Environment and Ecology 36 (2) : 473—478, April—June 2018
Website: environmentandecology.com ISSN 0970-0420

Changes in Physical and Chemical Properties of Decaying Deadwood in Broad-Leaf and Conifer Forests in Central Himalayas, India

Surindra Negi, Vir Singh

Received 24 December 2017 ; Accepted 10 January 2018 ; Published on 25 January 2018

Abstract Ecological significance of deadwood in forest ecosystems is poorly understood. In the present investigation an attempt has been made to evaluate the physical and chemical changes as well as estimate qualitative and quantitative characteristics of deadwood based on a study of broad-leaf and conifer in the subtropical region of Tarai in the district of Udham Singh Nagar and a temperate mountainous region in the district of Nainital in the Central Himalayas, India. The broad-leaf forest showed the higher amount of deadwood than that of the conifer forest. Out of the two taxa the angiosperms showed higher wood density, nitrogen, phosphorus and α-cellulose concentration than gymnosperms. However, the gymnosperm deadwoods showed higher amounts of moisture content, carbon, lignin and C-N ratio with increased decay phase, i.e. from decay phase 1 (least decayed) to decay phase 4 (highly decayed). The showed that due to the different wood characteristics of the two taxa and different forest type there was a great variation in the amount of deadwood nutrients in different decay phases.

Keywords Broad-leaf forest, Conifer forest, Deadwood, Decay, Cellulose.

Surindra Negi*, Vir Singh
Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar (US Nagar), Uttarakhand, India
e-mail: surindranegi05@gmail.com
*Correspondence

Introduction

Greenhouse gas emission and wildfire management have recently included inventory of C stored in deadwood at broad scales [1, 2]. Deadwood is distinguished into two types, viz. standing and lying deadwood [3]. Standing deadwood consists of standing dead trees refered to as snags and stumps. Snags are defined as vertical pieces of dead trees, typically with a specified lower size limit. Coarse woody debris (CWD) reaches the ecosystem through tree death and the eventual fall of standing dead material.

The stage of deadwood decay is a very important parameter in order to analyze ecological dynamics and quantify carbon pools [4]. Among various ways of classifying the level of decomposition of deadwood, the most common classification system is a 5-class system [5]. Nutrients are slowly released from decomposing wood, which apparently prevents their loss by leaching and contributes to their conservation, thereby helping to satisfy long-term nutrient requirements of tree species [6]. Nutrients are released from deadwood slowly over a long time ; hence deadwood acts as a natural fertilizer [7—10]. The release of nutrients can be performed by several different processes.

Relatively not adequate research on the amount, composition or dynamics of deadwood in Indian forests has been carried out. In this study, the deadwood was sampled from the two mixed forest of Tarai and hill zone and the identification of wood species

Table 1. The volume (m^3/ha ; means and standard deviations) of different deadwood types in two different forests and test statistics for testing the difference in volume between two forests.

Type of deadwood	Volume m^3/ha Broad-leaf forest	Conifer forest	Proportion of total volume (%) Broad-leaf forest	Conifer forest	Test statistic ($p < 0.05$)	Significant level
Standing dead-wood	3.62 ± 2.21	2.74 ± 0.55	47.1	51.1	$t = 0.36$	Significant
Lying dead-wood	3.76 ± 2.26	2.48 ± 1.11	34.9	30.97	$t = 0.29$	Significant
Stump	4.82 ± 2.77	2.09 ± 2.75	17.91	17.2		
Total dead-wood	12.2	7.36				

due to advanced state of decaying was not possible hence simple distinction conifer / broadleaved was applied [11]. Further, the deadwood from the broadleaf and conifer forest of Uttarakhand, India are taxonomically grouped into angiosperm and gymnosperm to get better understanding of decomposition of tree species having different wood characteristics. The overall aim of this study was a quantitative and qualitative assessment of deadwood in natural forests and evaluation of changes of physical and chemical content of deadwood during decomposition in relation to decay classes and tree species.

