Soil Carbon Storage in Mountain Grasslands of Kashmir, India

Javaid M. Dad¹ and Zafar A. Reshi²

¹,²Department of Botany, University of Kashmir Srinagar–06, India
E-mail: ss.sajad@gmail.com

ABSTRACT

On account of their ecological, economical and cultural significance, grasslands are an important mark and a unique heritage in Jammu and Kashmir. However, the details of distribution of vast reserves of soil organic carbon (SOC) in these ecosystems are not well known because most of the previous investigations on these ecosystems have been devoted towards highlighting their importance as repositories of biodiversity. This is extremely limiting, considering that in the face of changing climate, this information is most valuable and central to any of our efforts to mitigate the ill effects of climate change. In this context, this article reports the results of measuring the stocks of SOC in mountain grasslands of Kashmir valley with an objective to highlight the status of Kashmir Himalayan grasslands as repositories of SOC.

Keywords: Altitudinal gradient; depth profile; grassland soils; soil carbon storage.

INTRODUCTION

Cognizant of the increasing carbon concentrations that threaten earth’s climate and natural habitats (Mitchell et al., 1995; Lal, 2003), efforts at various scales are being made to identify the potential mitigation strategies on a long-term basis. Grasslands are unique because besides being most sensitive and vulnerable to such changes due to their extensive soil carbon reserves (Korner, 2003), they are also promising targets for longer-term carbon uptake (Schimel, 1995). There is evidence that the soil carbon depends on combination of changes in floristic and community composition (biodiversity), land use and conservation practices which cause differences in quality and quantity of carbon input as well as in its decomposition rates. Although the carbon storage in grasslands has been studied worldwide but only a handful time restricted experiments have reported the influence of soil properties and biodiversity on the soil carbon fluxes (Adair et al., 2009; Steinbeiss et al., 2008). The use of the semi-natural/natural communities in such studies is all but meager. Given the fact that grasslands and mountain meadows are an important mark and a unique heritage in Jammu and Kashmir, India we postulated that estimating the soil carbon stocks of these grasslands will give us a primary indication of their importance as repositories of soil carbon in Kashmir valley and thus will provide an added impetus for their better management. With this objective we undertook a field investigation in mountain grassland to estimate and evaluate the storage of carbon in it.
METHODS

Two grasslands situated in Kashmir valley and located on its southern part in district Pulwama were selected for this study. While one grassland (Trag-further referred to as site 1) stretches between 33° 58’ 00.3” N latitude and 75° 10’ 43.0” E longitude at an altitude of 2502 m a.s.l., the other (Hobelpather-further referred to as site 2) is located between 34° 05’ 11.4” N latitude and 75° 06’ 04.1” E longitude at an altitude of 3033 m a.s.l. The quality of organic carbon data of the soils depends on sampling methods, the kind of vegetation, and the method of soil analysis performed in the laboratory. At each site, soil monoliths were excavated to a depth of 0.50 m. For each profile, soil samples were taken at depths of 0–10, 10–20, 20–30, 30–40 and 40–50 cm, using a standard cylindrical corer. The soil samples were air dried and then oven dried at 105 °C for determining the bulk density. For carbon analysis, soil samples were sieved through a 2mm mesh, handpicked to remove plant detritus and then ground. The soil carbon was analysed with Walkley and Black (1934) rapid titration method while moisture content was determined gravimetrically. Soil acidity (pH) and salt level (conductivity) were also measured following standard procedure (Gupta, 1999). Total SOCS in kg m⁻² were calculated as the sum of the content of each horizon and taking into account OC concentration and the measured soil bulk density and stoniness of each sample as follows:

\[ \text{SOCS} = \sum_{i=1}^{n} \text{OC}_i \times \text{BD}_i \times \text{th}_i \]  

(1)

where \( i \) represents each sampled horizon of the soil profile, \( \text{OC} \) is the organic carbon concentration (\%) in the fine earth (<2 mm), \( \text{BD} \) the soil bulk density (kg m⁻³) and \( \text{th} \) is the thickness (m) of each horizon.

RESULTS

The soil carbon content in studied grasslands ranged between 8.1 and 11.99 kg C m⁻² (mean ± SE: 2.009 ± 0.41 kg C m⁻²), with the highest values being recorded at site 1 and lowest at site 2 (Table 1). While comparing the soil organic carbon values of studied sites with each other, the carbon stock tended to decrease with increasing altitudes.

