88	93.32 ± 0.91	55.55 ± 0.76	99.05 ± 13.47
10	3600	109.68 ± 0.78	77.73± 0.34	41.60 ± 0.30	93.47± 17.47
		170.24 ± 10.01^{a}	92.85 ± 5.59^{b}	57.33 ± 3.3^{c}	106.81 ± 6.42

Overall means (Means ± SE) followed by same letter (s) across columns and rows are not significantly different with respect to altitude and depth at P≤ 0.05.

Discussion

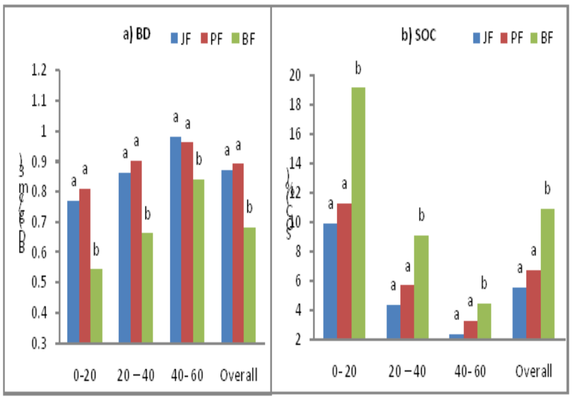
Distribution of Soil organic carbon with altitude

Forest ecosystem store almost 60% of the world's terrestrial carbon, so it represents a significant carbon pool to global carbon budget. It is estimated that forest ecosystem has stored more than 80% of the above ground terrestrial carbon and more than 70% soil organic carbon (Chhabra *et al.,* 2003; Six *et al.,* 2002; Winjum *et al.* 1992). Our study illustrates that SOC stock, bulk density vary with respect to altitude, slope aspect, vegetation communities and intensity of deforestation. The mean values of SOC stock were increased by increasing altitude upto 3,460 m and then slightly decreased up to the altitude 3,600m. The increases in SOC stock by increasing altitude probably due to decreasing temperature, increasing precipitation, soil acidity and vegetation density. Cooler temperature and higher precipitation retard the decomposition of litter. Soil organic matter (SOM) accumulation increases with increasing precipitation and decreases with increasing temperature (Kidanemariam *et al.,* 2012; Cole *et al.,* 1993; Schlesinger 1997). Likewise, soil pH may control biotic factors, such as biomass composition of bacteria and fungus (Baath *et al.,* 2003). In our study pH had negative correlation with SOC and altitude. The decrease in pH with increasing altitude in our study could be due to the increase of base cation leaching at higher altitude due to the greater soil water thus confirming previous report (Smith *et al.,* 2002) The change in altitudinal gradients can also influences SOM by controlling soil water balance, soil erosion and geological deposition processes (Lal *et al.,* 2004). The slightly decrease in SOC stock at altitude range from 3,460-3,600 m is might be due decrease in net primary production with increasing altitude driven by a shorter growing season. Our results are justified by previous literature (Hansen *et al.,* 2000; Peterson 2001; Peterson *et al.,* 2001; Makinen *et al.,* 2002). The highest value of SOC (21.61 %) found in top layer of Rakhan forest with altitude 3460 m. Our result is justified with reported by Noor (2013) and Schichkoof (2002). They reported SOC contents 19.19% and 21.9% at 3610 m and 3500 m from Astor valley and Batura II respectively. In present study decreasing trend of bulk density was observed by the increasing altitude. It might be high accumulation of SOM at high altitude. Thus, the soils with high organic matter accumulation are higher in percent pore space regardless of the amount of soil particles in the soil and results in lower bulk density whereas the soils with lower organic matter are lower in percent pore space and results in higher bulk density. Similar report by Sanjay *et. al.* (2010) also point out that the lower bulk density at high altitude are good indication of soil that has occupied coarser structure of organic matter and enriches the spaces by organic matter. Relationship between altitude and climate (temperature and precipitation) variation in study area (Bagrot valley) was calculated by Creamer (2000) that an average temperature decrease of 0.63 ° C per 100 m and a statistical increase of the precipitate to +17.6 mm per 100 m between 2,700 m and 4,000 m above sea level. Reports have also revealed that by increasing altitude temperature will typically decrease and the corresponding precipitation will increase (Barry 1981; Ineson *et al.,* 1998). Our results are consistent with the literature that both the SOC and altitude has a positive correlation (Sims 1986; Tate 1992).



