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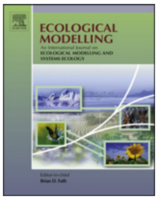

Modelling above- and below-ground mass loss and N dynamics in wooden dowels (LIDET) placed across North and Central America biomes at the decadal time scale

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ABSTRACT

This article focuses on modelling above and below-ground mass loss and nitrogen (N) dynamics based on the wooden dowels (*Gonystylus bancanus* [Miq.] Kurz) of the decadal Long-term Intersite Decomposition Experiment (LIDET) data. These dowels were placed at 27 locations across North and Central America, involving tropical, temperate and boreal forests, grasslands, wetlands and the tundra. The dowel, inserted vertically into the soil with one half remaining exposed to the air, revealed fast mass and N losses under warm to humid conditions, and slow losses under wet as well as cold to dry conditions. The model formulation, referred to as the Wood Decomposition Model, or WDM, related these losses to (i) mean annual precipitation, mean monthly January and July air temperatures, and (ii) mean annual actual evapotranspiration (AET) at each location. The resulting calibrations conformed well to the time-in-field averages for mass remaining by location: $R^2 = 0.83$ and 0.90 for the lower and upper parts, respectively. These values dropped, respectively, to 0.41 and 0.55 for the N concentrations, and to 0.28 and 0.43 for N remaining. These reductions likely refer to error propagation and to as yet unresolved variations in N transference into and out of the wood specific to each individual dowel location. Recalibrating the model parameters by ecosystem type reduced the R^2 values for actual versus best-fitted mass loss by about 0.15. Doing the same without location- or ecosystem-specific adjustments reduced the R^2 values further, by about 0.3.

1. Introduction

Predicting the rate at which wood decays and mineralizes is important for assessing past, current and future ecosystem-level carbon (C) and nitrogen (N) responses under varying and changing climate conditions (Laiho and Prescott, 2004). Quantifying these processes, however, is a complex task because of their dependence on wood type, size, shape, density, lignin content, presence of wood preservatives, configuration of placement, wood-consuming organisms at work, and antecedent conditions (Harmon et al., 1995; Stevens, 1997). For example, woody debris that remains dry mineralizes fairly slowly. In contrast, wood that remains moist decays more quickly by providing optimal conditions for the entry and growth of decay-causing organisms such as fungi, bacteria, insects and wood dwellers. Wood placed into the ground may decay even more quickly than wood resting on the ground, depending on differences in moisture content and the physical, chemical and biological conditions of the adjacent soil (Busse, 1994; van der Wal et al., 2007). With regard to N, decaying wood has low N concentrations prior to decay (Hungate, 1940). Hence, transference of exogenous N from adjacent soil and decaying litter is likely to occur on account of physico-chemical processes such as diffusion from N-enriched soil solution into wood and biological processes such as N_2 fixation, and transfer of exogenous N and other nutrients into the wood via invading organisms, especially fungal mycelia (Becker, 1971; Ausmus, 1977; Freya et al., 2003). Ecologically, decaying wood may therefore provide temporary storage for N and other nutrients for later use (Boddy and Watkinson, 1995; Pyle and Brown, 1999).

To gain insight into the overall mass and N dynamics in decaying wood, recent forest litter studies dealing with forest litter decay across widely ranging site and climate conditions have also produced data for wood decay. Among these studies are: the Long-term Intersite Decomposition Experiment in the United States (LIDET, 1995; Parton et al., 2007; Adair et al., 2008), the Decomposition

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Study in Europe (DECO: Jansson and Reurslag, 1992), the Canadian Intersite Decomposition Experiment (CIDET: Trofymow and CIDET Working Group, 1998; Preston et al., 2009a,b) and the International Research Group on Wood Preservation (IRG, Jurgensen et al., 2003). In general, wood represents a large portion of annual forest litter accumulations on top or within the existing forest floor, and within the mineral soil in the form of decaying roots (Harmon et al., 1986; Scheu and Schauermann, 1994). Local forest disturbances due to, e.g., fire, insects, storms, harvesting and fires add to this accumulation in the form of snags, harvest residues, and whole-tree blow-down. Under moist and warm conditions, which are also associated with high rates of evapotranspiration, rates of wood decay and N gains and losses in fallen or soil-emplaced wood would be highest, and would be least under consistently cold and dry conditions (Griffith and Boddy, 1991; Meentemeyer, 1978; Currie et al., 2010). It is, however, not known to what extent wood decomposition and N uptake and losses influence one another, and how these rates vary above and below the ground within and across ecosystems from tropical to arctic biomes.

The objective of this article is to quantify and model the extent of above- and below-ground mass and N loss and N concentrations in the LIDET dowels over the course of a decade as affected by location, ecosystem type, and across locations using time-in-field and climate variables such as annual rates of actual evapotranspiration, precipitation, and mean monthly July and January temperature as predictor variables. The resulting model formulation followed the earlier work on the Forest Litter Decomposition Model FLDM by Zhang et al. (2007, 2008). This particular approach revealed that progressive mass losses and related changes in N content within decaying leaf litter can be modeled across boreal to temperate forest conditions for a wide range of leaf litters. This was done by using first- to second-order rate equations for leaf litter decay and N mineralization, and invoking a gradual transitioning from an initially fast and perhaps N limited decay process to slow and eventually C limited mass and N losses from the increasingly humified residue. A similar transitioning can be expected to occur in decaying wood.

