

## An Assessment of C-stock and Soil physico-chemical properties in standing dead trees of Pine (*Pinus roxburghii* Sargent) forests in a Mountain Watershed Kumaun Himalaya, India

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### Abstract

The present study was carried out in Pine (*Pinus roxburghii* Sarg.) forest to assess the soil physico-chemical properties, dead standing trees biomass and C-stock between 1261 to 2200m elevations in Sitlakhet, Bimola forests, district Almora, Uttarakhand. Pine is a tall evergreen conifer tree with a spreading crown found in the Himalayas from Kashmir to Bhutan and in the Siwalik hills at altitudes of 450 - 2,400m asl. Pine are important and very often dominant components of the vegetation over large part of Himalayas out of total 24,414.80 km<sup>2</sup> area under forests; it occupies 3,943.83 km<sup>2</sup> which is 16.15 % of total forest area of the Uttarakhand. Pine is the most common resin producing species of India and also provide alternate source of fuel-wood, leaves for bedding materials and also influence ecosystem in many ways as they affect biogeochemical cycles, hydrology and fire regimes. In sub-tropical region of Kumaun Himalaya, large numbers of standing dead trees have been observed. Dead standing trees in the forest play equal role in C-stock storage as live trees. Although regular inputs of dead tree components play important role in enrichment of forest floor though litter, twigs, fruits and sometime entire tree. The result shows that average total C-stock in Bimola dead standing tree Pine forests was found more than twice as compared to Sitlakhet Pine forests 29.29 vs 56 t/ha. Physico-chemical properties of soil of two study sites Sitlakhet, Bimola in Kumaun Himalaya, across five soil depths, and winter, rainy and summer seasons were analysed. In general, all the soil parameters, viz. Soil moisture, water-holding capacity, organic carbon and organic matter were higher in Bimola Pine forest as compared than Sitlakhet Pine forests and those values were decreased significantly with increasing soil depth may explain that the zone of accumulation of nutrients is not well established in the forest soils of this mountainous region due to strong leaching effect. However, pH did not show any trend with soil depth in both forests. Soil nutrient concentration of soils in Sitlakhet Pine forests declining due to past forest fire.

**Keywords:** Standing dead Pine trees, Soil physico-chemical properties, Biomass, C-stock, Kumaun Himalaya.

### 1. Introduction

Biomass can be defined as the total quantity of live and dead organic matter, above and below ground expressed in tonnes of dry matter per unit area such as hectare. Biomass is a measure of forest structure and function, with both live and dead components and it is important for national development planning as well as for scientific studies of ecosystem productivity, carbon budgets Bohn, 1997, Brown, 1997, McDicken 1997 [6, 8, 43]. Forest biomass represents the largest terrestrial carbon sink and accounts for approximately 90% of all living terrestrial biomass Khera. 2001 [34]. Almost 70% of India's burgeoning population live in the rural areas and biomass plays an intimate role in their everyday life Rana. 1989, Robert. 1981) [51, 56]. Plant biomass provides the primary energy source and acts as the foundation for all the life forms. It is an important and major source of food, fodder for livestock, timber for housing and furniture and many other products needed for human existence in the world over Ravindranath, Hall, 1995 [52]. Live biomass through photosynthesis activity sequesters carbon from the atmosphere, whereas, dead biomass retains carbon for longer period even for decades and releasing it gradually by decomposition process Ravindranth 1997. [54]. above ground biomass is the most important visible and dominant C pool in the forests Wani, Lal 2003 [67]. Forests contain 85% of global above-ground carbon and thus play an important role in the global C cycle IPCC, 2001; Olson. 1983; Schimel 2001. [28, 47, 59]. The

