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Production of Mass and Nutrient Content of Decaying Boles in Mature Deciduous Forest in Kwangnung Experimental Forest Station, Korea

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ABSTRACT: In order to elucidate the characteristics of standing crop biomass, production and nutrient content of dead bole in mature ecosystem, we surveyed the dynamics of decaying bole of old-aged deciduous forest in 1993 and 2002 in Kwangnung Experimetal Forest Station. In addition, we and estimated annual bole production, water content, wood density and nutrient content and compared the results with that of temperate ecosystem. Total dead wood biomass was estimated to be 5.6ton/ha in 1993 and 17.6 ton/ha in 2002. Standing dead tree accounted for a total of 1.1 ton/ha in 1993 and 4.8 ton/ha in 2002, which was 20% and 27% of the sum of dead bole mass in 1993 and 2002, respectively. Annual production of bole biomass was 1.3 ton/ha/yr. These values fall into the low range of dead wood biomass for the mature temperate ecosystems. Tree species composing standing bole was mainly *Quercus* and *Carpinus* trees. This bole species composition resembles alive species composition of this forest. Water content of bole increased as positive logarithmically, but wood density of bole decreased as negative exponentially along with the progress of decay. N, P, Ca and Mg concentrations in decaying boles generally increased with decay, except for K. Annual nutrient input via dead bole is 1.6 kg/ha/yr for N, 0.04 kg/ha/yr for P, 1.0 kg/ha/yr for K, 1.7 kg/ha/yr for Ca and 0.3 kg/ha/yr for Mg, respectively.

Key words : Bole biomass, Decay class, Mature forest, Nutrient content, Snags

INTRODUCTION

Dead bole is important as a pool of energy, carbon, and nutrients in ecosystems. For many microbes, invertebrates, vertebrates, and plants, dead boles and its associated microenvironment represents a habitat and /or food source. Knowledge of these boles is very important to effectively manage ecosystems because removal of boles may lead to an unexpected alternation of ecosystems unless these roles are appreciated.

Nutrient storage in decaying boles have been studied in a number of forest ecosystem, and its importance in forest nutrient cycling is widely recognized(Harmon *et al.* 1986). In some ecosystems, dead wood represents a high proportion of ecosystem biomass as well as nutrients(Greenland and Kowal 1960, Solins *et al.* 1980), Where in others it is a minor biomass compartment(Edwards and Grubb 1977). In cold-temperate and montane forests, slow decomposition and mineralization can result in the accumulation of organic matter and nutrients(Foster and Morrison 1976, MacLean and Wein 1978). If large amounts of nutrients are stored in boles, they could act as an important, slowly-available pool for plant uptake.

In Korea, mostly forests have younger age, because of disturbance under the use of tree as fuel resource and the Korean war. Only several areas, including Kwangnung and Mt. Chiri, and Mt. Jumbong show the decaying boles. However, no estimates have been made of the quantity or chemistry of woody debris component of these forest in Korea. This paper adds to the relatively limited information and data available on the woody debris component of forest ecosystem in Korea. The objectives of this study were: (1) to quantify the biomass of decaying boles and to estimates nutrient storage in this component; (2) to determine changes in nutrient concentration and content with advancing decay; and (3) to get an information for the management of old forest in Korea. Also, I wish inferring from this information the relative importance of decaying wood and its characteristics to restore the habitate of white-bellied black woodpecker, *Dryocoupus javensis richardsi* Tristram(endangerd, endemic bird species; Ham 1982) disappered in Kwangnung area since the mid 1980's.

STUDY SITE

The study area is a mature deciduous forest community locat-

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ed in Kwangnung Experimental Forest Station(2,331 ha; 37° 45′ N, 127° 10′ E), Kyonggi-do, South Korea. This forest ranges in elevation from 280 m to 477 m. This forests are considered to be typical temperate old-growth deciduous climax community, mainly consisted of *Quercus serrata, Q. aliena, Carpinus cordata* and *C. laxiflora*(You *et al.* 1995).

The climate of this area is characterized by heavy rain in summer and very dry in spring. Average precipitation is about 1,292mm yr^{-1} with approximately 60 percent occurring in from June to September, and as snow from December to January(You *et al.* 2002). Mean annual temperature is 11.3 ℃ (Park 1982). Mother rock is Kyonggi-gnesis compex and forest soils had an organic and litter layers which ranged in thickness from 5 to 30 cm(You *et al.* 2002). Soil depth ranges from 15 to greater than 90 cm.