2. Methods

2.1. LIDET procedures

Wooden dowels (61 cm long, 13 mm in diameter) of a tropical hardwood species *Gonystylus bancanus* [Miq.] Kurz, generally referred to as “ramin”, were placed at 27 locations across North and Central America over the course of several years from 1990 to 1995 (LIDET, 1995). These locations represent a cross-section of biomes, varying from boreal, temperate and tropical forests to grasslands, wetlands and tundra (Table 1). Dowel emplacement occurred in two separate years in 24 locations, and only in one year at three locations. At each location, 48 dowels were placed on level ground

Table 1
LIDET locations, with specifications for mean annual precipitation, actual evapotranspiration (AET), and January and July temperatures, arranged by ecosystem type.

	Location	State/country	Ecosystem	17°5T Lat.	65°52’ Long.	Elev. (m)	Ppt (cm)	AET (cm)	T_{Jan} (°C)	T_{Julv} (°C)
BNZ	Bonanza Creek Experimental Forest	Alalaska	Boreal Forest	64°45′	148°00′	300	40.3	36.0	−24.9	16.4
LVW	Loch Vale Watershed	Colorado	Boreal Forest	4O°1T	105°39′	3160	109.6	85.1	−9.3	14.6
JUN	Juneau	Alaska	Temperate Conifer Forest	58°00′	134°00′	100	287.8	49.5	−5.6	12.9
BSF	Blodgett State Research Forest	California	Temperate Conifer Forest	38°52	120°39′	1300	124.4	75.3	9.4	23.4
AND	H. J. Andrews Experimental Forest	Oregon	Temperate Conifer Forest	44°14′	122°11′	500	230.9	76.4	0.3	18.3
OLY	Olympic National Park	Washington	Temperate Conifer Forest	47°50′	122°53′	150	153.1	79.4	5.1	16.2
UFL	University of Florida	Florida	Temperate Conifer Forest	29°45′	82°30′	35	123.8	116.6	15.3	26.8
NLK	North Temp. Lakes (Trout Lake Station)	Wisconsin	Temperate Deciduous Forest	46°00′	89°40′	500	67.7	64.9	−12.5	19.1
HBR	Hubbard Brook Experimental Forest	New Hampshire	Temperate Deciduous Forest	43°56′	71°45′	300	139.6	71.2	−8.7	18.8
CDR	Cedar Creek Natural History Area	Minnesota	Temperate Woodland Humid Grassland	45°24′	93°12′	230	82.3	73.3	−13.5	21 2
HFR	Harvard Forest	Massachusetts	Temperate Deciduous Forest	42°40′	72°15′	335	115.2	85.1	−6.9	20
CWT	Coweeta Hydrol. Laboratory	North Carolina	Temperate Deciduous Forest	35°0′	85°30′	700	190.6	117.3	3	21.5
GSF	Guanica State Forest	Puerto Rico	Dry Tropical Forest	17°57′	65°52′	80	50.8	50.2	24.9	27.7
MTV	Monte Verde	Costa Rica	Tropical Elfin Cloud Forest	10°18′	84°48′	1550	268.5	108.4	18.3	16.8
LUQ	Luquillo Experimental Forest	Puerto Rico	Humid Tropical Forest	18°19′	65°49′	350	336.3	123.4	20.8	24.8
BCI	Barro Colorado Island	Panama	Humid Tropical Seasonal Forest	9°10′	79°51′	30	269.2	136.8	25.2	25.6
LBS	La Selva Biological Station	Costa Rica	Humid Tropical Forest	10°00′	83°00′	35	409.9	169.9	24.9	25.9
SMR	Santa Margarita Ecological Reserve	California	Annual Grassland	33°30′	117°45′	500	24.0	23.6	12	20
SEV	Sevilleta	New Mexico	Warm Semi-desert	34°29′	106°40′	1572	25.4	25.2	2.9	25
JRN	Jornada Experimental Range	New Mexico	Warm Semi-desert	32°30′	106°45′	1410	29.8	29.2	3.8	26
CPR	Central Plains Eperimental Range	Colorado	Temperate Shortgrass	40°49′	104°46′	1650	44.0	43.0	−3.1	21.6
KNZ	Konza Praerie Research	Kansas	Temperate Tallgrass	39°05′	93°35′	366	79.1	74.7	−2.7	26.6
KBS	Kellogg Biological Station	Michigan	Agro Ecosystem	42°24′	85°24′	288	81.1	70.6	−5.1	22.5
VCR	Virginia Coast Reserve	Virginia	Wetland	37°30′	75°40′	0	113.8	99.3	3.1	25
NIN	North Inlet (Hobcaw Barony)	South Carolina	Wetland	33°30′	79°13′	2	149.1	120.6	8.4	26.9
ARC	Arctic Site, Toolik Lake	Alaska	Tundra	68°38′	122°11′	760	32.7	28.4	−20.3	10.8
NWT	Niwot Ridge & Green Lakes Valley	Colorado	Tundra	40°03′	105°37′	3650	124.9	64.7	−13.2	8.2