above ground and below ground biomass both need to measure to enable better calculations of the total amount of forest carbon Bargali, Singh 1997; Humberg, 2000; IPCC, 2000. [3, 22, 29]. The improved quantification of pools and fluxes related to the forest carbon cycle is important for understanding the contribution of Indian forests to net carbon emissions as well as their potential for carbon sequestration Chhabra. 2003; Fahey, 1983 [12, 16]. Soil organic carbon SOC is the largest carbon reservoir in many terrestrial ecosystems including grasslands, savannas, boreal forests, tundra, some temperate forests, and cultivated systems, comprising as much as 98% of ecosystem carbon stocks in some systems Harmon, 1986; Schlesinger, 1977. [24, 60]. It has been estimated that SOC sequestration has the potential to mitigate 5-14% of total annual greenhouse gas emissions for the next 50-100 years Chan 2008; Dixon 1994. [10, 14]. The global climate has warmed by 0.7° C during the last century and is projected to rise by 1.8-4.0° C during the current century IPCC, 2007 [27]. Carbon sequestration by forests provides an important mechanism for the mitigation of global warming Dixo 1994; Lal 2004; Pant, Tewari, 2013. [14, 40, 49] and has become a key issue for researchers and forest managers. Consequently, much of the current research in this field focuses on improving our estimation of carbon stocks in the different components of forests, which are also of particular interest in terms of forest productivity Lal, 2005 [39]. The C-stock in a forest ecosystem can be broadly categorized as biotic vegetation carbon and

pedologic soil carbon components. The forest C-stock varies according to geographic location; plant species and age of plant stand Harmon 1990; Van Noordwijk 1997 [23, 66].

Standing and fallen dead tree are major types of coarse woody residues, act as both source and sink of carbon. It is playing an important role in the structure and function of ecosystems Franklin *et al.*, 1987 [17] provide habitat for organisms Harmon 1986, McKenny, Kirkpatrick, 1999 [24, 44] influence wildfires Kauffman 1998 [33] and help in maintain environmental carbon and nutrient cycles Fahey 1983; Krankina, Harmon 1995 [16, 36]. Volume of deadwood depends on productivity, pattern of natural disturbance, different forest types, management systems succession stages, forest history and human intervention Kumar, 2015 [38]. A standing dead tree biomass and C-stock related study was carried out by Domke 2011 [15] in the U. S. And suggest that density reductions and structural loss in standing dead trees substantially decreases estimates of standing dead tree biomass and carbon at tree, plot, and regional scales. Similarly Pugh, Gordon 2012 [50] carried out a study in Western North America with snow-dominated hydrology, and the result showed that widespread tree death in these watersheds can dramatically alter many eco-hydrological processes including transpiration, canopy solar transmission and snow interception, sub-canopy wind regimes, soil

infiltration, forest energy storage and snow surface albedo. IPCC 2000 [29] estimated the total soil carbon pool in top 1 m as 2011 Lal PgC 1999 [41] gave a conservative estimate of soil carbon pool as 2300 PgC, which is about 4.1 times the biotic pool, and about three times the atmospheric carbon pool. A substantial portion of carbon fixed by vegetation is transferred to the soil annually Roy 2001, Van 1997 [57, 66] a portion of which is refractory material with long turnover times, the rest decomposes relatively rapidly and is returned to the atmosphere as CO<sub>2</sub> Wairiu, Lal 2003; Woomeer, 1999 [67, 69]. Pine forests are one of the dominant forest of Kumaun Himalayan regions. Therefore, soils of these forests can be potential mitigation tool for the rising atmospheric CO<sub>2</sub> levels. Scientific management and conservation of these forests is imperative to sustain and improve the C-stocks of the country. Studies on the quantification and distribution of SOC are needed to ascertain the capacity and potential of C-sequestration by Pine forest soils. Keeping this context in mind, the present study was undertaken to estimate the C-stock and soil physico-chemical properties of Pine forests of Sitlakhthet and Bimola ranges in Kumaun Himalaya. In forest ecosystem, enormous carbon stored which is classified in five pools (IPCC, 2007) [27].

