Technical note: Testing Ion Exchange Resin for quantifying bulk and throughfall deposition of macro and micro-elements on forests

Supplementary information

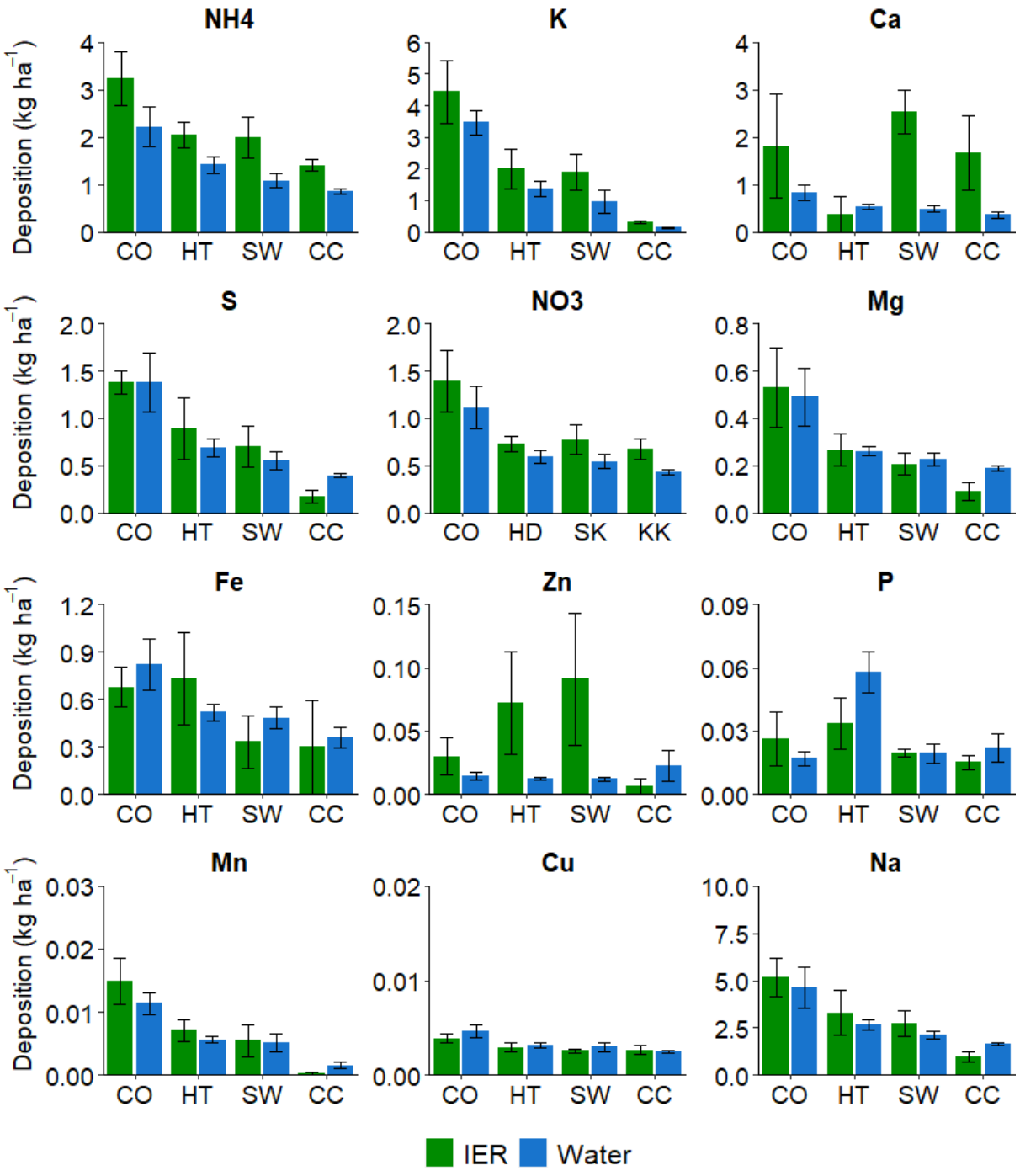

Figure S1: Deposition estimates of the IER-method (kg ha^{-1}) and the water-method (kg ha^{-1}) in the treatments control (CO), high-thinning (HT), shelterwood (SW) and clearcut (CC) for a 10-week measurement period.

Table S1: Conversion factor to calculate total deposition within a forest stand based on bulk precipitation data. Original data underneath the multiplication factors were corrected for canopy uptake of NH_4 and NO_3 and canopy leaching of Mg, Ca, K and Mn except for the inert ions Na, SO_4, Zn and Cu. The ion Na is in all cases used to calculate canopy leaching of Ca, Mg and K. Stem flow (SF) was only included for beech forest and one Douglas fir stand.

