Ecohydrologic and Biogeochemical Process Networks in Forest Ecosystems in Monsoon East Asia: Identification and Interpretation

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Abstract

Forest ecosystems play a critical role in the cycles of carbon and water from local to global scales. These cycles and their variability, in turn, play an important role in the non-trivial emergent and self-organizing interactions between forest ecosystems and their environment. Observational evidence, based on micrometeorological eddy covariance measurements, suggests that heterogeneity and disturbance (both human and natural) in forest ecosystems in monsoon East Asia may facilitate to build resilience for adaptation to change. Yet, the principles that characterize the role of variability in these interactions remain elusive. A process network is defined as a network of feedback loops and the related time scales, which describe the magnitude and direction of the flow of energy, matter, and information between the different variables in a complex system. We attempt to delineate and interpret such process networks by analyzing multivariate ecohydrologic and biogeochemical time series data based on information flow statistics.

Introduction

Complex systems are systems in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution (Mitchell, 2009). Thus, the science underlying complex systems should focus not only on the concepts of energy, force and matter, but also on those of feedbacks, information, communication, and purpose.

In Asia, it is of great concern that ecosystem services are being degraded by natural disturbance such as monsoon activity accompanied by typhoons reinforced by anthropogenic factors in a changing climate. Recent finding suggests that under projected climate scenarios, terrestrial carbon sinks in monsoon Asia will decline if the monsoon disturbance will exceed its natural range of variation and if there is no enhancement in the resilience of the ecosystems in this region (e.g., Kwon et al., 2010; Hong and Kim, 2011).

Resilience-based system approach suggests that complex systems evolve through active adaptive cycles to cope with change. Ecohydrologic and biogeochemical processes associated with water and carbon cycles in complex forest ecosystems can be viewed as a network of processes of a wide range of scales involving various feedback loops.

Finding such networks of feedback loops for key ecosystems in monsoon Asia is of great value and concern. However, the traditional correlation-based analysis cannot delineate such complex processes with detailed information on direction and strength of the coupling between the variables. Following Ruddell and Kumar (2009), we examined the dependence between a series of variables measured at the flux towers in AsiaFlux by quantifying the information flow between the different variables along with the associated time lag. The objective of our study is to test the applicability of information theory to ecohydrologic and biogeochemical systems with the datasets obtained at various forest sites in East Asia with different levels of complexity and heterogeneity.

Methods and Materials

We used Shannon's information entropy as our methodology (Shannon, 1948) and calculated the transfer entropy (*TE*) to measure the reduction in the entropy of the current state of a measured variable $X_t^{(j)}$ due to the knowledge of prior state in another variable $X_t^{(i)}$, which is in addition to the information provided by the immediate prior history of $X_t^{(j)}$ (e.g., Ruddell and Kumar, 2009). We normalized *TE* using m (set at 11) discrete bins to estimate the probability distribution function. The information flow process network consists of the asymmetric pair wise *TE* between the i^{th} and j^{th} variable from the set of n_v observed variables and is represented as an adjacency matrix (Kumar and Ruddell, 2010).

We used the time series data in 2008 from two adjacent KoFlux tower flux sites (in deciduous and coniferous forests) located in Korea. The description of the sites and the data can be found in AsiaFlux homepage (http://www.asiaflux.net). In this analysis, we selected 15 variables associated with ecohydrologic and biogeochemical processes in forests, which are atmospheric pressure (*PA*), net ecosystem CO_2 exchange (*NEE*), gross primary productivity (*GPP*), ecosystem respiration (*RE*), latent heat flux (*LE*), precipitation (*Precip*), solar radiation (R_g), air temperature (T), vapor pressure deficit (*VPD*), soil temperature (T_s), soil water content (*SWC*),

sensible heat flux (*H*), canopy temperature (T_c), wind direction (*WD*), and wind speed (*WS*). We computed process networks for each of thirty-six sub-daily time lags between 30 minutes and 18 hours. Our spectral analysis shows that this subdaily time scale explained more than 30% of the variances of the above variables associated with carbon and water cycles, reflecting that this range is an important scale of land-atmosphere interactions. In this process, the complexity and heterogeneity embedded in the observed flux data may hinder the application and interpretation of such information flow statistics. Therefore, estimation and methodological issues were examined by comparing these two adjacent forests with different levels of heterogeneity and complexity.