Overall means followed by same letter(s) across each depth are not significantly different with respect to slope aspect at P≤ 0.05. NFS and SFS are north and south facing slope; BD and SOC are bulk density and soil organic carbon.

Fig. 1. Soil bulk density and organic carbon in relation to slope aspect in different depths.

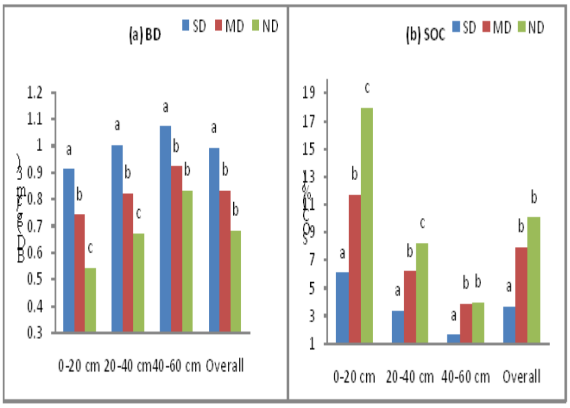


Means values followed by same letter(s) in each depth are not significantly different with respect to type of vegetation at P ≤ 0.05. JF, PF, BF, BD, SOC are Juniperous, Pine, Betula forest, bulk density, soil organic carbon).

Fig. 2. Soil bulk density and organic carbon in relation to vegetation type in different depth.

Soil organic carbon in relation to the slope aspect and vegetation

Our findings showed that SOC stock was slightly higher in north facing slope than south facing slope. The directional positions are a main factor for the differences in climate and vegetation distribution. In study area the south facing slope was warmer/drier than the north facing slope due to differences in micrometrological condition. The humid forest belt on north facing slope marks the climatic and ecological optimum zone of the natural vegetation. The southern slope receives higher solar radiation especially in winter. It was also observed that scatter dwarf *Juniperous excelsa* vegetation dominantly grown in south facing slope due to drought resistance ability. While in north facing slope dense coniferous forest (*Pinus walchinia, Picea smithinai* and *Betula utilis*) were observed due lower temperature high moisture content. The higher content of SOC stock in north facing aspect may be due the greater soil water content and lower soil temperature and high litter production. These factors may be contributing lower organic carbon turnover rate and favoring accumulation of considerably high amount of organic matter in these in these vegetation communities. Our results consisted with previous reports (Zhang *et al.,* 2007; Yimer *et al.,* 2006). Types of vegetation and density also effect on the SOC stock capacity. The highest SOC stock was found in Betula utilis forest is most probably be due to high density of tree and litter production by falling leaves at autumn every year. So, our result is justified by the literature that amount of organic matter high in these habitats where vegetation is dense (Noor 2013).



Means values followed by same letter(s) in each depth are not significantly different with respect to deforestation at P≤ 0.05.); SD, MD and ND (Severely, moderately and non-deforestation respectively). BD (bulk density); SOC (soil organic carbon).

Fig. 3. Soil bulk density and organic carbon in relation intensity of deforestation in different depth.

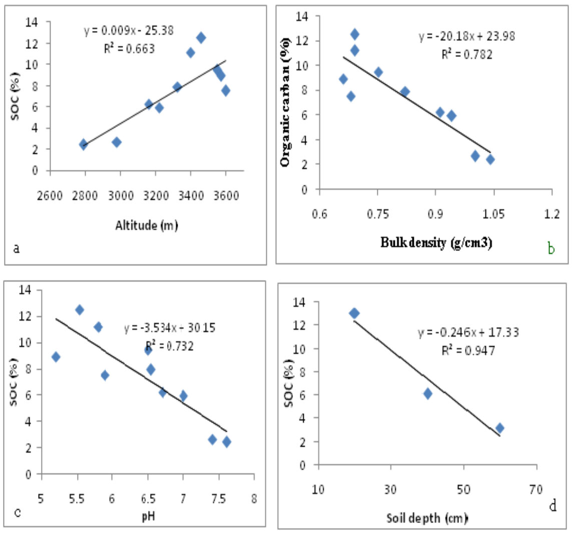


Fig. 4. Relationship of soil organic carbon with (a) altitude (b) bulk density (c) pH (d) depth.

