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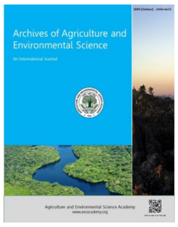

ORIGINAL RESEARCH ARTICLE

Carbon sequestration potential of various litter components in temperate coniferous forests of Kashmir Himalaya, India

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ABSTRACT

Natural forests play a key role in the mitigation of atmospheric carbon and have been studied by various workers but very limited work was carried out towards to the contribution of litter in carbon mitigation potential. The current study estimated the carbon sequestration potential in different components of litter in temperate coniferous forests. The results found that carbon content was found highest in cone followed by needle, branch and bark. Seasonal variation was found in all the components of the litter with highest carbon in autumn found at Daksum. During spring season Kuthar showed maximum contribution followed by Pahalgam in summer. Among different components of litter Cone contributed maximum at Kuthar while needle at Pahalgam. The result revealed that litter decomposition was directly related to the accumulation of soil organic carbon in all the ranges which depict the relation of litter with soil organic carbon. It was concluded that litter has an important contribution in sequestering atmospheric carbon as well as providing nutrients to the standing vegetation that mitigates the carbon dioxide.

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INTRODUCTION

Natural forests play an important role in the carbon sequestration. They act both as source and sink of carbon and vary with the geographic area and activities (IPCC, 2000). The temperate forests are responsive to changing climate during different seasons with respect to carbon (Mitchell and Jones, 2005; Piao *et al.,* 2008). These terrestrial ecosystems are productive and susceptible to environmental fluctuation which varies with seasonal carbon fluxes and other functions occurring in the forests (Baldocchi, 2008; Stoy *et al.,* 2008; Smith *et al.,* 2015). The carbon content of forest ecosystems depends on different component and these components have impact on total carbon cycle due to their small change. Sinks for carbon due to conservation and protection can be increased from the forests present (Brown *et al.,* 1996; Christopher *et al.,* 2003). Forests and soil have shared 60% of the total global terrestrial carbon (Winjum *et al.,* 1992) and are possible sinks of carbon present in the with great contribution in carbon mitigation (Bajracharya *et al.,* 1998; Lal, 2004; Kumar, 2015). Litter plays an important role in carbon sequestration. Mitigation of about 8% takes place by the litter components present on the floor of forests (Heath *et al.,* 2003; Chojnacky and Amacher, 2006), has key role in physical, chemical and biological processes occurring in the forest ecosystem (Graham *et al.,* 1999). Protection of soil from degradation, erosion as well as maintaining the soil moisture by forming mulch on the forest floor occurs only due to litter (Bonan, 2002). Forest floor affects the nutrient cycling (Sanchez *et al.,* 2006) and various nutrients like Sodium, Phosphorus, Potassium, Magnesium and Calcium stored and released during decay (Switzer *et al.,* 1979). Soil carbon storage assessment at various scales has gained importance in understanding carbon cycle changes (West *et al.,* 1994). Litter is positively correlated with soil organic carbons and rate of decomposition and soil organic carbon shows variation with elevation and northern region has more soil organic carbon as compared to southern region (Sharma *et al.,* 2011). Vegetation type as well as geographical position of the area influences the carbon sequestration rate (Han *et al.,* 2009). Since western Himalayas are temperate evergreen forests and litter fall occurs round the year. Thus litter has an important contribution towards carbon mitigation (Krishan *et al.,* 2009; Joshi and Negi, 2015). The current work was taken to study and estimate the variation of carbon in litter during different seasons of the year and its contribution towards the sequestration of increasing carbon dioxide level.

MATERIALS AND METHODS

Description of the study area: The study was carried out at four sites (Ranges) of Anantnag Division Viz. Pahalgam, Daksum, Kuthar and Kokernag with coordinates, (Pahalgam Latitude 33°57′08.3N Longitude 75°18′43.4E, Daksum Latitude 33° 34′43.1N Longitude 75° 23′17.2E, Kuthar Latitude 33° 34′43.1N Longitude 75° 23′17.2E and Kokernag Latitude 33° 34′43.1N Longitude 75° 23′17.2E). The study sites shows variation in altitude with Pahalgam 2115 amsl, Daksum 2370 msl, Kuthar 1986 msl and Kokernag 2029 msl. Influence of local people, tourism, and forest management were also taken into consideration during research work.