Preliminary Results

The adjacency matrix for the 15 variables results in 210 potential pairwise couplings, about 25% out of which were found to be statistically significant at one or more time lags for both deciduous and coniferous forests. Preliminary results on network matrix are presented in Tables 1-4.

Table 1. Network matrix for mutual information

Gwangneung Forest, 2008 May, GDK(GCK)

AI	PA	NEE	GPP	RE	LE	Precip	Rg	T	VPD	Ts	SWC	H	Tc	WD	WS
PA	*93.5 (94)*	2.7 (3.4)	2.9 (3.5)	12.3 (6.9)	1.9 (2.8)	1.8 (1.8)	4.7 (4.8)	11.8 (9.5)	6.7 (6)	16.3 (-)	14.2 (15.7)	3.8 (5.4)	10.7 (9.9)	5.1 (3.8)	4.9 (6.2)
NEE	2.7 (3.4)	*55.5 (59.6)*	44.2 (47.3)	1.8 (3)	7.3 (6.9)	1.2 (1.3)	11.2 (9.9)	1.9 (2.9)	3.1 (4.3)	2 (-)	2.2 (2.6)	7.9 (8.6)	3 (3.6)	2.4 (3.4)	2.4 (3.6)
GPP	2.9 (3.5)	44.2 (47.3)	*56.4 (57.3)*	2 (1.5)	7.7 (7.3)	1.4 (1.5)	11.7 (11)	2.1 (2.6)	3.7 (4.3)	2.2 (-)	2.1 (2.9)	7.9 (9)	3.2 (3.4)	2.5 (3.6)	2.4 (4)
RE	12.3 (6.9)	1.8 (3)	2 (1.5)	*93.3 (48.5)*	2.5 (1.8)	2.3 (0.8)	4.2 (2.9)	54.6 (23.9)	15.9 (10)	18.7 (-)	8.2 (3.5)	3.1 (2.3)	45.3 (23.3)	2.9 (1.4)	3.4 (1.7)
LE	1.9 (2.8)	7.3 (6.9)	7.7 (7.3)	2.5 (1.8)	*49.6 (63.6)*	0.7 (1.2)	8 (9.8)	3 (3.6)	4.3 (6.3)	2.3 (-)	2.5 (4)	5.3 (9.2)	3.5 (4.1)	2.3 (2.2)	1.5 (4.4)
Precip	1.8 (1.8)	1.2 (1.3)	1.4 (1.5)	2.3 (0.8)	0.7 (1.2)	*15.2 (15.8)*	1.6 (1.5)	2.3 (2.1)	1.6 (1.6)	1.6 (-)	2.5 (3.7)	0.9 (1)	1.9 (2.4)	1.2 (1.2)	0.9 (1.8)
Rg	4.7 (4.8)	11.2 (9.9)	11.7 (11)	4.2 (2.9)	8 (9.8)	1.6 (1.5)	*60.2 (59.2)*	4 (5.1)	6.5 (7.9)	3.9 (-)	3.2 (5.4)	19.8 (21.7)	6.2 (6.3)	4.1 (4.6)	2.6 (6.3)
T	11.8 (9.5)	1.9 (2.9)	2.1 (2.6)	54.6 (23.9)	3 (3.6)	2.3 (2.1)	4 (5.1)	*94.5 (91.1)*	18.5 (15.7)	22.2 (-)	8.5 (8)	3.1 (4.2)	55 (55.3)	2.9 (2.9)	3.1 (3.5)
VPD	6.7 (6)	3.1 (4.3)	3.7 (4.3)	15.9 (10)	4.3 (6.3)	1.6 (1.6)	6.5 (7.9)	18.5 (15.7)	*81.9 (76.8)*	9.7 (-)	7 (5.2)	4.3 (6.2)	18.6 (16.4)	2.8 (2.9)	3.4 (7.3)
Ts	16.3 (-)	2 (-)	2.2 (-)	18.7 (-)	2.3 (-)	1.6 (-)	3.9 (-)	22.2 (-)	9.7 (-)	*96.3 (-)*	13.9 (-)	3.4 (-)	19.5 (-)	3.9 (-)	5.3 (-)
SWC	14.2 (15.7)	2.2 (2.6)	2.1 (2.9)	8.2 (3.5)	2.5 (4)	2.5 (3.7)	3.2 (5.4)	8.5 (8)	7 (5.2)	13.9 (-)	*65.9 (65.7)*	2.7 (5.1)	7.5 (7.9)	3.9 (3)	3.3 (5.1)
H	3.8 (5.4)	7.9 (8.6)	7.9 (9)	3.1 (2.3)	5.3 (9.2)	0.9 (1)	19.8 (21.7)	3.1 (4.2)	4.3 (6.2)	3.4 (-)	2.7 (5.1)	*63.9 (65.3)*	4.9 (4.8)	4.5 (5.6)	2.4 (5.9)
Tc	10.7 (9.9)	3 (3.6)	3.2 (3.4)	45.3 (23.3)	3.5 (4.1)	1.9 (2.4)	6.2 (6.3)	55 (55.3)	18.6 (16.4)	19.5 (-)	7.5 (7.9)	4.9 (4.8)	*93.3 (92.5)*	2.8 (3.2)	3.5 (3.8)
WD	5.1 (3.8)	2.4 (3.4)	2.5 (3.6)	2.9 (1.4)	2.3 (2.2)	1.2 (1.2)	4.1 (4.6)	2.9 (2.9)	2.8 (2.9)	3.9 (-)	3.9 (3)	4.5 (5.6)	2.8 (3.2)	*87.8 (79.1)*	3.2 (4.2)
WS	4.9 (6.2)	2.4 (3.6)	2.4 (4)	3.4 (1.7)	1.5 (4.4)	0.9 (1.8)	2.6 (6.3)	3.1 (3.5)	3.4 (7.3)	5.3 (-)	3.3 (5.1)	2.4 (5.9)	3.5 (3.8)	3.2 (4.2)	*77.9 (74.7)*

