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Short communication

Direct effects of litter decomposition on soil dissolved organic carbon and nitrogen in a tropical rainforest

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ABSTRACT

To clarify how litter decomposition processes affect soil dissolved organic carbon (DOC) and soil dissolved nitrogen (DN) dynamics, we conducted a field experiment on leaf litter and collected DOC and DN from the underlying soil in a tropical rainforest in Xishuangbanna, southwest China. Principal components analysis (PCA) showed the first PCA axis (corresponding to degraded litter quantity and quality) explained 61.3% and 71.2% of variation in DOC and DN concentrations, respectively. Stepwise linear regression analysis indicated that litter carbon mass controlled DOC and hemicellulose mass controlled DN concentrations. Litter decomposition was the predominant factor controlling surface-soil DOC and DN dynamics in this tropical rainforest.

Soil dissolved organic carbon (DOC) and nitrogen (DN) are the most labile C and N fractions in biogeochemical cycling of surface soil. Most studies in temperate and boreal zone consider litter mass (Alison and John, 2000; Dawson et al., 2002; Evans et al., 2006; Kalbitz et al., 2007; Wu et al., 2010), litter species and litter chemical fractions (Magill and Aber, 2000; Park et al., 2002; Don and Kalbitz, 2005; De Troyer et al., 2011) as the main factors affecting surface-soil DOC and DN. In addition to litter quality and quantity, soil temperature and moisture have positive correlations with soil seasonal DOC and DN dynamics (McTiernan et al., 2003; Cleveland et al., 2004; Fröberg, 2004; Don and Kalbitz, 2005; Iqbal et al., 2010). Soil dissolved organic matter (DOM) production also increased with organic matter content in the long term (Saviozzi et al., 1994; Delprat et al., 1997; Gregorich et al., 2000) in high latitude forests and croplands. However, none of those experiments examined soil DOC and DN dynamics during continuous litter decomposition in field. Therefore, the relative importance of litter quality and quantity, environmental factors, and interacting effects related to these factors in controlling soil DOC and DN dynamics remain unclear. Furthermore, these studies were done in temperate and boreal zones, and comparable research in tropical forests has not been published.

To clarify the dynamics and main factors affecting soil DOC and DN during litter degradation and decomposition in field settings in tropical rainforest, a one year *in-situ* field litter decomposition experiment was carried out at the northern-most edge of Asian tropical rainforest in Xishuangbanna, southwest China (Study site and experimental details are described in the Supplementary material).

Both the soil DOC and DN concentrations under the litter bags decreased significantly after an initial peak (DOC: 113.4 ± 16.4 mg C kg^{-1}; DN: 27.4 ± 3.8 mg N kg^{-1}) with increasing degradation and decomposition of litter (Fig. 1). Patterns of DOC and DN concentrations did not correspond with seasonal changes of soil moisture and temperature (Fig. 1, Supplementary Fig. S1), which contrast results from field and laboratory experiments in temperate and boreal forests (McTiernan et al., 2003; Cleveland

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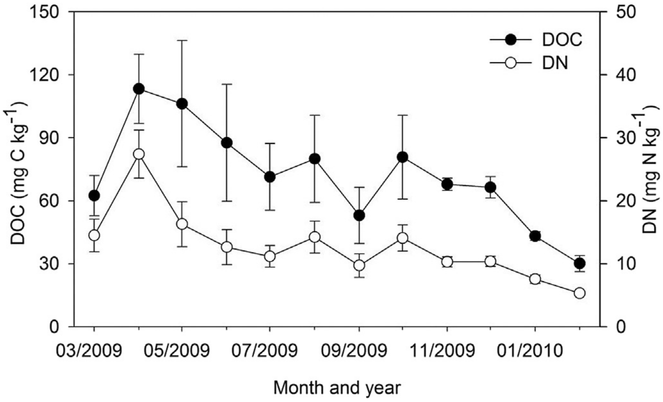

Fig. 1. Dynamics of soil dissolved organic carbon (DOC) and soil dissolved nitrogen (DN) concentrations during litter decomposition in the tropical rainforest of Xishuangbanna, southwest China. Data showed by 5 replicated mean ± standard deviation. Note: DOC and DN detected methods. Surface soil (0–10 cm) sample was collected using a 5-cm-diameter stainless steel corer immediately after removal of the litter bag at each row in 50 m × 100 m experiment plot per month from March 2009 to February 2010. Upon harvest, fresh soil samples were immediately sieved through a 2-mm mesh to remove fine roots, larger particles, and visible soil fauna. The water extracts of soil were vacuum-filtered through 0.45-μm glass filter fibre (GFF) (Tianjinshi Dongfang Changtai Environmental Protection Technology Co., Ltd., China). The Filter was detected DOC and DN by a TOC/TN analyser (LiquiTOC II, Elementar Analyzer system GmbH, Germany) within 24 h.

