TREE TRADE-OFFS IN STREAM RESTORATION PROJECTS: IMPACT ON RIPARIAN GROUNDWATER QUALITY

Presenters: Sujay S. Kaushal[1] and Kelsey L. Wood[1]

Research Team Includes: Philippe G. Vidon[2]
Joseph G. Galella[1]

[1]University of Maryland
[2]State University of New York ESF

Outline

- Overview/ Key Questions
- Methods/ Study Sites
- Results/ Discussion
- Management Implications

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Motivation

- Trees in riparian zones provide key water quality functions
- Trees can be removed from riparian zones during stream restoration
- There is a lack in our understanding of the effects of tree removal on water quality

How does removing trees affect groundwater quality?

Courtesy Gwen Sivirichi

Research Questions

- What is the impact of riparian tree removal during stream restoration and subsequent recovery (if any) on groundwater quality across restored, degraded, and forested reference sites in Maryland?

- Which type of broadly available data are best suited to predict both the nominal and cumulative impacts of riparian zones with various history of tree dynamics / disturbance on water quality at the watershed scale?

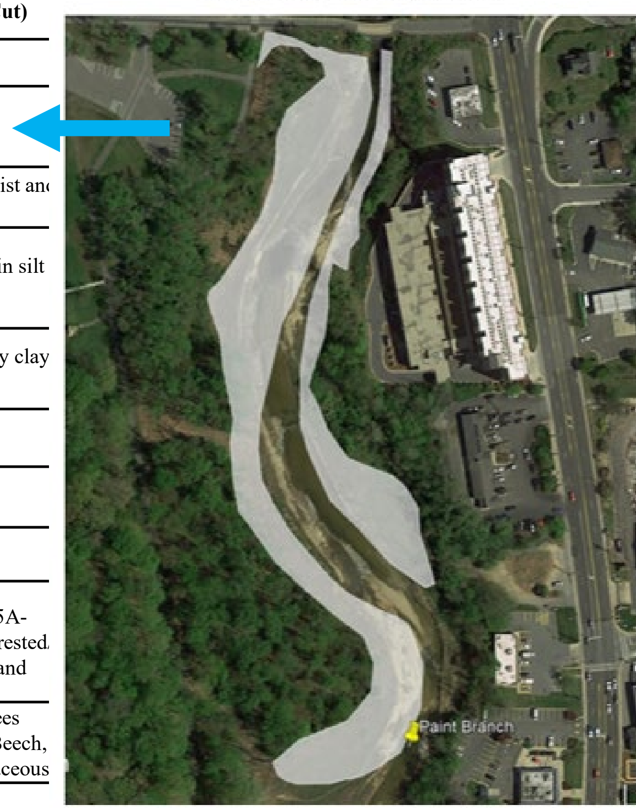
Experimental Design

- Chronosequence of restoration up to 20 years
- Variety of stream restoration types
- Paired riparian zones with undisturbed trees and with trees removed in same watershed
- Measure concentrations of common plant nutrients and contaminants in ground water