Sampling techniques on the field: Simple random sampling method was used to take samples. Sample plots were laid based on various factors like anthropogenic activities, protected or opened type, and altitudinal variation of the study area. Eight permanent randomly sampling quadrat of (20 × 20 m) in each site was established. For Litter sampling polythene mesh of 1m^2 were laid down inside the quadrat in a triangular form so that there is uniformity in collecting the litter samples. The carbon stock was determined by field survey and laboratory analysis. Sampling was done on seasonal basis viz., autumn; spring and summer season during the year 2014 to 2016.

Estimation of carbon in litter samples: Each of the litter samples were weighed using a digital scale and recorded. The samples were mixed well and a subsample of 50 gm each was taken for moisture content determination. The samples collected were subjected to air and oven drying. Oven drying was set at 65 – 70 degree and observed for at least 48 hours or until the samples reached their stable weight. Oven dried weight of subsamples were determined to compute for the total dry weights using the formula (Hairiah *et al.,* 2001). Carbon content was found 50% by oven dry weight (Walkey and Black, 1934; Schliesinger, 1991).

Total dry weight (kgm^{-2}) = Total fresh weight (kg) × subsample dry weight (g) / Subsample fresh weight (g) × sample area (m^2)

Statistical analysis: All the data generated were subjected to the statistical analysis using Sigma Stat 3.5 software for standard error, mean, standard deviation and analysis of variance (ANOVA).

RESULTS AND DISCUSSION

The total carbon content of different components of litter was estimated and found that Daksum showed highest litter fall during autumn season with total of 1.38 ton/ha in 2014 and 1.64 ton/ha in 2015 followed by Pahalgam 1.06 ton/ha in 2014 and 1.28 ton/ha in 2015, Kokernag 0.69 ton/ha in 2014 and 0.80 ton/ha in 2015 and Kuthar 0.98 ton/ha in 2014 and 1.1 ton/ha in 2015. Among different litter components of different range during autumn season, annual increment was found and the results revealed that cone showed maximum contribution in Kuthar with annual increment of 0.11 ton/ha (45.83%) followed by Pahalgam 0.08 ton/ha 33.33%, Daksum 0.03 ton/ha (12.5%) and Kokernag 0.02 ton/ha (8.33%) respectively. Needle carbon was found highest in Pahalgam with increment of 0.03 ton/ha (15%) and lowest was found in Kokernag with increment of 0.01 ton/ha (5%). Daksum and Kuthar showed the same increment of carbon with 0.02 ton/ha (10%) each. Branch was found highest in Pahalgam with increment of 0.08 ton/ha (44.44%) and lowest in Daksum with 0.02 ton/ha (11.11%) of increment. Kokernag and Kuthar showed same contribution of 0.04 ton/ha (22.22%) of carbon increment in each range. Bark carbon contribution was found highest in Pahalgam with increment of 0.07 ton/ha (33.33%) among all the ranges and lowest in Kokernag with increment of 0.04 ton/ha (19.04%). Again Daksum and Kuthar showed same contribution of 0.05 ton/ha (23.80%) (Figure 1).