et al., 2004; Fröberg, 2004; Don and Kalbitz, 2005; Iqbal et al., 2010). DOC and DN concentrations were significantly correlated to remaining litter, litter carbon, litter nitrogen and acid detergent fibre masses. In addition, DOC concentrations were positively correlated to soil temperature at 10-cm depth, while DN concentration significantly correlated to litter carbon, cellulose, and neutral detergent fibre masses (Table 1). As Pearson correlation results showed multiple collinearity among all environmental, litter, and soil factors (Supplementary Table S1), Principal Components Analysis (PCA) and stepwise linear regression were performed to reveal the main factors on surface soil DOC and DN dynamics during litter decomposition.

The principal components (PC) 1 and PC2 together explained 67.4% of the variance of all 20 parameters (Fig. 2; Supplementary Table S2). Stepwise linear regression between DOC and DN concentrations and the six PCs showed PC1 explained 61.3% and 71.2% of the variation in DOC and DN concentrations, respectively, expressed according to.

$$DOC = 72.026 + 19.272\ \mathrm{PC1};\ r^2 = 0.613,\ p = 0.002 \quad (1)$$

$$DN = 12.501 + 4.772\ \mathrm{PC1};\ r^2 = 0.712,\ p < 0.001 \quad (2)$$

During litter decomposition, the most labile decomposition components are hemicellulose, followed by cellulose, ADF, NDF and finally lignin (Kalbitz et al., 2006, 2007). All these fractions lead to the release of C and N from litter by decomposition and allow them to enter soil. Thus the large variances in DOC and DN explained by PC1 indicate that degraded litter quality and quantity influence soil DOC and DN dynamics. This result predicts that decomposing litter mass influences forest surface soil DOC and DN dynamics in tropical forests, as in other forests (Li et al., 2003; Don and Kalbitz, 2005; Park and Matzner, 2006; Uselman et al., 2007). To clarify which litter fraction is the most limiting factor on concentrations of DOC and DN in surface soils, a stepwise linear regression between DOC and DN concentrations and all 7 PC1 parameters was performed, and showed the following:

$$\text{DOC concentration} = 10.727 + 21.527\ \text{litter carbon mass};\ r^2 = 0.720,\ p < 0.001 \quad (3)$$

$$\text{DN concentration} = 4.269 + 18.92\ \text{hemicellulose mass};\ r^2 = 0.800,\ p < 0.001 \quad (4)$$

These results show that the strongest limiting factor for DOC was litter carbon mass. Although different litter fractions varied during decomposition (Supplementary Fig. S2), the litter carbon mass is sum of all carbon fractions. So, litter carbon mass controlled surface-soil DOC concentration dynamics. In contrast, the limiting factor for soil DN was hemicellulose mass, composed of sugar polymers. A significant correlation between sugars and microbial mass has been observed, as nitrogen biogeochemical dynamics are controlled by microbiota (Ghehi et al., 2013). We conclude from our study and the results of Ghehi et al. (2013) that DN dynamics is associated with variations in monosaccharide components.

Soil temperature, moisture and rainfall were positively correlated to litter decomposition rates (Fig. 2, Supplementary Table S1), thus influence litter remaining mass and then affect surface soil DOC and DN dynamics according to PC2 and our stepwise linear regression results (Fig. 2). In the short term, relationships between DOC and SOC concentrations, and between DN and soil nitrogen concentrations, were not significant at our study site, inconsistent with the conclusion that DOC and DN varied with soil C and N in the long term (Saviozzi et al., 1994; Delprat et al., 1997; Gregorich et al., 2000).

Therefore, this study showed that in tropical rainforest, factors most directly affecting surface-soil DOC and DN are litter carbon mass and hemicellulose mass respectively during litter decomposition. Considering that global change may affect litter input and decomposition rates, to clarify the role of DOC and DN in C and N cycles, more attention should be paid to the mechanisms controlling biogeochemical cycles of DOC and DN in future studies.

Table 1
Correlations between concentrations of DOC and DN and all other measured parameters in the tropical rainforest of Xishuangbanna, Southwest China. This table only shows significant correlations between DOC and DN and litter, soil and environment parameters (Pearson correlation test). LRM: litter remain mass; LC, litter carbon content; CE.C: litter Cellulose content; T10: soil temperature at 10 cm depth; LC.M: litter carbon mass; LN.M: litter nitrogen mass; NDF.M: litter neutral detergent fibre mass; ADF.M: litter acid detergent fibre mass.

