Effect of nutrient cycle by different thinning practice in temperate forest

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Abstract
The plantation thinning and associated managements can influence the functions and structure of forest ecosystems as well as the status and dynamics of soil nutrients and organic matter that affect the forest ecosystem and related environment reciprocally. The objective of this study was to investigate the influences of thinning treatments to soil nutrient cycles and dissolved organic matter. This study was carried out in a 40-year-old *Cryptomeria japonica* plantation located at central Taiwan. Thinning intensity divided to control, 40% and 60%. Before and after thinning, soil was sampled and analysed for soil properties and dissolved nutrients such as dissolved organic carbon (DOC), cations and anions. The dissolved K^+ of control treatments was significantly higher than that of thinning treatments suggesting that K^+ was leaching down by rainfall after thinning treatment. The nitrate concentration extracted from fresh soil increased with thinning intensity indicating that fresh litter accumulated in the soil, the litter was decomposed by microbes and protein was released from plant tissue. Organic matter decomposed from litter was also transformed to NO_3^-, and therefore increased NO_3^- concentration. Thinning treatments affected concentrations of K^+, Fe^3+ Al^{3+}, and anions. Although the DOC concentrations showed no significantly difference, it might be complexed with induced with cations such Fe^{3+} and Al^{3+}. Nutrients are released from fresh litter decomposition after thinning treatment. Therefore, DOC plays an important role after plantation thinning. The results also can be a reference for nutrient management of plantation.

Key Words
Dissolved organic carbon, nutrient cycle, thinning practice

Introduction
Reasonable management of plantations is one of the most important strategies to improve timber production and stabilize forest ecosystems. Plantation thinning and associated managements can influence the functions and structure of forest ecosystems as well as the status and dynamics of soil nutrients and organic matter that affect the forest ecosystem and related environment. Litter accumulation and decomposition rate are affected by different thinning treatments. When litter decomposes, it also releases dissolved organic matter (DOM), such as dissolved organic carbon (DOC). The DOM can be stored in soil mineral layers and also affect the nutrient sorption capacity by soil (McDowell and Linkens 1988; Qualls and Haines 1991a; Currie *et al.* 1996). However, the transformation and dynamic of DOM is still obscure. Thus, the objective of this study was to investigate the influences of thinning treatments on soil nutrient cycles and dissolved organic matter.

Methods
Site Descriptions and Thinning Treatments
This study was carried out in a 40-year-old *Cryptomeria japonica* plantation located at Experimental Forest of National Taiwan University, Sitou, central Taiwan (Figure 1). The study site is a montane area with elevations ranging from 1800 to 1900 m. The annual precipitation is 2500 mm, occurring mainly between May and September, characteristically as thunderstorms associated with typhoons. The mean annual temperature of the site is 17.9°C. The parent materials are sandstones and clay sediments interbedded with Tertiary shale and slate (Ho, 1988). These three thinning treatments were setup at late 2008 as control (i.e., 0%), 40% and 60% thinning treatments according to the thinning intensities. Before the thinning treatment, we set four plots in each thinning treatment. Study zones are separated by 50 m and plot size was 5 x 5 m. Plots were randomly located within each zone. Four soil samples in each plot were collected from the O horizon (0-15cm) and A horizon (15-30 cm) at randomly as background for soil physical and chemical analyses. Soil samples were air-dried, sieved and passed through 2 mm sieve.The soils can be classified as sandy loam or silty loam, mixed, mesic, Typic Dystrudepts (Soil Survey Staff, 2006). The pH of soil samples was measured in distilled water (soil to solution = 1:2 w/w). Total C and N contents of the soils were

determined by a CHN analyzer. Cation-exchange capacity (CEC) of the soils was determined by ammonium acetate (NH_4OAc) exchange method (Rhoades, 1982). The exchangeable cations were determined by conductivity coupled plasma atomic emission spectroscopy (ICP-AES) (Perkin Elmer Optima 2000DV).

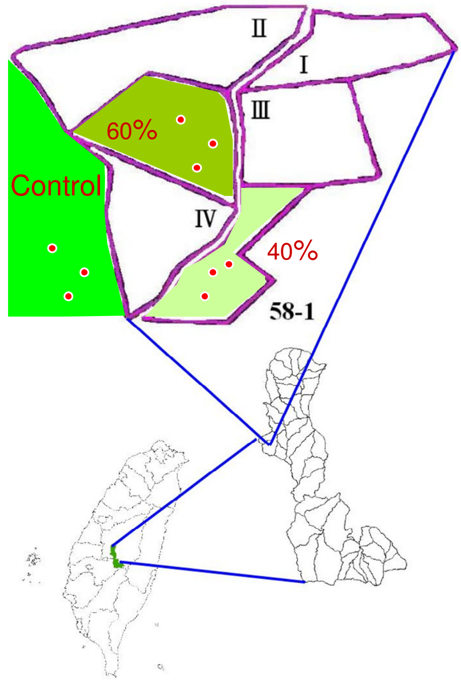

Figure 1. Location of sampling site.

Dissolved nutrient analysis

Before and after thinning, fresh soils (0-15 cm) were collected 1 kg from each plot and immediately sieved and passed through 4 mm sieve. The sub-samples were then stored in 4□ freezer for analysis. Fresh soil samples (100 g) were extracted with 1000 mL distilled water on a mechanical shaker for 4 hr. Soil extracts were filtered with a 0.22µm filter. The extracted solution was analysed for anions by ion chromography (Metrohm IC 792), cations by ICP-AES, and dissolved organic carbon by TOC analyser (Shimazu TOC-VCS).