Table 2. Network matrix for uncertainty percentage

Gwangneung Forest, 2008 May, GDK(GCK)

Air	PA	NEE	GPP	RE	LE	Precip	Rg	T	VPD	Ts	SWC	H	Tc	WD	WS
PA	*100 (100)*	4.9 (5.7)	5.2 (6.1)	**13.2 (14.2)**	3.9 (4.4)	**12.1 (11.7)**	7.9 (8.1)	**12.5 (10.4)**	8.2 (7.9)	**17** (-)	**21.6 (23.9)**	5.9 (8.3)	**11.4 (10.8)**	5.8 (4.8)	6.3 (8.3)
NEE	2.9 (3.6)	*100 (100)*	**78.5 (82.7)**	2 (6.3)	**14.7 (10.9)**	7.9 (8)	**18.6 (16.8)**	2 (3.2)	3.8 (5.6)	2.1 (-)	3.3 (3.9)	**12.3 (13.1)**	3.2 (3.9)	2.7 (4.3)	3.1 (4.8)
GPP	3.1 (3.7)	**79.6 (79.5)**	*100 (100)*	2.1 (3)	**15.5 (11.5)**	9 (9.5)	**19.4 (18.5)**	2.2 (2.9)	4.6 (5.6)	2.3 (-)	3.1 (4.4)	**12.4 (13.9)**	3.4 (3.6)	2.8 (4.5)	3.1 (5.3)
RE	**13.2** (7.3)	3.3 (5.1)	3.5 (2.6)	*100 (100)*	5.1 (2.8)	**15.2** (5.1)	6.9 (5)	**57.7 (26.2)**	**19.4 (13)**	**19.4** (-)	**12.5** (5.3)	4.8 (3.6)	**48.5 (25.2)**	3.3 (1.7)	4.4 (2.3)
LE	2.1 (3)	**13.1 (11.6)**	**13.6 (12.7)**	2.7 (3.7)	*100 (100)*	4.4 (7.7)	**13.3 (16.6)**	3.2 (3.9)	5.3 (8.2)	2.4 (-)	3.8 (6.1)	8.4 **(14.1)**	3.8 (4.4)	2.6 (2.8)	1.9 (5.8)
Precip	2 (2)	2.2 (2.1)	2.4 (2.6)	2.5 (1.7)	1.4 (1.9)	*100 (100)*	2.6 (2.5)	2.5 (2.3)	2 (2.1)	1.6 (-)	3.8 (5.6)	1.5 (1.6)	2 (2.6)	1.3 (1.5)	1.1 (2.4)
Rg	5.1 (5.1)	**20.2 (16.7)**	**20.7 (19.1)**	4.5 (6.1)	**16.2 (15.5)**	**10.3** (9.2)	*100 (100)*	4.2 (5.6)	7.9 **(10.3)**	4 (-)	4.9 (8.3)	**31 (33.2)**	6.7 (6.8)	4.7 (5.8)	3.3 (8.4)
T	**12.6 (10.1)**	3.4 (4.9)	3.7 (4.5)	**58.5 (49.3)**	6.1 (5.6)	**15.3 (13)**	6.6 (8.6)	*100 (100)*	**22.6 (20.4)**	**23.1** (-)	**12.9 (12.2)**	4.8 (6.4)	**58.9 (59.8)**	3.3 (3.7)	4 (4.7)