**Table 1:** Different forest carbon pools

S.No.	Carbon pools	Description
1.	Above ground biomass (AGB)	All living biomass above the soil including stem, stump, branches, bark, seed and foliage
2.	Below ground biomass (BGB)	All living biomass of live roots, fine roots of less than 2 mm diameter
3.	Dead wood	It include all non-living woody biomass, dead roots
4.	Litter	It includes all non-living biomass with a diameter less than 5 cm (FSI), lying dead, in various states of decomposition above the mineral or organic soil
5.	Soil organic matter (SOM)	It includes organic carbon in mineral and organic soils to a specific depth

**Table 2:** Allometric biomass regression equations used for estimating dead biomass of Pine forests

Biomass (kg tree <sup>-1</sup> )	Intercept (a)	Slope (b)	r <sup>2</sup>
Bole	-6.42	2.60	0.99
First order branch	-9.83	2.98	0.98
Other branches	-9.34	2.63	0.96
Leaf	-6.11	1.87	0.95
Stump root	-7.22	2.45	0.98
Lateral root	-9.16	2.59	0.97
Fine root	-9.10	2.07	0.94

## Materials and methods

### Study Area

The study was carried out in Sitlakhthet and Bimola Pine forests of Kumaun Himalaya in Almora district (Khulgad watershed) of Uttarakhand. The study sites are located between 29°43'196" to 29°34'742" N latitude and 79°33'56" to 79°36'89" E longitude at 1261 to 2200m asl altitude. In this watershed conifer (*Pinus roxburghii*; Chir Pine) tree species make the dominant forests and occupy 36 km<sup>2</sup> area of the watershed. The climate of the study area is quite distinct in a year and represents three different marked seasons, i.e. summer, winter and rainy. The climate is influenced by

Monsoon pattern of rainfall. The average annual rainfall reported 1000 mm and approximately 75% rainfall is received from mid-June to mid-September. The winter is very cold with minimum temperature dropping to 1°C (December) and during summer temperature reaches up to 30°C June. In the Kumaun Himalayan region Chir Genus *Pinus* forests occur at lower altitudes 1000-1500 m asl, having low total species richness of shrubs and herbs.

### Standing dead tree forest biomass and C-stocks estimation

Carbon estimation of Pine dead standing trees in each site was carried out by quadrat method. The data was collected for diameter at breast height 1.3 m of individual tree, using allometric regression. Size of the quadrat used for tree (10 x 10m) was followed from Saxena and Singh (1982) [58]. The different size classes of the vegetation used were: tree (>30 cm, circumference at breast height, cbh); sapling (10-30 cm, cbh), and seedlings (<10 cm, cbh). Standing dead tree layer biomass was estimated using the allometric regression for each tree component developed by Chaturvedi and Singh (1987) [11] and Rawat and Singh (1988) [55] as follows:

$$\ln Y = a + b \ln X$$

Where, Y= biomass per tree and X is the circumference at breast height, a = intercept and b = slope of regression

C-stock of standing dead tree was determined using the biomass value of tree species multiplied by a factor (C= Biomass × 0.475) following Magnussen and Reed (2004) [42].

### Soil sampling and analysis

Soil samples were collected at five depths across (0-15 cm, 15-30 cm, 30-50, 50-70 and 70-90 cm) during summer, rainy and winter seasons. To minimize the effect of the inherent site variability three replicates of soil from each plot were sampled and mixed to make a composite sample for each depth. The soil samples were brought to the laboratory in air tight zipper bags and dried at room temperature for three days and sieved through a 2 mm sieve to remove stones and roots and coarse debris. Soil pH (soil: water ratio 1:5) was measured with the help of pre-calibrated digital pH meter with buffer solutions of

4.0, 7.0 and 9.2 (Black and Allen 1975) <sup>[5]</sup>. Soil water holding capacity (WHC) was determined by Hilgard Cup method (Cassel and Neilson 1986) <sup>[9]</sup>, and soil moisture was determined gravimetrically (ASTMD, 1986) <sup>[2]</sup>. Among the chemical parameters, soil organic carbon (SOC) was determined by modified Walkley and Black (1934) <sup>[68]</sup> method. Soil organic matter (SOM) was measured as follows (Singh and Singh 1992) <sup>[64]</sup>.

$SOM (\%) = SOC (\%) \times 1.724$ ; Where, 1.724 is Van Bemmelen factor.