Materials and Methods

The study was carried out in two natural forests in the Kumaon Division of Uttarakhand the subtropical forest of Tarai zone of Udham Singh Nagar district (29°N latitude 79.30 E) longitudes ; altitude 243.8 m) and temperate forest of mountain zone in the Nainital district (29°21´ - 29°24´ N latitude and 79°25´ - 79°29´E longitude ; altitude 1,940-2,100 m). Stand structure is heterogeneous with *Shorea robusta* as a dominant tree species of different sizes, canopy, gaps and regeneration patches. The shrub layer is nearly absent, but the forest floor is covered with carpet of herbs. This area receives about an average of 1400 mm rainfall annually. The forest in Nainital district comprised of *Cupressus torulosa* as a dominant tree species. Average annual rainfall received in this area is 2488 mm.

Lying deadwood was sampled from study areas for the physical and chemical analysis.The assignment of deadwood to a decay class in the field was based on a visual assessment of deadwood morphological characteristics. Representative specimens of deadwood with the different decay classes and regions were collected in the month of August. The subsamples were taken by a chisel and a knife, the deepness of sampling holes was about 10 cm. At all sampling points the diameter of the log and decay phase were recorded. The samples were wrapped in plastic bags, brought to the laboratory and stored at 2°C. Subsamples were taken.

Volume of stump, standing and lying deadwood was measured by recording length and diameter. The formula of volume of cylinder is used for calculating the volume of stump as the shape of stump can be considered as a cylindrical. The volume of downed logs was estimated by new genetic model for volume estimation [12].

$$\text{Ln (volume)} = -2.2845 + 2.0349 \times \text{Ln (dbh)} + 0.6594 \times \text{Ln (length)}$$

(with dbh in cm, length in m and volume in dm^3)

The wood density of each block shaped deadwood samples was measured with the water displacement method. The quality of deadwood can be determine on the basis of visual features of dead trees [13, 14]. Decay levels were assessed according to the five decomposition classes [15] in the field of study areas and deadwood sample logs were brought to the labo-

Table 2. Means of investigated physical and chemical variables in different taxas with increase in decay phases.

Laxas and decay phase	Moisture (%)	Density (g/cm³)	C (%)	N (%)	P (kg/ha)	Lignin (mg/g)	α cellulose (mg/g)	C:N ratio	pH
Angiosperm									
1	45.32	0.68	40.86	0.27	42.4	18.76	18.20	151.87	5.38
2	47.6	0.73	40.83	0.34	44.33	18.13	17.43	121.1	4.33
3	53.6	0.37	38.75	0.40	80.3	15.43	14.23	96.88	4.56
4	59.34	0.29	37.83	0.58	63.47	14.09	12.6	65.23	4.36
Gymnosperm									
1	49.76	0.58	45.1	0.29	38.23	21.86	17.7	153.83	4.30
2	56.73	0.45	45.8	0.34	39.23	20.93	14.5	138.72	5.23
3	59.42	0.30	46.67	0.34	48.4	20.36	12.2	131	4.53
4	59.8	0.20	47.3	0.53	56.56	19.20	10.5	89.43	4.50

ratory for the physical and chemical analysis. Moisture content measured by measuring sample weight loss method and pH were analyzed using pH meter in the laboratory. Lignin content was determined by a round robin test protocol [16]. α-cellulose was extracted according to the standard procedure used by [17]. Total of 50% of the ash-free mass will be calculated as the carbon (C) content [18]. Determination of total nitrogen was done by kjeldahl method. The statistical analysis for the above mentioned parameters was carried out using *t*-test and two-way analysis of variance (ANOVA) technique through microcomputer 32 (with the help of STPR-15 and 2).