Species	Na	NH_4	NO_3	K	Mg	SO_4	PO_4	Ca	Mn	Zn	Cu	Country	SF	Source
Beech	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.2			Germany	Yes	(Talkner et al., 2010)
Beech						1.6								(Augusto et al., 2002)
Beech	2.4	3.6	2.0	3.1	2.4	4.8		2.4				Belgium	Yes	(Adriaenssens et al., 2012)
Beech	1.2					1.6						Czech Republic	Yes	(Růžek et al., 2019)
Beech	1.2					1.2				1.1	2.1	Poland	Yes	(Kowalska et al., 2016)
Douglas fir	2.3	2.3	2.3	2.2	2.2	2.3	2.1	2.4				France	Yes	(Marques et al., 1997)
Douglas fir	2.3			1.4	1.8	3.3		1.5				Netherlands		(Van Ek and Draaijers, 1994)
Douglas fir	2.3	3.7	2.1	2.3	2.3	3.6	2.5	2.3				Netherlands	Yes	(Draaijers et al., 1997)
Coniferous forest										2.4	2.6			(De Vries and Bakker, 1996)
Scots pine	1.1			1.2	1.2	1.6		1.1				Poland	No	(Kozłowski et al., 2020)
Scots pine	2.3			1.5	1.9			1.6				Netherlands	No	(Van Ek and Draaijers, 1994)
Scots pine	2.0					1.5				1.1	1.3	Poland	No	(Kowalska et al., 2016)
Corsican pine	1.5	6.5	3.5	3.4	1.9			1.4				Belgium	No	(De Schrijver et al., 2004)
Average														
Beech	1.5	2.4	1.6	2.2	1.8	2.3	1.3	1.8	1.2					
Douglas fir	2.3	3.0	2.2	2.0	2.1	3.1	2.3	2.1		2.4	2.6			
Scots pine	1.7	6.5	3.5	2.0	1.7	1.6		1.4						

N.B. The bulk throughfall deposition of SO_4^{2-} was assumed to be not influenced by canopy exchange as the stomatal uptake of SO_2 is balanced by foliar leaching of SO_4^{2-} (Draaijers and Erisman, 1995). However, Staelens et al. (2007) estimated that canopy leaching contributed 7% to the combined bulk throughfall and stemflow of SO_4^{2-} which was in line with the findings of Potter et al. (1991). Canopy exchange of Al and Cu are neglectable as both elements in deposition is found in a colloidal fraction and almost entirely complexed by DOC (Gandois et al., 2010). The free metal ion forms of Zn (on average 30%) do interact with the canopy however concentration is only slightly increased or decreased (Gandois et al., 2010).

[1] measured under a single tree, therefore not representative for a forest stand.

Table S2: Overview of the columns (n = 45) prepared for the different laboratory tests.

Pre-treatment	Loading	n	Used for adsorption tests	Used for extraction tests
Heat	1 * macro- and microfluid	3	Yes	Yes
Drought	1 * macro- and microfluid	3	Yes	Yes
Frost	1 * macro- and microfluid	3	Yes	Yes
None	1 * macro- and microfluid	30	Yes, 3 columns	Yes
None	2 * macro- and microfluid	3	Yes	No
None	3 * macro- and microfluid	3	Yes	No

Table S3: ANOVA F and P values for HCl extraction of different molarities, pre-treatments (DW or FW) and different extraction types (Drip or Shake-Drip).

	DF	F-value	P-value
Element	9	250	< 0.0001
Pre-treatment	1	68	< 0.0001
Molarity	6	16	< 0.0001
Extraction type	1	4.2	0.043
Element * Pre-treatment	9	19	< 0.0001
Element * Molarity	54	7.8	< 0.0001
Element * Extraction type	9	2.2	0.025

Table S4: Elemental concentrations under detection limit (%) after 10-week long field sampling of the atmospheric bulk (throughfall) deposition in the Netherlands. Elemental concentrations were often under detection limit for the original method (Org), especially for the treatments (TM) shelterwood (SW) and clearcut (CC) and less often for the treatments control (CO) and high thinning (HT). For the Ion Exchange resin method (IER) values were less often under detection limit.

TM	Method	Ca	Cu	Fe	K	Mg	Mn	Na	P	S	Zn	NH4	NO3
CO	Org	83	100	100	0	0	50	0	100	0	83	0	0
HT	Org	100	100	100	0	0	100	0	100	0	100	0	0
SW	Org	100	100	100	50	17	100	0	100	0	100	0	0
CC	Org	100	100	100	100	33	100	0	100	0	83	0	0
CO	IER	0	0	20	0	0	0	0	40	0	0	0	0
HD	IER	0	0	40	0	0	0	0	20	0	0	0	0
SK	IER	0	0	17	0	0	0	0	0	0	17	0	0
KK	IER	0	0	0	0	0	0	0	60	0	20	0	0