**Fig 2:** A. Dead standing trees in natural Pine forest sites B. Close view of dead standing tree in forests C. Large number of young dead trees D. Litter fall from dead standing trees.

**Table 3:** Soil physico-chemical properties (across 0-90 cm depth) in Sitlakhthet standing dead Pine forest during winter, summer and rainy season

Soil physico-chemical characteristi	Standing dead Pine forests		
	Winter	Summer	Rainy
Water holding capacity (%)			
0-15	22.17±2.31	20.22±2.09	26.59±3.01
15-30	19.54±2.04	18.94±1.85	24.18±1.29
30-50	17.02±1.19	15.88±1.82	22.04±2.15
50-70	15.91±1.07	14.01±2.11	20.13±1.49
70-90	13.32±2.22	12.89±1.63	18.69±2.09
Mean	17.59±1.77	16.39±1.90	22.33±2.01
Moisture content (%)			
0-15	6.16±0.99	5.21±1.21	8.85±2.07
15-30	5.09±1.20	4.85±1.06	7.15±0.68
30-50	4.91±1.08	4.09±0.94	6.09±1.09

50-70	3.07±0.89	3.00±0.72	5.81±1.72
70-90	2.43±1.01	2.01±0.29	4.03±1.48
Mean	4.33±1.03	3.83±0.84	6.39±1.40
pH			
0-15	6.02±0.087	5.14±1.020	6.80±0.097
15-30	6.00±0.049	6.07±0.099	6.03±1.110
30-50	6.61±0.025	5.95±0.063	5.19±0.211
50-70	5.99±0.036	6.18±0.097	5.24±0.097
70-90	6.04±0.018	6.79±0.056	6.21±0.234
Mean	6.13±0.040	6.02±0.270	5.89±0.350
Organic carbon (%)			
0-15	1.08±0.060	1.31±0.141	1.40±0.098
15-30	1.00±0.071	1.20±0.067	1.00±0.102
30-50	0.84±0.056	1.17±0.940	0.54±0.068
50-70	0.59±0.044	1.00±0.480	0.49±0.046
70-90	0.28±0.067	0.56±0.130	0.19±0.121
Mean	0.76±0.060	1.05±0.350	0.72±0.090
Organic matter (%)			
0-15	1.86±0.68	2.26±1.04	2.42±0.89
15-30	1.73±0.12	2.07±0.59	1.73±1.09
30-50	1.45±0.16	2.02±0.61	0.93±0.68
50-70	1.02±0.09	1.73±0.28	0.85±1.02
70-90	0.48±0.97	0.96±0.21	0.33±0.91
Mean	1.31±0.41	1.81±0.55	1.25±0.92

**Table 4.** Soil physico-chemical properties (across 0-90 cm depth) in Bimola standing dead Pine forest during winter, summer and rainy season

Soil physico-chemical characteristics	Standing dead Pine forests		
	Winter	Summer	Rainy
Water holding capacity (%)			
0-15	24.22±3.01	21.69±1.98	29.37±1.19
15-30	22.91±2.11	20.07±2.04	25.70±1.87
30-50	19.36±1.28	17.48±3.11	23.08±3.08
50-70	17.61±2.09	15.11±1.62	22.93±1.66
70-90	15.30±1.16	13.99±1.51	21.31±1.40
Mean	19.88±1.93	17.67±2.05	24.48±1.84
Moisture content (%)			
0-15	7.22±0.57	6.15±0.76	9.17±1.11
15-30	6.13±0.33	5.08±0.94	8.05±0.97
30-50	5.02±0.94	4.16±0.36	7.31±1.77
50-70	4.31±0.77	4.02±0.82	6.07±0.91
70-90	3.06±0.61	3.01±0.91	5.00±1.21
Mean	5.15±0.65	4.49±0.76	7.12±1.19
pH			
0-15	5.12±0.014	6.01±0.011	5.41±0.038
15-30	5.87±0.037	5.97±0.079	5.97±0.081
30-50	6.11±0.055	6.35±0.097	6.05±0.014
50-70	6.09±0.016	5.97±0.072	6.00±0.102
70-90	5.91±0.032	6.30±0.061	5.88±0.078
Mean	5.82±0.300	6.12±0.640	5.86±0.060
Organic carbon (%)			
0-15	1.21±0.036	2.04±0.099	1.19±0.081
15-30	1.08±0.018	1.94±0.041	1.11±0.069
30-50	1.00±0.066	1.40±0.038	0.61±0.061
50-70	0.94±0.097	1.08±0.240	0.52±0.053
70-90	0.77±0.011	0.91±0.109	0.31±0.110
Mean	1.00±0.460	1.48±0.110	0.75±0.074
Organic matter (%)			
0-15	2.09±1.11	3.52±1.16	2.05±0.48
15-30	1.86±0.97	3.35±0.78	1.92±1.02
30-50	1.72±0.87	2.42±1.01	1.05±0.77
50-70	1.62±1.07	1.86±0.69	0.89±0.13
70-90	1.33±0.79	1.57±1.66	0.54±0.81
Mean	1.73±0.97	2.55±1.06	1.29±0.81