Results and Discussion

Qualitative and quantitative analysis of deadwood

On the basis of decay classification system [15] the quality of deadwood was assessed including standing deadwood, lying deadwood and stumps in both broad-leaf and conifer forest of Uttarakhand. Due to regular interruption of local people it was not possible to find out the final decay class of lying deadwood, as it is often removed from the site to be utilized as fuel wood.

There was a significant difference ($p < 0.05$) in the components of deadwood volume of broad-leaf forest and conifer forest. Statistical *t* - tests were not performed considering stump due to the low number of their occurrences in the data. In this study it was found that the volume of deadwood was higher in broad-leaf forest of Tarai region than the volume of deadwood in the conifer forest of the Himalayan mountains in Nainital district (Table 1). Lying deadwood and cut stumps are frequently used as a forest fuel in the hill zone so this practice likely altered the deadwood composition in the forest. Forest fuel harvesting reduces the volume of deadwood. The wood density of gymnosperm was lower than that of the angiosperm in decay phases. The wood density decreased very fast from decay phase 1 to 4 but from decay phase 3 to 4 it decreased gradually in both the species (Table 2).

Physical analysis of deadwood

pH decreases with decay phases but no clear trend was found in data. The effect of tree species, decay phases and their interaction were found to be significant ($p < 0.05$). The pH of deadwood for both the taxas was found slightly acidic in nature. Most of the investigations have been found showing decreasing pH values during decay [19]. Variation in the moisture content of deadwood found significant ($p < 0.05$) among decay phase between two species. Moisture

Table 3. Statistical analysis (two-way ANOVA) of the physical and chemical parameters. Factor a=tree species, Factor b=decay phase, a*b = Interaction of tree species and decay phase, NS=Non-significant ($p > 0.05$), ** = Highly significant ($p<0.05$), *=Less significant.

		SEm	CD	Significant level
Moisture				
	Factor a	0.11	0.33	NS
	Factor b	0.15	0.46	**
	a*b	0.22	0.66	**
Density	Factor a	0.32	0.98	NS
	Factor b	0.46	0.13	**
	a*b	0.65	0.19	**
C	Factor a	0.21	0.63	NS
	Factor b	0.29	0.89	NS
	a*b	0.42	1.26	**
N	Factor a	0.59	0.17	**
	Factor b	0.83	0.25	**
	a*b	0.11	0.35	**
P	Factor a	0.43	0.12	NS
	Factor b	0.60	0.18	**
	a*b	0.86	0.25	**
L	Factor a	0.38	1.15	NS
	Factor b	0.54	1.63	**
	a*b	0.77	2.31	NS
α cellulose	Factor a	0.34	0.10	NS
	Factor b	0.49	0.14	**
	a*b	0.69	0.20	**
C:N	Factor a	2.28	6.8	NS
	Factor b	3.23	9.6	**
	a*b	4.57	13.7	*
pH	Factor a	0.56	0.16	**
	Factor b	0.79	0.23	**
	a*b	0.11	0.33	**

content increased during decay, its value being low in decay phase 1 to 2 and was much higher in decay phase 3 to 4 in angiosperm whereas the value of moisture content in gymnosperm was slightly more than in angiosperm. The moisture content found in this study was different for gymnosperm and angiosperm, which might be due to the heavy rainfall at the time of sample collection from the study area. The water holding capacity and porosity of well decayed, soft woody material is much higher than that of the hardwood.

Chemical analysis of deadwood

In this study, deadwood type (i.e. broad-leaf vs conifer) alone did not show any significant difference in the carbon content of deadwood ($p > 0.05$) and non-significant difference among decay phases was observed ($p > 0.05$) (Table 3). It was observed that there was significant ($p < 0.05$) interaction between the tree species and decay phases. In the case of gymnosperm wood, there was more C content as it was decayed to a greater extent. The inverse appeared true for angiosperms. In angiosperm there was 7.41% decrease in the amount of carbon content from decay phase 1 to decay phase 4 whereas there was 4.5% increase in the carbon content in the gymnosperm. A possible cause of different temporal patterns in major tree taxa might be associated with the prevalence of white versus brown - rot fungi. White-rots are commonly responsible for the degradation of lignin in angiosperm whereas brown-rots, which are incapable of degrading lignin, are more prevalent in gymnosperms.