VPD	7.2 (6.4)	5.6 (7.2)	6.6 (7.6)	**17 (20.6)**	8.7 (9.9)	**10.7 (10.4)**	**10.8 (13.3)**	**19.6 (17.2)**	*100 (100)*	**10.1** (-)	**10.7** (7.9)	6.7 (9.5)	**19.9 (17.7)**	3.2 (3.6)	4.4 (9.7)
Ts	**17.5** (-)	3.7 (-)	3.9 (-)	**20** (-)	4.6 (-)	10.4 (-)	6.4 (-)	**23.5** (-)	**11.8** (-)	*100 (-)*	**21.1** (-)	5.4 (-)	**20.9** (-)	4.5 (-)	6.8 (-)
SWC	**15.2 (16.7)**	3.9 (4.4)	3.7 (5)	8.8 (7.2)	5.1 (6.3)	**16.3 (23.2)**	5.3 (9.2)	9 (8.8)	8.6 (6.8)	**14.5** (-)	*100 (100)*	4.3 (7.8)	8 (8.5)	4.4 (3.8)	4.3 (6.8)
H	4 (5.8)	**14.2 (14.4)**	**14.1 (15.8)**	3.3 (4.8)	**10.8 (14.5)**	6.2 (6.4)	**32.9 (36.6)**	3.2 (4.6)	5.3 (8.1)	3.6 (-)	4.1 (7.8)	*100 (100)*	5.3 (5.2)	5.1 (7.1)	3.1 (7.8)
Tc	**11.4 (10.6)**	5.4 (6.1)	5.6 (5.9)	**48.6 (48.1)**	7.1 (6.5)	**12.5 (15.1)**	**10.3 (10.6)**	**58.1 (60.8)**	**22.7 (21.3)**	**20.2** (-)	**11.3 (12)**	7.7 (7.4)	*100 (100)*	3.2 (4)	4.5 (5.1)
WD	5.4 (4.1)	4.3 (5.8)	4.4 (6.3)	3.1 (2.8)	4.6 (3.5)	7.8 (7.5)	6.9 (7.8)	3 (3.2)	3.4 (3.8)	4.1 (-)	5.9 (4.6)	7 (8.6)	3 (3.4)	*100 (100)*	4.1 (5.6)
WS	5.3 (6.6)	4.4 (6.1)	4.3 (7)	3.7 (3.6)	3 (6.9)	5.8 **(11.5)**	4.3 **(10.6)**	3.3 (3.9)	4.2 (9.5)	5.5 (-)	5.1 (7.7)	3.7 (9)	3.8 (4.1)	3.6 (5.3)	*100 (100)*

Table 1 shows the matrix for the mutual information between pairs of variables at zero time lag. Source variable *X* index *i* is in rows; sink variable *Y* index *j* is in columns. Matrix is symmetric. Italics indicate matrix diagonal. All values are in percent. The values before and with parenthesis are for deciduous (GDK) and coniferous forest (GCK), respectively.