Restoration Chronosequence

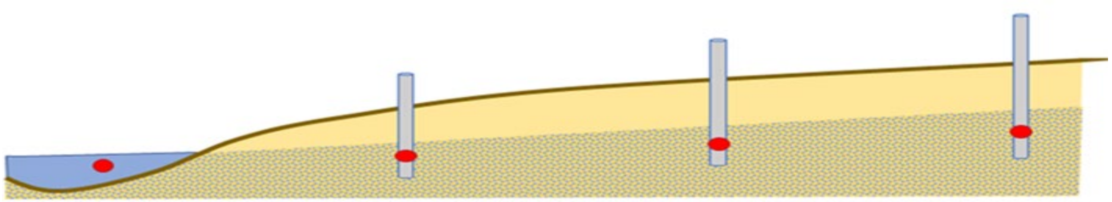
	Campus Creek (uncut)	Paint Branch (5-year Cut)	Scott's Level (Uncut/ 5-year Cut)	Stony Run (10-year Cut)	Minebank Run (20-year Cut)
Year restored	2019	2014	2014	2009	1999
Area of Tree Canopy Removed (km^2)	TBD	13.958	9.703	6.089	NA
Geologic Province	Coastal plain (quaternary sediments)	Coastal plain (quaternary sediments)	Piedmont (quartz feldspar schist and granulite)	Piedmont (gabbro and norite)	Piedmont (schist and gneiss)
USDA Soil Classification	ZS—Zekiah and Issue soils, frequently flooded	CF- Codorus and Hatboro soils, frequently flooded	hbA- Hatboro silt loams	50A- Hatboro-Codorus complex, frequently flooded	MmA- Melvin silt loam
Soil Texture	Loam, silt loam, mucky silt loam, fine sandy loam, sandy loam	Silt loam, loam	Silt loam, silty clay loam, sandy loam	Silt loam, Gravelly silt loam, very gravelly silt loam	Silt loam, silty clay loam
Riparian Zone Slope	0.05	0.12	0.07	0.09	0.1
Riparian Zone Width (m)	32-35	40+	5-25	10-18	20-25
Channel Width (m)	2-3	10-12	2-4	2-4	1-2
NWI Wetland Classification	PFO1A Freshwater forested/ shrub wetland	PFO1A Freshwater forested/ shrub wetland	PEM5Ax- Freshwater emergent wetland PFO1Ax-Freshwater forested/ shrub wetland	R3UBH- Riverine	PFO1/EM5A- Freshwater forested/ shrub wetland
Vegetation	Mature Trees (Maple, Holly, Beech)	Herbaceous near river, Mature trees upland (Tulip Magnolia, Maple)	Transect A: Herbaceous Transect B: Mature trees (Hickory, Oak)	Young/relatively smaller trees (Redbud, Beech)	Mature trees (Sycamore, Beech, Oak) & herbaceous
Drainage Basin Area (mi^2)	0.59	29.3	1.19	0.64	0.41
Impervious Surface Cover in Watershed	22.8 %	31.6 %	37.7%	39.6%	40.8
Forest Cover in Watershed	24.9 %	25.6 %	19.9 %	12 %	25 %

Tree Removal Area



Wood et. al. (In Review)