The nitrogen content varied significantly between tree species and among decay phase ($p < 0.05$). In both species, N content increased from decay phase 1 to 4. The concentration of nitrogen increased during decay. The nitrogen (N) in deadwood is released at slower rates than fine litter and retained within the ecosystem for a long time, suggesting that deadwood is a pool for slow N circulation.

There was no significant ($p > 0.05$) difference in phosphorus concentration among decay phases. The significant ($p < 0.05$) interaction between tree species and decay phase was observed. Earlier studies indicated that P was most limiting at the fir site. It is been reported that phosphorus has strong potential to remain immobilized in woody debris [20].

In gymnosperm wood α-cellulose varied significantly ($p < 0.05$) from decay phase 1 to 4. Significant differences were observed due to interaction between tree species and decay phases. Cellulose content was not statistically different between species. The cellulose concentration decreased with the increase in the decay phase in both the species. The cellulose content of gymnosperm was decreased by 40.6% from decay phase 1 to 4, whereas cellulose content of deadwood decreased by 30.7% from decay phase 1 to 4. Cellulose is easily decomposed by decomposing organisms, particularly in coniferous trees that are characterized by a relatively simple wood structure [21]. In gymnosperms there was 12% loss of initial amount whereas in angiosperm 24.89% loss of initial amount was observed.

The lignin concentration decreased with the increase in decay phase. Decay phase showed significant ($p < 0.05$) differences in the amount of lignin. Statistically, the interaction of tree species and decay phase was found non-significant ($p > 0.05$). The amount remained the same in the initial decay phase from decay phase 1 to 2 in angiosperm and then decreased faster from decay class 3 to 4. In gymnosperm lignin decreased slowly from decay class 1 to 3 and then sudden change in the lignin content was observed. In gymnosperms, lignin would be slowly degraded due to the resistance to decay of guaiacyl-based lignin, while in angiosperms ; syringyl-based lignin would tend to be more easily decomposed [22]. The decomposition of lignin was higher in the initial stage of decomposition in angiosperm than in gymnosperm while in the late stage of decay, lignin decomposition tended to be higher in gymnosperm.

C : N is a key indicator of decomposition process in deadwood. Tree species showed non-significant ($p > 0.05$) difference in ratio. Highly significant ($p < 0.05$) difference was observed in the C : N among decay phases. The tree species and decay phase interactions were found significant ($p < 0.05$). Gymnosperm shows higher C : N ratio in initial decay phase than gymnosperm and decreases with the increase in decay phases in both the species.

Certain environmental conditions as well as the growth and activity of the microorganism and insects in both the forests may contribute to the fast loss of nutrients from dead trees as well. Precipitation in Tarai region is abundant and often evenly distributed throughout the frost-free season which may enhance the leaching process.

Conclusion

Deadwood may serve as a vital component in the forest ecosystem by carrying out the nutrient cycling and transferring the nutrient from one system to another. The nutrients of deadwood vary between tree species and regions. The purpose of this study was to estimate the contribution of the deadwood in maintaining the forest health.