Table 2 shows the matrix for the percentage of uncertainty of each Y explained by X. Table 3 shows the matrix for the ratio of the maximum lag to mutual information for all significant couplings. Table 4 shows time lags of significant information flow on the interval, including the first significant lag, last significant lag, number of significant lags, and peak time lag. Significant lag times are [first-last (number), max].

Table 3. Network matrix for the ratio of the maximum lag to mutual information

Gwangneung Forest, 2008 May, GDK(GCK)

Atz	PA	NEE	GPP	RE	LE	Precip	Rg	T	VPD	Ts	SWC	H	Tc	WD	WS
PA	x (x)	x (x)	x (x)	x (x)	2.7 (x)	1 (x)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (2.8)	x (x)
NEE	x (x)	0.1 (0.1)	0.1 (0.1)	x (x)	0.7 (1)	1.2 (1.3)	x (x)	x (x)	x (x)	x (-)	x (x)	0.7 (0.7)	x (x)	x (2.2)	x (x)
GPP	x (x)	0.2 (0.2)	0.1 (0.1)	x (x)	0.7 (1)	1.1 (1.1)	x (x)	x (x)	x (x)	x (-)	x (x)	0.7 (0.7)	x (x)	x (2.1)	x (x)
RE	x (x)	x (1.3)	x (2.7)	x (0.1)	2 (2.4)	0.8 (x)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
LE	x (x)	0.7 (1)	0.6 (0.8)	x (x)	0.1 (0.1)	1.9 (1.3)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
Precip	x (x)	1.5 (x)	1.7 (x)	x (x)	2.3 (x)	0.1 (0.1)	x (x)	x (x)	x (x)	x (-)	1.2 (x)	3.2 (x)	x (x)	x (x)	x (x)
Rg	x (x)	0.7 (0.9)	0.7 (0.8)	x (1.2)	0.7 (0.8)	1.2 (1)	x (x)	x (x)	x (x)	x (-)	x (x)	0.3 (x)	x (x)	x (1.7)	x (x)
T	x (x)	3.4 (x)	x (x)	x (0.2)	x (x)	0.8 (1.1)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
VPD	x (x)	2 (1.6)	1.7 (1.6)	x (x)	1.3 (1.1)	1.2 (1)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (3.2)	x (x)
Ts	x (-)	3.5 (-)	x (-)	x (-)	2.5 (-)	1.3 (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)
SWC	x (x)	x (2.2)	x (2.1)	x (x)	x (1.6)	0.8 (0.6)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (2.9)	x (x)
H	x (x)	0.8 (0.8)	0.8 (0.8)	x (1.5)	0.9 (0.8)	2.3 (1.8)	x (x)	x (x)	x (x)	x (-)	x (x)	0.1 (x)	x (x)	x (x)	x (x)
Tc	x (x)	2.1 (1.9)	x (x)	x (0.2)	1.4 (x)	1 (0.8)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
WD	x (x)	2.7 (2.1)	2.6 (1.9)	x (x)	2.2 (3.2)	1.8 (1.5)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (0.1)	x (x)
WS	x (x)	x (x)	x (x)	x (2.1)	x (x)	1.8 (x)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)

Table 4. Network matrix for time lags of significant information flow on the interval

Gwangneung Forest, 2008 May, GDK(GCK)