METHODS

Field measurement

Thirty nine 0.01 ha(10 m x 10 m) permanent transect plots were placed contiguously through the forest area. All measurements of decaying boles were made within these plots. A system of dead bole classification was modified from Harmon *et al.*(1986) in order to accomodate differences in vegetation and climate of this forest(Table 1). Five decay classes were defined for fallen boles based on characteristics such as presences or absences of bark, branches, herb and consistency of wood. Class I boles were actually undecomposed with most of the bark and branches intact. And the other extreme class, V boles were covered with herb and moss and the wood was broken down into small fragments. The rest of other classes fit into a continuum between two extremes. To determine class assignments, several logs were samples randomly to develop a practical suite of characteristics for objectively classifying boles into distinct decay classes. These tallying traits were then utilized to assign samples into decay classes in the field survey.

The diameter of all dead boles were recorded in each plot during an inventory of standing trees. Branch wood was not included. Cross sections were cut from downed boles and standing dead trees for determination of density and chemistry. Boles and standing dead trees were chosen subjectively for sampling, following identification of the decay class. A total of 50 samples was analyzed, distributed among the decay classes with slightly more samples in the less-decayed classes. Bark and wood were not separated on the subsamples. Field survey was carried out in 1993 and 2002.

Laboratory measurements and calculations

Samples densities were determined from volume displacement of dried millet grain(Fahey 1988). For each sample the average of five volume determinations was used. Water content of dead bole(%) was measured on the basis of dry weight at each decaying class. The samples were dried at 60℃ to constant weight for mass determination. The biomass was calculated for each decay class using the allometric equation with the parameter of bole diameter(Park 1984). And then dead bole biomass per hectare was calculated by applying the mean density value for each decay class to the mean biomass for that class. We determined the annual production of bole biomass from the difference of bole biomass between the value of 1993 and one of 2002.

The dried samples were ground to pass a fine screen(20 mesh per cm). Phosphorus, K, Ca and Mg were analysed with a Perkin-Elemer inductively coupled argon plasma analyzer(ICP) in Inistitue of Engineering Analytical Center of Seoul National University. For these analyses, samples were dry-ashed in quartz crucibles at 450℃, dissolved in concentrated HNO_3 plus 30% H_2O_2, and heated to dryness. Total N was analyzed using a micro-Kjeldahal digestion method(APHA 1989). Mean nutrient concentration were calculated for each decay class, including bark when it was present on the sample. Nutrient pools within the dead wood compartment were then calculated by applying mean nutrient concentrations to estimated biomass for each decay class.

RESULTS AND DISCUSSION

Biomass

Dead bole biomass decreased as negative geometrical function with advancing decaying class(Fig. 1). Total dead wood bio-

Table 1. Selected characteristics of decay classes of dead boles in mature deciduous forest in Kwangnung Experimental Forest Station

Character	Decay class				
	I	II	III	IV	V
Branches	Intact	Intact, but pull out easily	no	no	no
Bark intact(%)	50<	25-49	0	0	0
Bole shape	Round	Round	Round	Elliptical	Elliptical
Wood consistency	Solid hard	Solid hard	Solid soft	Fragmenting	Completely fragmented
Litter accumulation	No	No	Yes	Yes	Yes
Herbs	No	No	No	No	On log

mass was estimated to be 5.6ton/ha in 1993 and 17.6 ton/ha in 2002, including standing boles(Fig. 1). This value falls into the low range(16-38.4 ton/ha) of dead wood biomass for the mature ecosystems that have been measured in temperate region(Table 2), and also it is a relatively low proportion(6%) of total above-ground biomass(287 ton/ha; You 1994). There are several possible reasons that a relatively low percentage of ecosystem biomass resides in dead boles in this ecosystem. First, it is underestimated because we only considered larger bole(diameter >10 cm) to be decaying bole. Second, the humid and warm growing season, especially in summer, combined with the high organic contents of soil, results in high decomposition, short residence time, and low accumulation of dead boles. Finally, successional later tree species, *Quercus* and *Carpinus* plants, have longer longevity and harder density than earlier species such as Pinus tree and thus more resistant to disturbances such as typhoon and heavy snow precipitation. The lower biomass suggests that faster turnover rates may result in these nutrients being mobilized sooner in mature deciduous forests.