<table>
<thead>
<tr>
<th>Soil Depth</th>
<th>SOC (%)</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10</td>
<td>5.70</td>
<td>4.31</td>
<td></td>
</tr>
<tr>
<td>10–20</td>
<td>4.29</td>
<td>2.30</td>
<td></td>
</tr>
<tr>
<td>20–30</td>
<td>2.96</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>30–40</td>
<td>1.96</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>40–50</td>
<td>0.97</td>
<td>0.42</td>
<td></td>
</tr>
</tbody>
</table>

Due to a marked difference in site histories, grazing pressures and altitudinal contrasts there was a high variability in soil carbon stocks across the studied sites which was statistically significant also (\( p < 0.5 \)) The SOCS showed a positive relationship with soil depth and a decreasing trend in soil organic carbon (SOC) was observed with increased soil depths. Comparing the soil
carbon stocks of the two studied grasslands depth wise, it becomes quite evident that highest stocks at both the locations are present in the upper depths. On a percentage basis, the average stocks in the five soil depths (0–50 cm) are 47.48; 27.93; 10.96; 8.13 and 5.50 respectively. On an individual level, almost a similar trend was observed although the variation was much apparent at site 1 where the first two soil depths (0–10 and 10–20 cm) recorded more than 80% of the total carbon content. The same two equal soil depths at site 2 had almost 70% of the total carbon content.

![Fig. 1: Mean Soil Organic Carbon (%) Versus Soil Depth (cm) at Studied Grasslands](image)

The nature of soil was neutral to acidic across all the soil depths in the two studied grasslands and when averaged for all soil depths for individual grasslands, it varied between 5.77 and 6.71 at sites 2 and 1 respectively. However, the upper soil depth between the sites showed a little variation and ranged between 5.85 and 5.88 at sites 1 and 2, respectively. The salt level of sites also showed a little variation and ranged between 0.04 µS cm⁻¹ and 0.07 µScm⁻¹ at sites 2 and 1 respectively. The studied soil properties showed significant statistical differences and across all comparisons with altitude differed significantly (p < 0.05).

**DISCUSSION**

The soil carbon content in the studied grasslands (8.1–11.99 kg C m⁻²) is higher than what has been reported for the either temperate grasslands (11.7 kg C m⁻²- Jobbagy and Jackson- 2000) or in the Swiss alpine grasslands (6-9 kg C m⁻²- Leifeld et al., 2005). Our values are also higher than what has been reported for the forest ecosystems in other regions of India (Krishnan et al., 2007). It highlights the carbon sequestration potential of the Kashmir Himalayan grasslands. As is evident, across all the sites, the soil organic carbon decreased with increasing altitude and also with an increasing depth at both locations.
The higher organic carbon content in the top soil layer may be due to rapid decomposition which occurs in this region. SOC represents a significant pool of carbon within the biosphere (Grace et al., 2006), with climate shifts in temperature and precipitation exerting a major influence on both the decompositions and amount of SOC stored within an ecosystem as well as that released into atmosphere. However, the rate of cycling of carbon at different depths and in different pools across different vegetal cover is still not clear and consequently there is not, as yet, enough information to predict how the size and residence time of different fractions of soil organic carbon varies (Dinakaran and Krishnayya, 2008).

The depiction of our results that a higher concentration of soil organic carbon is present in top layer is in conformity with other studies where workers have also recorded this observation (Alamgir and Amin, 2008). The steep fall in the SOC content as depth increases is an indication of higher biological activity associated with top layers. This reflects that soil depth is an important variable to improve SOCS estimations in Kashmir Himalayan grasslands but a more extensive study is required to test and verify this trend across whole of the Kashmir Himalayan grasslands which stretch across a wide altitudinal, topographical and management gradient.

The maximum carbon stock was present at site 1 which is located at a lower altitude. The higher percent of soil organic carbon at this site may be due to a dense vegetation cover and higher input of litter which results in maximum accumulation and storage of carbon stock. A study carried out in the Western Ghats, India also shows the decline of soil organic carbon from 110.2 t C ha$^{-1}$ at an elevation > 1400 m to 82.6 t C ha$^{-1}$ at an elevation > 1800 m (Krishnan et al., 2007). The increasing tendency of carbon density with decreasing altitude may be better stabilization of SOC at lower altitudes. The production and decay rate of detritus in grassland depends both on climatic conditions as well as grazing pressure. The decreasing trend of C might also be attributed to the lower mineralization rate and net nitrification rate at the higher altitude. It is thus not surprising that altitude is often employed as an important factor to study the effects of climatic variables on SOM dynamics (Lemenih and Itanna, 2004). It is primarily because altitude has a profound effect on several other co-varying environmental variables which affect the accumulation and decomposition of soil organic matter. Particularly, the changes in climate along altitudinal gradients influence the composition and productivity of vegetation and, consequently, affect the quantity and turnover of soil organic matter (SOM). Altitude also influences SOM by controlling soil water balance, soil erosion and geologic deposition processes (Tan et al., 2004). To summarise, our results also point to the fact that grasslands are promising targets for longer-term carbon uptake, but given the fact that most of these ecosystems are under severe threat from invasive alien species, globalization, urbanization, and other anthropogenic pressures, the management of these ecosystems, in the face of changing climate, requires an added impetus from both policy as well as scientific community at both local, regional and national scale.
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REFERENCES