Tau	PA	NEE	GPP	RE	LE	Precip	Rg	T	VPD	Ts	SWC	H	Tc	WD	WS
PA	x (x)	x (x)	x (x)	x (x)	1-33(10)32 (x)	1-7(4)7 (x)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (7-7(1)7)	x (x)
NEE	x (x)	2-8(7)3 (2-9(8)2)	2-9(8)3 (2-9(8)4)	x (x)	1-10(9)2 (1-8(8)3)	1-32(10)2 (2-16(2)16)	x (x)	x (x)	x (x)	x (-)	x (x)	1-7(5)1 (2-2(1)2)	x (x)	x (3-5(3)3)	x (x)
GPP	x (x)	2-8(7)3 (2-9(8)2)	2-9(8)3 (2-9(8)4)	x (x)	1-10(9)2 (1-9(9)3)	1-12(8)3 (2-16(3)16)	x (x)	x (x)	x (x)	x (-)	x (x)	1-7(5)3 (3-3(1)3)	x (x)	x (2-5(4)3)	x (x)
RE	x (x)	x (1-33(5)25)	x (25-36(6)32)	x (2-6(5)2)	36-36(1)36 (30-36(4)30)	1-5(4)1 (x)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
LE	x (x)	1-6(6)2 (1-8(8)1)	1-6(6)2 (1-8(7)1)	x (x)	2-9(7)2 (2-9(8)3)	1-36(7)36 (1-11(3)11)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
Precip	x (x)	1-1(1)1 (x)	2-36(2)36 (x)	x (x)	12-12(1)12 (x)	2-12(8)3 (2-7(5)3)	x (x)	x (x)	x (x)	x (-)	1-1(1)1 (x)	33-36(4)36 (x)	x (x)	x (x)	x (x)
Rg	x (x)	1-36(10)1 (1-9(9)1)	1-36(9)3 (1-36(9)1)	x (19-26(7)24)	1-9(9)1 (1-9(9)3)	1-34(17)6 (1-9(6)6)	x (x)	x (x)	x (x)	x (-)	x (x)	1-4(4)1 (x)	x (x)	x (1-4(2)4)	x (x)
T	x (x)	4-4(1)4 (x)	x (x)	x (1-6(6)2)	x (x)	1-6(4)5 (1-4(3)1)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
VPD	x (x)	2-36(4)36 (1-36(7)34)	32-36(5)32 (1-36(6)35)	x (x)	1-36(7)36 (1-36(4)36)	1-30(9)1 (2-3(2)3)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (28-36(5)28)	x (x)
Ts	x (-)	35-35(1)35 (-)	x (-)	x (-)	1-36(31)11 (-)	1-6(6)5 (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)	x (-)
SWC	x (x)	x (1-8(7)6)	x (1-29(15)1)	x (x)	x (1-9(6)3)	1-36(36)6 (1-31(30)18)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (4-4(1)4)	x (x)
H	x (x)	1-7(7)1 (1-7(7)3)	1-7(7)6 (1-7(7)4)	x (17-23(5)18)	1-8(8)3 (1-6(6)4)	1-15(14)9 (5-19(4)19)	x (x)	x (x)	x (x)	x (-)	x (x)	2-4(3)2 (x)	x (x)	x (x)	x (x)
Tc	x (x)	3-4(2)3 (4-7(2)7)	x (x)	x (1-5(5)1)	1-2(2)1 (x)	1-6(6)1 (1-2(2)1)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)
WD	x (x)	2-31(3)31 (1-10(8)1)	18-35(5)32 (1-15(7)1)	x (x)	1-27(10)20 (1-9(6)1)	1-35(25)31 (3-17(5)3)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (2-3(2)2)	x (x)
WS	x (x)	x (x)	x (x)	x (23-23(1)23)	x (x)	3-5(2)5 (x)	x (x)	x (x)	x (x)	x (-)	x (x)	x (x)	x (x)	x (x)	x (x)

Acknowledgments

This study was supported by Long-Term Ecological Study and Monitoring of Forest Ecosystem Project of Korea Forest Research Institute, a grant (code 1-8-3) from Sustainable Water Resource Research Center for 21st Century Frontier Research Program; A3 Foresight Program of Korea Research Foundation; and Research Settlement Fund for the new faculty of Seoul National University. We thank Minseok Kang and Bindu Malla Thakuri and Jaeil Yoo for their field support and data analysis.

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