Annual carbon increment, during spring season in all the components among different ranges was found highest in Kuthar with total of 0.77 ton/ha in 2015 and 0.83 ton/ha in 2016 followed by Pahalgam 0.58 ton/ha in 2014 and 0.83 ton/ha in 2016, Kokernag showed 0.70 ton/ha in 2014 and 0.77 ton/ha in 2016. 0.52 ton/ha of carbon was found in Daksum during 2014 and 0.79 ton/ha in 2016. Highest needle carbon increment of carbon was found in Pahalgam with 0.13 ton/ha (40.62%) among all the ranges followed by Kokernag with 0.09 ton/ha (28.12%), Daksum showed 0.06 ton/ha (18.75%) and Kuthar 0.02 ton/ha (6.25%). Carbon increment of branch was found highest in Daksum with 0.14 ton/ha (63.63%) and lowest in Pahalgam with 0.02 ton/ha (9.09%). Kokernag and Kuthar has same contribution of 0.03 ton/ha (13.63%) of carbon increment. As far as cone is concerned Pahalgam showed maximum increment of 0.08 ton/ha (44.44%) followed by Daksum 0.07 ton/ha (38.88%), Kuthar showed carbon increment of 0.01ton/ha (5.55%). No increment of carbon was found in Kokernag during the spring season. Bark contributed lowest in all the ranges with highest at Pahalgam of increment with 0.02 ton/ha (66.66%) followed by Kokernag with increment of 0.01 ton/ha (33.33%). No increment of carbon was found in Daksum and Kuthar during spring season (Figure 2).

During summer season maximum litter carbon among all the components was found highest at Pahalgam with 0.94 ton/ha in 2015 and 1.04 ton/ha in 2016 followed by Daksum 0.83 ton/ha in 2015 and 0.88 ton/ha in 2016, Kokernag has total carbon of 0.54 ton/ha in 2015 and 0.56 ton/ha in 2016 and Kuthar contribute carbon of 0.76 ton/ha in 2015 and 0.86 ton/ha in 2016. Needle contribution was found highest in Pahalgam with increment of 0.03 ton/ha (42.85%), followed by Kuthar with increment of 0.02 ton/ha (14.28%). Pahalgam and Kuthar have contribution of 0.03 ton/ha (42.85%) each. Kokernag has increment of 0.01 ton/ha (14.28%), while no increment in bark was found at Daksum range. Daksum and Pahalgam showed similar carbon increment of cone with 0.04 ton/ha (36.36%) each followed by Kuthar with increment of 0.03 ton/ha (27.27%). Kokernag has found no increment of cone during the summer season. Highest increment of bark carbon was found in Kuthar with increment of 0.02 ton/ha

(100%) while all the remaining ranges viz. Daksum, Pahalgam and Kokernag showed zero increment regarding bark carbon (Figure 3). The litter component among all the range was subjected to ANOVA and was found no significant difference at ($P \leq 0.05$) during all the seasons.

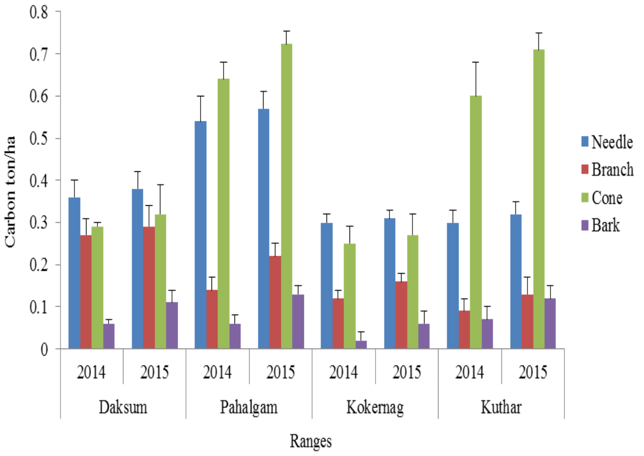

Figure 1. *Carbon content variation (ton/ha) of various components in different ranges during autumn season.*

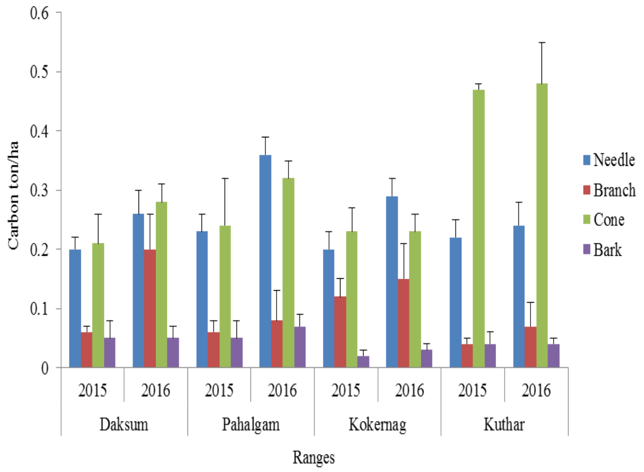

Figure 2. *Carbon content variation (ton/ha) of various components in different ranges during spring season.*