	LRM	LC	CE.C	T10	LC.M	LN.M	NDF.M	ADF.M
DOC	0.6229*			0.5804*	0.5884*	0.6335*		0.7769**
DN	0.6683**	0.5656*	−0.5477*		0.6679*	0.7485*	0.6351*	0.7460**

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

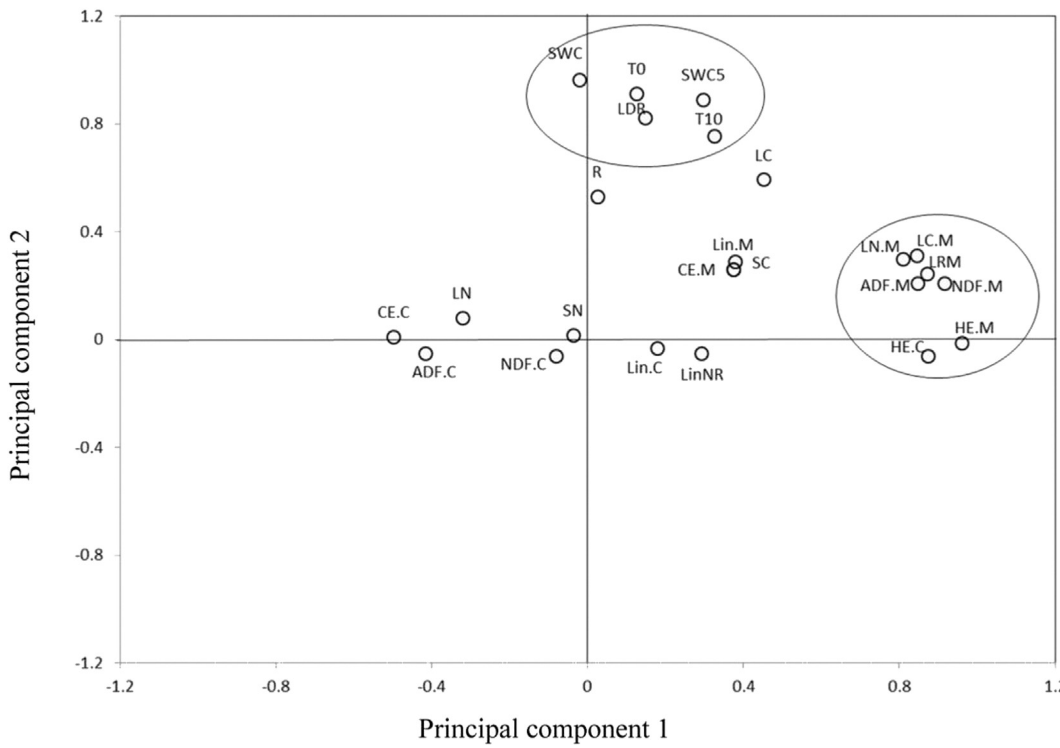

Fig. 2. Principal component analysis of patterns in litter, soil and environmental variables during the decomposition progress under the litter bag in the tropical rainforest of Xishuangbanna, southwest China. Notes: The first two axes (shows in the circles) explain 48.00 and 19.44% of the variability, respectively. Extraction method: PCA; Rotation method: Varimax with Kaiser normalization. LDR: litter decomposition rate; LRM: litter remain mass; LC, litter carbon content; LN: litter nitrogen content; ADF.C: litter acid detergent fibre content; NDF.C: litter neutral detergent fibre content; Lin.C: litter lignin content; HE.C: litter Hemicellulose content; CE.C: litter Cellulose content; LC.M: litter carbon mass; LN.M: litter nitrogen mass; NDF.M: litter neutral detergent fibre mass; ADF.M: litter acid detergent fibre mass; HE.M: litter Hemicellulose mass; CE.M: Litter cellulose mass; Lin.M: litter lignin mass; T0: surface temperature; T10: soil temperature at 10 cm depth; R: rainfall; SWC: soil water content of soil sample time; SWC5, monthly soil water content; SOC: soil organic carbon content; SN: soil nitrogen content. Litter sampling and quality and quantity analysis method. Five litter bags were randomly collected each month, one from each row from February 2010, after a total of 12 months of field exposure. For each harvested litter bag, we measured the percentage of litter mass remaining (LMR), the monthly litter decomposition rate (LDR) by oven dried method. After drying and weighing, the harvested litter was ground to pass a 1-mm screen. Total concentrations of C and N were determined using an element auto analyser (Vario MAX CN, Elementar Analysensysteme GmbH, Germany). Neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) concentrations were determined using a Fibertec system (Tecator, Hoganas, Sweden), hemicellulose content, cellulose content, and lignin content were calculated by the NDF, ADF and ADL contents. Mass of different litter fractions were the product of each fraction content multiply LMR. The SOC and TN concentrations of the soil were determined using an element auto analyser (Vario MAX CN, Elementar Analysensysteme GmbH, Germany).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.soilbio.2014.11.019.

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