Standing dead tree accounted for a total of 1.1 ton/ha in 1993 and 4.8 ton/ha in 2002, which was 20% and 27% of the sum of dead bole mass in 1993 and 2002, respectively(Fig. 2). This value falls into low range(1-150 ton/ha) of snags reported (Harmon 1980). There were much standing bole biomass of oak and *Carpinus* trees than pine. This result are concurring with the pattern of live trees of this forest community analyses(You *et al.* 1995). *Pinus* bole mass was found only in 1993. These results is very important in that white-bellied black woodpeckers (*Dryocoupus javensis richardsi*) nest, breed and feed mainly on the pine tree, and thus there is rarely habitat for these birds. In order to restore the habitat for this endangered bird, we should prepare the plan that supports the success of pine regeneration.

Water content increased as positive logarithmically, but wood density decreased as negative exponentially along with the advancing decaying class(Fig. 3). This high water content facilitates the growth of basidiomycetes and ascomycetes and fungi imperfectii causing soft rots(Kaarik 1974)

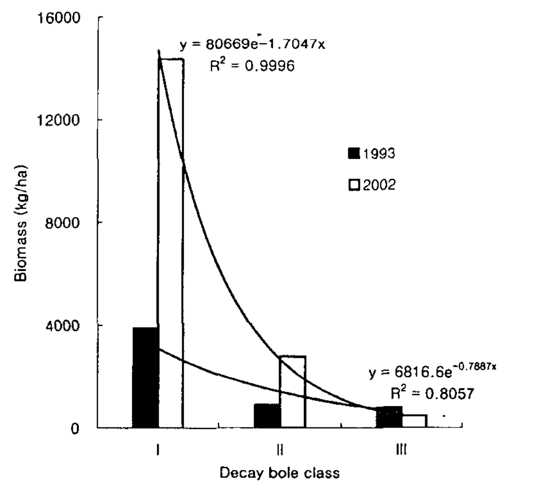

Fig. 1. Biomass of decay bole in mature deciduous forest of Kwangnung Experimental Forest Station in 1993 and 2002.

Table 2. Comparison of biomass of dead wood compartment of temperate forest ecosystems

Ecosystem	Ages (Years)	Biomass (ton/ha)	References
Quercus-Carpinus	500+	17.6	This study
Acer-Fagus	-200	38.4	Tritton(1980)
Fagus-Betulla	200+	29	Harmon(1980)
Quercus mixed	330+	21	Lang and Forman(1978)
Quercus mixed	220+	16	MacMillan(1981)
Quercus mixed	200+	24	Harmon(1980)
Quercus prinus	200+	21	Harmon(1980)

Nutrients in decaying boles

With the exception of K, element concentrations in decaying boles generally increased with decay(Table 3). Patterns of concentration changes in wood were masked by the inclusion of bark in the tissue analyses for standing dead and class I boles. With the advancement of decay, the largest changes in concentration were observed for P, followed by Ca, N, K and Mg, respectively. Content of N, P, and Ca increased with decay, despite the sloughing of nutrients-rich bark. Such increases have been observed by others(Grier 1978, Lang and Forman 1978, Lambert *et al.* 1980, Solins *et al.* 1980, Foster and Lang 1982) and may reflect additions from a variety of possible sources such as throughfall, litterfall, N-fixation, translocation by fungal hyphae, and root colonization(Lambert *et al.* 1980, Solins *et al.* 1980, Foster and Lang 1982). As in other studies(Foster and Lang 1982), the N:P ratio in decaying wood approached 20 in the most advanced decay class; however, this ratio declined to

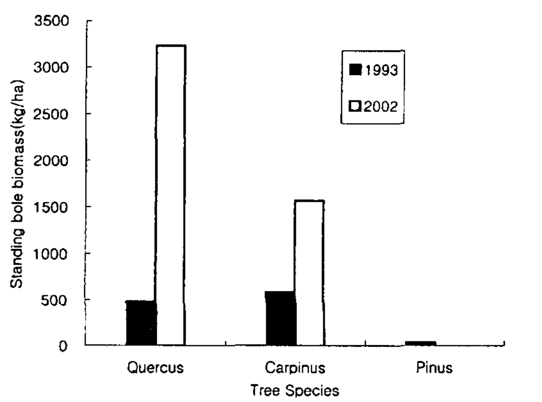

Fig. 2. Standing bole biomass of tree species of mature deciduous forest in Kwangnung Experimental Forest Station in 1993 and 2002.