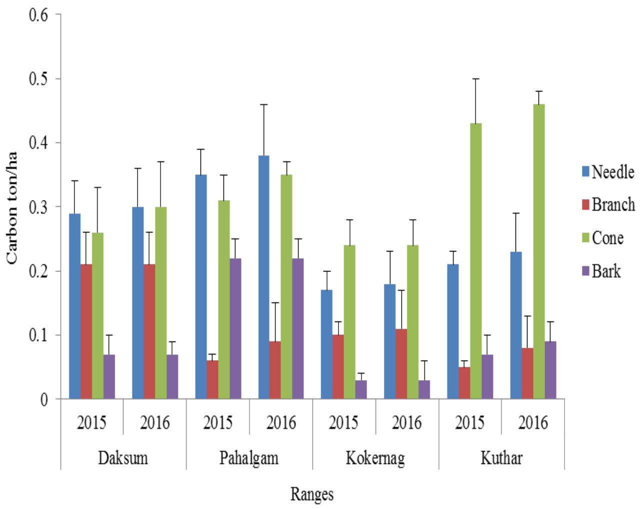

Figure 3. *Carbon content variation (ton/ha) of various components in different sites during summer season (mean ± within SD).*

Environmental factors and anthropogenic activities plays important role in seasonal variation of litter fall (Kavvadias *et al.,* 2001 Pedersen and Hansen, 1999). Previous workers had also segregated the litter into different components and observed variation on seasonal and monthly basis (Ogunyebi *et al.,* 2012). The litter fall quantity and its decomposition process varied with the density, age of the vegetation, growing rate and seasons of the year (Ogunyebi *et al.,* 2012; Duvigneaud and Denaeyer, 1970). Different workers (Rawat, 2012) showed highest litter fall in summer followed by spring and winter which are antagonistic to the current work but the reason for the same is nature of the vegetation, geographical location and climate of the area. The variation in carbon content among different ranges may be due to the age of the standing vegetation, anthropogenic involvement, and climatic factors as seasonal fluctuation has great impact on the litter variation. The highest contribution of litter is due to the tree density and protected nature of the area. Litter fallen there gets decomposed and converted into various nutrients thus helping in the fertility of the soil which again helps in regeneration of diversity. The cone contribution of Kuthar may be because of maturity of the cones at that time interval as same has been found in Pahalgam. As far as bark is concerned the same occurs due to the age of the tree and the trees of Kokernag were found old aged than corresponding ranges thus its contribution was found highest at Kokernag. Branch contribution was found highest in Daksum because of young aged trees where the branches arise continuously, hence, contributes maximum among all the ranges. Seasonal variation was also studied by (John, 1973). Previous workers (Ogunyebi *et al.,* 2012) showed similar results of seasonal variation with highest litter fall during autumn season. The lowest carbon content observed during spring season is due to the growth of fresh components on the trees which are new and replace the existing old ones, hence, take time for the various components to mature and fell down which eventually takes place in summer and autumn.

Conclusions

The current work concludes that temperate forests play an important role in mitigation of atmospheric carbon with litter as one of the important component to take part. Litter carbon varies with different components as well as different seasons which directly affect the soil organic carbon and other nutrients present in the soil. The litter carbon directly concludes the protection of the natural reserve as good density could be the best in litter production, hence carbon mitigation. The carbon variation was also found among different ranges based on various factors and was concluded that age of the vegetation, density, anthropogenic activities and seasonal variation has great impact on litter carbon.

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