The degree of deforestation has significant effect on SOC stock and bulk density. In our study severely deforested site showed lowest SOC stock followed by moderately and undisturbed forest. This may due to increasingly deforestation of sub-humid forests. As result increased soil erosion, surface runoff and increase gravitational mass transfer processes. Consequently, extensive loss of soil organic carbon from topsoil, especially in the irregular steep slopes, hilltops, and ridges sites. The same reason is also available in literature when the cutting of trees occurs on steep mountain slopes due to the increased risk of erosion, the accompanying loss of nutrient capital, organic and inorganic material, as well as degradation of the soil structure (Cebecauer and Hofierka, 2008). Deforestation can impact soils in multiple ways including reducing organic carbon and nitrogen and increase bulk density (Pennock and Kessel 1997; Mroz *et al.,* 1985).

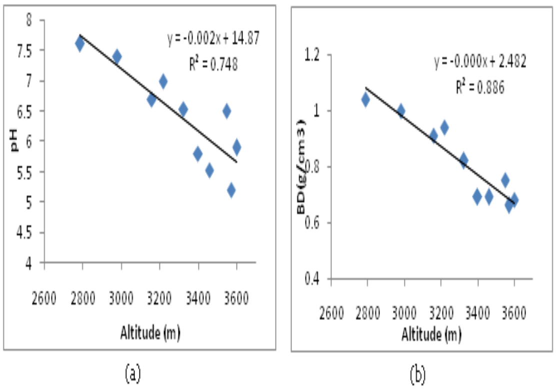


Fig. 5. Relationship among functional variables a) pH and altitude b) Bulk density and altitude.

Our finding showed that SOC stocking capacities in different layer were varied. About 50 -60 % SOC was stock in top layer while 25-30% in middle and 10-15% was bottom layer. It showed that top layer of soil is largest pool of SOC stock in forest soil. This is attributed partly to the continuous accumulation of undecayed and partially decomposed plant and animal residues in the surface soils. Hence findings of this study are in agreement with findings of similar and recent studies (Emiru 2013; Woldeamlak 2003; Genxu*et al.,* 2004).

Spatial distribution map of Soil organic carbon

From the analytical results and GPS readings of the 10-site of forest. The map locates the different forest sites. On the basis of SOC values forest was divided into 5-categories. (Figure 6). The spatial distribution may be very useful tool to locate the highly vulnerable site and provided base line data for policy makers and academia for effective management plane regarding the sustainable management of natural resources and mitigation of global climate change.

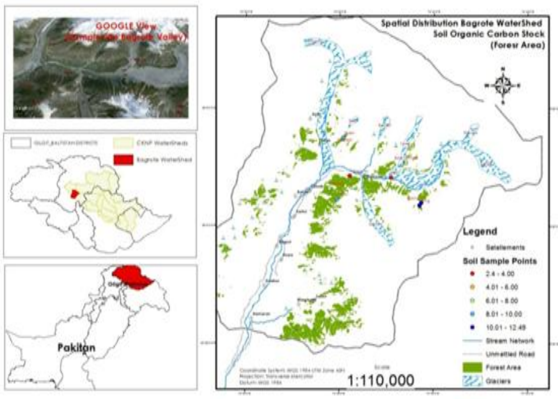


Fig. 6. Spatial distribution map of Soil organic carbon of the study area (Bagrot).

Conclusion

The forest of Bagrot valley, Central Karakoram is largest pool of soil organic carbon stock. The SOC stock was affected by altitude, aspect, vegetation type, deforestation intensity and depth. The undisturbed dense Betula utilis forest at north facing slope is largest reservoir of soil organic carbon. Similarly, SOC decreased with increasing intensity of deforestation. Further, top layer stock about 55-60% of total organic carbon as compared to lower layers. It is suggested that for sustainable environment and agriculture management there is dire need to be reduced deforestation and increased reforestation at north facing slope for maximum storage of SOC.

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