References

1. Woodall CW, Monleon VJ (2008) Sampling, estimation and analysis procedures for the down woody materials indicator. US For Serv Gen Tech Rep, NRS-22, Newtown Square, PA.
2. Heath LS, Smith J, Skog K, Nowak D, Woodall CW (2011) Managed forest carbon stock and stock-change estimates for the US Greenhouse Gas Inventory, 1990—2008. J For 109 : 167—173.
3. Vacik H, Rahman MM, Ruprecht H, Frank G (2009) Dynamics and structural changes of an oak dominated Natural Forest Reserve in Austria. Botanica Helvetica 119, pp 23—29.
4. Zell J, Kändler G, Hanewinkel M (2009) Predicting Constant Decay Rates of Coarse Woody Debris-a Meta-Analysis Approach with a Mixed Model. Ecol Modelling 220 : 904—912.
5. Hunter ML (1990) Wildlife, forests and forestry: Principles of managing forests for biological diversity. Englewood Cliffs, USA.
6. Ganjegunte LM, Condron PW, Clinton MR, Mahieu N (2004) Decomposition and nutrient release from radiata pine (*Pinus radiata*) coarse woody debris. For Ecol Manage 187 : 197—211.
7. Hruška J, Cienciala E (2002) Dlouhodobá acidifikace a nutricní degradace lesnich pud limitující faktor soucasného lesnictví, MZP, pp 160.
8. Janisch JE, Harmon ME (2001) Successional changes in live and dead wood carbon stores: Implications for net ecosystem productivity. Tree Physiol 22 : 77—89.
9. Mackensen J, Bauhus J (2003) Density loss and respiration rates in coarse woody debris of *Pinus radiata*, *Eucalyptus regnans* and *Eucalyptus maculata*. Soil Biol Biochem 35 : 177—186.
10. Turner DP, Koerper GJ, Harmon ME, Lee JJ (1995) A carbon budget for forests of the conterminous United States. Ecol Appl 5 : 421—436.
11. Stokland JN, Tomter SM, Söderberg U (2004) Development of deadwood indicators for biodiversity monitoring: Experiences from Scandinavia. EFI Proc , pp 207—228.
12. Wijdeven SMJ (2003) Stand dynamics in Pijpebrandje - a working-document on the dynamics in beech forest structure and composition over 12 years in pijpebrandje forest reserve, the Neitherland. Nat working report 30, pp 20.
13. Kruys N, Jonsson BG, Stahl G (2002) A stage-based matrix model for decay-class dynamics of woody debris. Ecol Appl 12 : 773—781.
14. Aakala T, (2010) Coarse woody debris in late-successional Picea abies forests I Northern Europe: Variability in quantities and models of decay class dynamics.

For Eco Manage 260 : 770—779.

15. Pyle C, Brown MM (1999) Heterogeneity of wood decay classes within hardwood logs. For Ecol Manage 114 : 253—259 doi : 10.1016/S03781127(98)00-356-9.
16. Aldaeus F, Schweinebarth H, Törngren P, Jacobs A (2010) Investigation and simplification of the determination of lignin content in kraft lignin samples and black liquors using the Klason method, submitted manuscript (in parts presented at 11^{th} European workshop on Lignocellulosics and Pulp, Hamburg, Germany).
17. Boettger T, Haupt M, Knöller K (2007) Wood cellulose preparation methods and mass spectrometric analysis of δ13C, δ18O and non-exchangeable δ2H values in cellulose, sugar and starch: An interlaboratory comparison. Anal Chem 79 : 4603.
18. Allen SE, Grimshaw HM, Parkinson JA, Quarmby C (1974) Chemical analysis of ecological materials. Oxford: Blackwell Scientific.
19. Christensen M, Vesterdal L (2003) Nat-Man WP7 Report: Denmark. Physical.
20. Idol TW, Figler RA, Pope PE, Ponder F (2001) Characterization of coarse woody debris across a 100 year chronosequence of upland oak-hickory forest. For Ecol Manage 149 : 153—161.
21. Laiho R, Prescott CE (2004) Decay and nutrient dynamics of coarse woody debris in northern coniferous forests: A synthesis. Can J For Res 34 : 763 : 778.
22. Ganjegunte LM, Condron PW, Clinton MR, Mahieu N (2004) Decomposition and nutrient release from radiata pine (*Pinus radiata*) coarse woody debris. For Ecol Manage 187 : 197—211.