Chronosequence of sites 5- 20 years and uncut comparisons



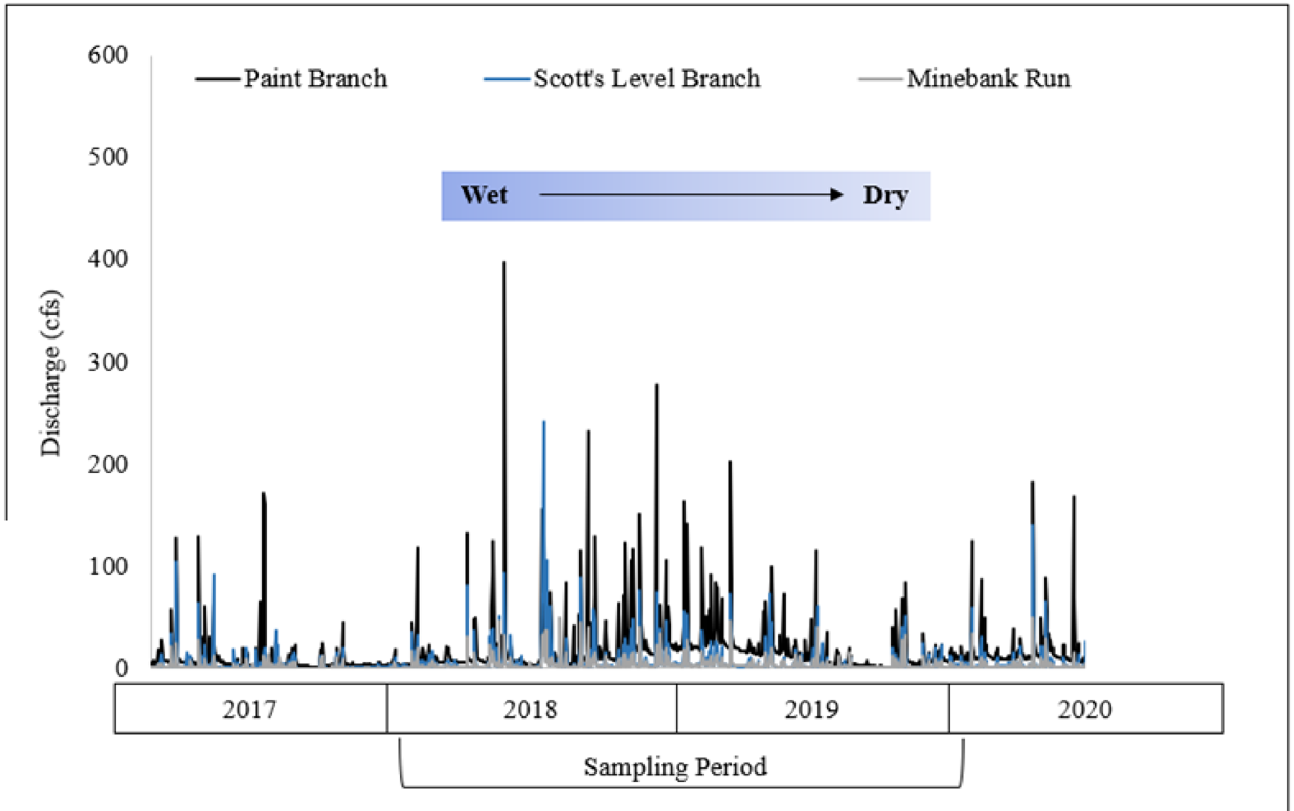
Wells installed in transects of 3

Results: Sites where trees were removed had higher nutrient concentrations than sites where no trees were removed

- Concentrations of common plant nutrients (nitrogen, potassium, calcium, *etc.*) were elevated in ground water in sites where trees were removed

- Concentrations of common plant nutrients in groundwater decrease downslope in riparian zones with trees, but increase downslope in riparian zones where trees were removed

190 samples collected over a 2 year period



Tree Composition

	Element	% dry wt. of tissue
TOC-L	C	45
	O	45
	H	6
TOC-L	N	1.5
ICP-OES	K	1
ICP-OES	Ca	0.5
ICP-OES	P	0.2
ICP-OES	Mg	0.2
ICP-OES	S	0.1
	Cl	0.01
ICP-OES	Fe	0.01
ICP-OES	Mn	0.005
ICP-OES	Zn	0.002
ICP-OES	B	0.002
ICP-OES	Cu	0.0006
ICP-OES	Mo	0.00001

Zinke 1977.