Results

1. Soil properties before thinning treatment

The texture and soil pH of O and A horizons were sandy loam and loam and 4.9 and 5.1, respectively. The organic carbon and total nitrogen of O and A horizons were 38.8 and 55.2 and 3.6 and 4.9 g/kg, respectively (Table 1). Soil dissolved organic carbon of O and A horizons were 205 and 321mg C/kg, respectively (Table 2). The results of extracted solutions showed that Cl^-, SO_4^{2-}, and PO_4^{3-} were the main anions in the soils.

Table 1. Soil properties for the plantation before thinning treatment.

Horizon	Depth	pH	O.C.	T.N.	C/N	Exchangeable				CEC
						Na	K	Mg	Ca	
	cm		---g/kg---			-----------------cmol/kg---------------				
O	0-15	4.9	38.8	3.6	10.7	0.7	0.2	0.5	0.4	23.1
		(0.02)	(0.20)	(0.10)		(0.00)	(0.00)	(0.00)	(0.00)	(0.78)
A	15-30	5.1	55.2	4.9	11.3	0.2	0.3	0.8	0.4	28.5
		(0.03)	(0.22)	(0.10)		(0.00)	(0.00)	(0.00)	(0.00)	(0.01)

Mean (SD); CEC: cation exchangeable capacity

Table 2. Amounts of exchangeable phosphate, dissolved organic carbon and anions in air-dried soil before the thinning treatment.

Horizon	Depth	Exchangeable P	DOC	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
	cm	mg/kg	mgC/kg	------------------mg/kg---------------			
O	0-15	85	205	29.4	140.6	nd	26.3
		(3.5)	(9.9)	(1.6)	(7.2)	nd	(0.8)
A	15-30	117	321	28.6	193.2	nd	25.5
		(6.8)	(12.5)	(3.5)	(4.9)	nd	(1.9)

DOC: dissolved organic carbon; nd: not detected

2. Soil cations, anions, and dissolved organic carbon after thinning treatment

Soil dissolved organic carbon concentration of A horizon with control, 40% and 60% thinning treatments were 134, 133 and 139 mg C/kg, respectively (Table 3). The DOC concentrations did not show a difference among treatments. The dissolved K^+ of control treatments is significantly higher than that of thinning treatments. It suggests that K^+ were leaching down by rainfall after thinning treatment. Liang *et al.* (2009) reported that K^+ loss from soil was affected by acid rainfall. The concentration of soil dissolved Fe^{3+} significantly increased to 3.8 mg/kg after 60% thinning treatment. On the other hand, the concentration of soil dissolved Al^{3+} also increased with thinning intensity. It suggested that litter accumulation immediately was increased by thinning treatments. Organic acids can be released after litter decomposition and leached down to soil. The fixed aluminium and iron were dissolved at low pH and complex with organic acids. Therefore, more litter accumulation, more concentrations of dissolved organic Fe^{3+} and Al^{3+} in the soil after thinning treatment.

Table 3. Concentrations of dissolved organic carbon and cations in fresh soil (0-15 cm) after the thinning treatment.

Treatment	DOC	Dissolved					
		Na^+	K^+	Mg^{2+}	Ca^{2+}	Fe^{3+}	Al^{3+}
	mgC/kg	------------------------mg/kg------------------------					
Control	134	13.9	26.2	4.9	119	nd	3.6
	(9.5)	(3.6)	(5.6)	(0.2)	(6.4)	nd	(0.7)
40 %	133	14.3	14.8	nd	79.4	nd	5.1
	(6.9)	(2.8)	(0.4)	nd	(10.1)	nd	(1.4)
60%	139	12.7	17	4.3	106.1	3.8	6.0
	(2.0)	(4.0)	(0.9)	(0.7)	(7.5)	(2.4)	(1.3)

The nitrate concentration extracted from fresh soil increased with thinning intensity (Table 4). It indicated that fresh litter accumulated in the soil, the litter was decomposed by microbe and protein was released from plant tissue. These organic matters decomposed from litter were also transformed to NO_3^-, and therefore increased NO_3^- concentration. The sulfate concentrations also significantly increased with thinning intensity (Table 4). It indicated that sulfate extracted from fresh soil was from atmospheric deposition. The sulfate can be retained by cations such as Ca^{2+}, Fe^{3+} and Al^{3+}. The plantation was created gaps after thinning treatments, therefore, these gaps received more sulfate from atmospheric deposition.

Table 4. Concentrations of anions in fresh soil (0-15 cm) after the thinning treatment.

Treatment	Dissolved Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
	-------------------mg/kg---------------------			
Control	15.0	270	nd	19.6
	(3.3)	(6.6)	nd	(1.9)
40 %	19.6	389	nd	25.9
	(0.7)	(4.9)	nd	(1.1)
60%	15.9	510	nd	21.4
	(4.9)	(19.4)	nd	(2.1)

Conclusion

Thinning treatments affected concentrations of K^+, Fe^3+ Al^{3+}, and anions. Although the DOC concentrations were not significant difference, it might be complex and induced with cations such Fe^{2+} and Al^{3+}. The nutrient released from fresh litter decomposition after thinning treatment. Therefore, DOC plays an important role after plantation thinning practice. The results also can be a reference for nutrient management of plantation.

Acknowledgement

We thank the National Science Council, Taiwan for financial support under the projects (NSC 97-2313-B-002-046, 98-2313-B-002-005-MY3). We also thank the Experimental Forest of National Taiwan University for financial support.

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