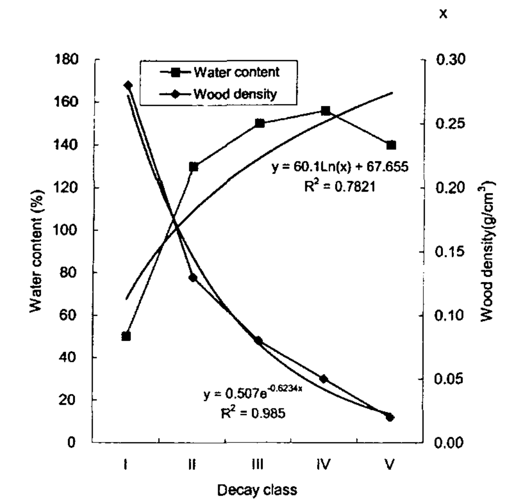

Fig. 3. Changes of water content and wood density along with the advancing decay class in Kwangnung Experimental Forest Station in 1993.

Table 3. Nutrient content(mg/g) of dead bole in mature deciduous forest dominated by *Quercus* and *Carpinus* in Kwangmung Experimetal Forest Station

Nutrient	Decay class				
	I	II	III	IV	V
N	1.18	0.98	1.32	1.67	5.32
P	0.03	0.04	0.74	0.01	0.27
K	0.75	0.91	0.30	0.31	0.29
Ca	1.31	2.12	2.43	2.97	6.53
Mg	0.22	0.33	0.34	0.38	0.5i6

about 16 in class IV wood before rising to 20 in class V.

Loss of K was greater than mass loss, a result that was expected due to the high mobility of this ion, but these results tend to exaggerate losses between decay class II and III. This behavior of K was also observed by Grier(1978), Lambert *et al.*(1980), and Graham and Cromack(1982). Magnesium content increased with decay. Others who have shown similar fluctuations in the amounts of Mg with bole decay(Foster and Lang 1982) have found this pattern difficult to explain.

We compared accumulations of nutrients in dead boles across several temperate ecosystems to identify general trends in the role of decaying wood as a nutrient storage poll(Table 4). All the amount of nutrient in dead bole falls into the low range of these ecosystems, except for K. In this forest, annual bole production is 1.3 ton/ha/yr which falls into the mean of ranges(0.5-1.9 ton/ha/yr) in temperate ecosystem(Table 5). Annual nutrient input via dead bole is 1.6 for N, 0.04 for P, 1.0 for K, 1.7 for Ca and 0.3 for Mg, respectively.

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Table 4. Comparison of biomass(toh/ha) and nutrient (kg/ha) of dead wood compartment of temperate forest ecosystems

Ecosystem	Ages (Years)	Mass (ton/ha)	N	P	K	Ca	Mg	References
Quercus-Carpinus	>500	17.6	20.3	0.9	13.3	25.9	4.2	This study
Quercus	>250	28	162	5	21	77	-	Lang and Forman (1978)
Mixed deciduous	40	4	310	-	20	430	-	Henderson *et al.* (1978)
Quercus/Carya	-	12	37	2	7	172	-	Lang and Forman (1978)
Quercus prunus	-	15	39	2	6	84	-	Lang and Forman (1978)

Table 5. Annual input of nutrients(kg/ha/yr) of decaying boles in selected temperate forest ecosystems

Ecosystem	Biomass (ton/ha/yr)	Nutrient(kg/ha/yr)					Referencess
		N	P	K	Ca	Mg	
Quercus-Carpinus	1.3	1.6	0.04	1.0	1.7	0.3	This study
Mixed northern hardwood	1.0	1.4	-	-	-	-	Gosz *et al.*(1972)
Mixed deciduous/pine	0.6-1.9	3.6	-	-	-	-	Harris *et al.*(1973)
Pseudotsuga menziesii	7.0	3.9	0.6	-	-	-	Solins *et al.*(1980)
Populus tremuloides	0.5	-	-	-	-	-	Gosz(1980)

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