**Table 5.** Biomass and C- stock in Sitlakhet standing dead Pine forest at five different sites

Study sites	Mean Cbh (cm)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	AGCS (t/ha)	BGCS (t/ha)	Total C- stock (t/ha)
Plot 1	48.00	90.40	63.15	153.56	42.95	30.00	72.95
Plot 2	35.26	48.55	33.78	82.33	23.06	16.04	29.12
Plot 3	45.00	84.33	58.89	143.26	40.07	27.97	68.05
Plot 4	53.28	101.05	70.66	171.72	47.99	33.57	81.57
Plot 5	38.00	35.13	24.47	59.59	16.69	11.63	28.31
Mean	43.91±3.28	71.89±12.74	50.19±8.93	122±21.67	34.15±6.05	23.84±4.21	56±11.35

AGB= above ground biomass, BGB= below ground biomass, AGCS=above ground carbon stock, BGCS= below ground carbon stock.

**Table 6.** Biomass and C- stock in Bimola standing dead Pine forest at five different sites

Study sites	Mean Cbh (cm)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	AGCS (t/ha)	BGCS (t/ha)	Total C- stock (t/ha)
Plot 1	35.5	32.61	22.69	55.29	15.49	10.79	26.27
Plot 2	30.0	27.06	18.78	45.86	12.85	8.92	21.78
Plot 3	42.5	39.66	27.66	67.33	18.84	13.14	31.98
Plot 4	40.0	37.14	25.89	63.03	17.64	12.29	29.94
Plot 5	48.0	45.21	31.58	76.79	21.47	15.01	36.47
Mean	39.2±3.06	36.34±3.09	25.32±2.18	61.66±5.26	17.26±1.47	12.03±1.04	29.29±2.49

AGB= above ground biomass, BGB= below ground biomass, AGCS=above ground carbon stock, BGCS= below ground carbon stock.