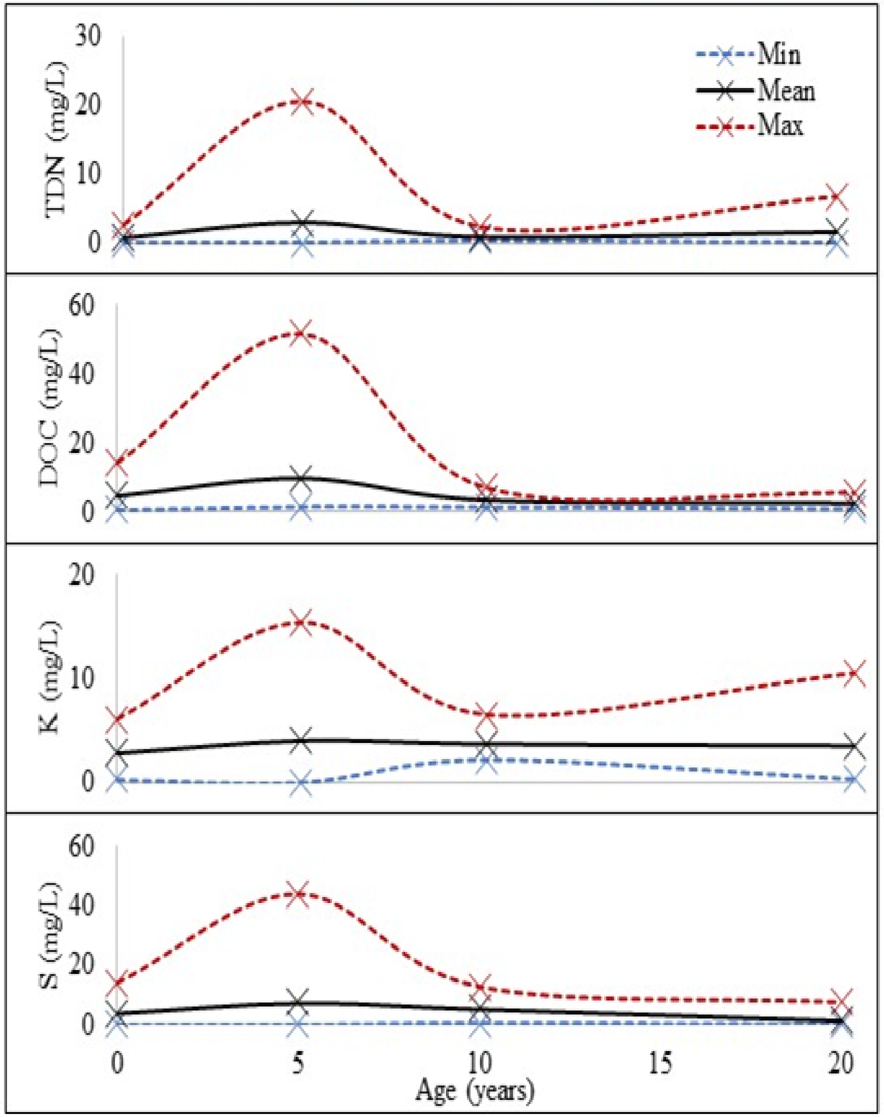
Multiple element approach

Nutrients and carbon were most elevated immediately following restoration/ tree removal

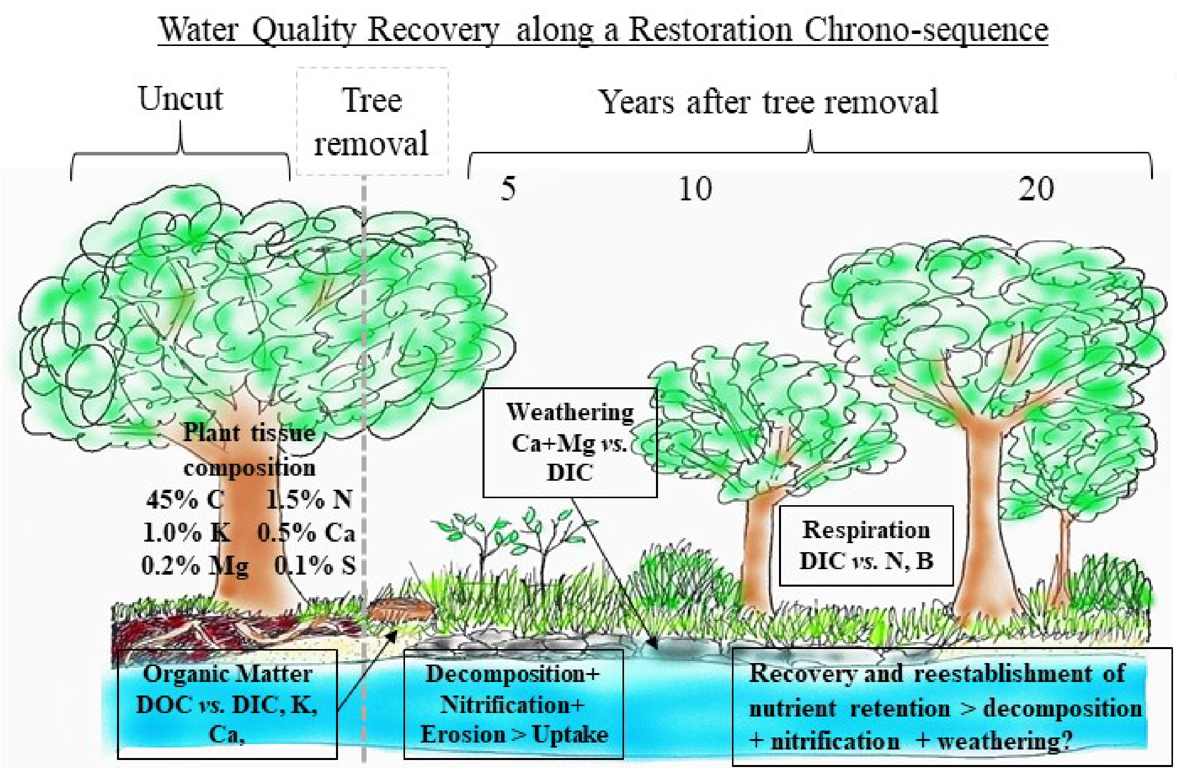
	DIC			DOC			TDN			Ca		
	Mean	SE	post-hoc*	Mean	SE	post-hoc*	Mean	SE	post-hoc*	Mean	SE	post-hoc*
Uncut	14.931	4.155	a	4.742	0.831	a	0.752	0.326	a	14.483	3.409	a
5-yr cut	42.186	4.753	b	9.126	0.95	b	2.535	0.373	b	48.118	3.926	b
10-yr cut	68.235	8.913	c	3.576	1.782	a	0.867	0.699	a,b	70.389	7.465	c
20-yr cut	64.384	5.406	c	2.657	1.081	a	1.5	0.424	a,b	65.281	4.539	c