## Results and Discussion

### Soil physico-chemical characteristics in Sitlakhet, Bimola dead tree Pine forest

The mean values of physico-chemical properties of soil across the five soil depths (0-15 cm, 15-30 cm, 30-50, 50-70 and 70-90 cm) during summer, rainy and winter seasons for Pine forests analysed (Table 4&5). Organic carbon value (summer 1.48 vs 1.05 followed winter 1.00 vs 0.76 and rainy 0.75 vs 0.72) was found higher in Bimola than Sitlakhet Pine forests respectively. Similarly organic matter was higher in Bimola than Sitlakhet Pine forests. The mean value of organic carbon was more in summer as compared to winter and rainy due to the more accelerated activities of microbiota responsible for the degradation of organic matter in summer seasons (Jina 2008, Negi 2015) [31, 46]. SOC (range = 0.62-0.75%) have also been reported for Pine forests (0.62-0.75%) in this region (Rana 1985) [51]. A wide range (0.2-6.9%) of SOC has been reported for the forest soils of Garhwal region (Chaturvedi, Singh, 1987) [11]. It was remarkable to note that all the soil physico-chemical properties in Pine forests decreased with increasing depths. Similar trend has been reported in Oak and Pine forests of this region (Gosain 2015) [20]. Similarly the organic matter was found higher in summer (2.55 vs 1.81) followed winter (1.73 vs 1.31) and rainy season (1.29 vs 1.25) in Bimola and Sitlakhet Pine forests. In Bimola Pine forest the water holding capacity ranged between 13.99 to 29.37 and 12.89-26.59 in Sitlakhet Pine forests the maximum values was found in summer season. In Sitlakhet Pine forests the water holding capacity and moisture content were reported higher in rainy season (22.33±2.01 vs 6.39±1.40) followed winter (17.59±1.77 vs 4.33±1.03) and summer (16.39±1.9 vs 3.83±0.84) also shows the similarity with the results reported by Sheikh and Kumar 2010 [61]. In Bimola Pine forests the soil physico-chemical properties was higher (Table 5) than Sitlakhet Pine forests due to healthy forest management. Soil water holding capacity is an important indicator of soil fertility and capacity of soil to store (Adams *et al.*, 1990) [1]. Soil moisture content also an important physical properties of soils which influence the vegetation growth (Sheikh and Kumar, 2010) [61]. Maximum pH was found in winter (6.13±0.04) followed

summer (6.02±0.27) and (5.89±0.35) in rainy season (Table 3). The presence of high humus content in forest soils is responsible for low pH (Gupta and Singh 1990) [21]. The pH ranged (6.51-6.77) in Pine forests also reported by Singh *et al.*, 1987 [64] in Central Himalayan. Organic carbon decreased with increasing depths across all the five sites of Pine forests across winter, summer and rainy seasons (Table 3) which may be due to the fact that humus formation and decomposition of organic matter takes place in upper layers (Gairola 2012 ; Ghosh 1981; Joao 2001) [18, 19, 32].

### Biomass and C-stocks in standing dead trees Pine forests

Mean tree diameter was found ranging from 35.26 to 53.28 cm in Sitlakhet and 30 to 48 cm in Bimola Pine forests (Table 4&5). The average total biomass 122.0 vs 61.66 t/ha in Sitlakhet and Bimola forests respectively. C-stock was found higher in Sitlakhet 56.0 t/ha as compared to Bimola Pine forests 29.29 t/ha due to more number of dead tree. The value of above ground biomass of standing dead Pine was 35.13 t/ha to 101.05 t/ha (Table 4). The maximum below ground biomass was 70.66 t/ha followed by 63.15 t/ha and 58.89 t/ha for plot IV, plot I and plot III respectively (Table 4). The maximum (171.72 t/ha) total biomass of Pine trees was recorded in plot IV followed by plot I (153.56 t/ha) and plot III (143.26 t/ha) (Table 4). The maximum above ground (47.99 t/ha) and below ground (33.57 t/ha) C-stock was found in plot IV. Total C-stock value was ranging from 28.31 to 81.57 t/ha (Table 4). Kumar (2015) [38] reported the C-stock range (10.39-180.01 t/ha) of dead Pine forests in Sub tropical part of Garhwal Himalaya.

### Conclusion

Our study suggests that the dead trees have potential in C-stock storage. Dead trees and their components also enrich forest floor biomass after falling due to decomposition. The process of further decomposition of dead trees and its components cannot be avoided. But some time these trees are cut and used by villagers for fuel wood and other purposes, which directly affect the natural process of enrichment of forest floor and the potential of C- sequestration. Therefore, the awareness of

villagers about its effect on forest floor and direct emission of gases through use of fuel wood can be minimized. Thus the human interference affect the natural decomposition process of trees is forest floor and further affect nutrient release and carbon storage from the fallen and standing dead trees. Therefore, special strategies need to be done on government level, village community level to aware the people for maintaining these standing dead trees and even after fallen trees in the forest floor for long term carbon sequestration and ecosystem services.

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