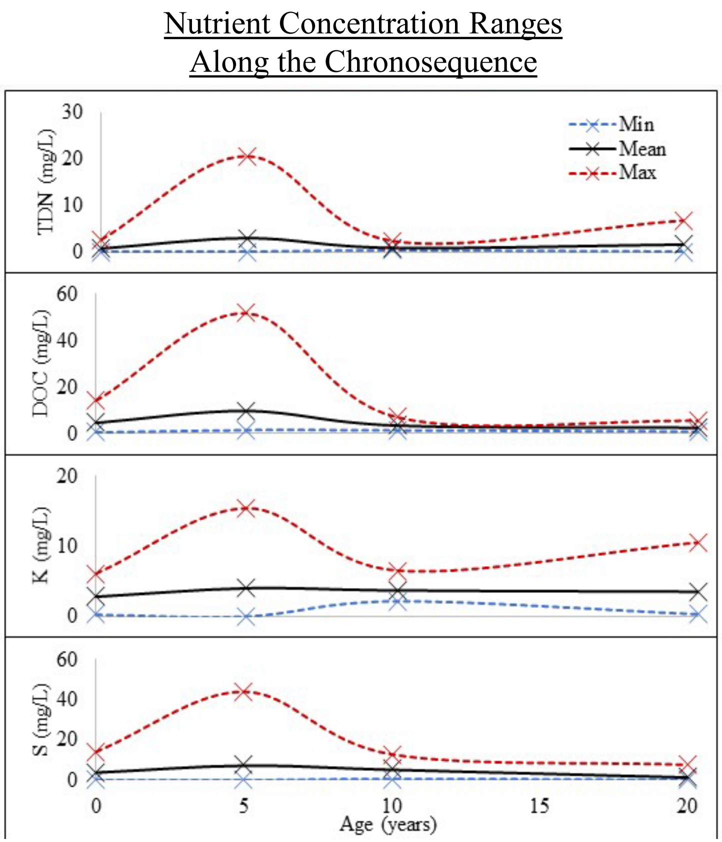
	K			Mg			Na			S		
	Mean	SE	post-hoc*	Mean	SE	post-hoc*	Mean	SE	post-hoc*	Mean	SE	post-hoc*
Uncut	2.746	0.253	a	4.625	1.028	a	6.283	0.855	a,b	4.166	0.732	a
5-yr cut	3.777	0.291	a	8.691	1.184	b	8.435	0.985	a	7.143	0.843	b
10-yr cut	3.958	0.553	a	11.554	2.252	b	7.468	1.873	a,b	5.534	1.602	a,b
20-yr cut	3.5	0.336	a	24.751	1.414	c	4.357	1.139	b	1.63	0.974	a

Tukey's (*post-hoc) results from restoration age-based ANOVA (Wood et. al. 2021)



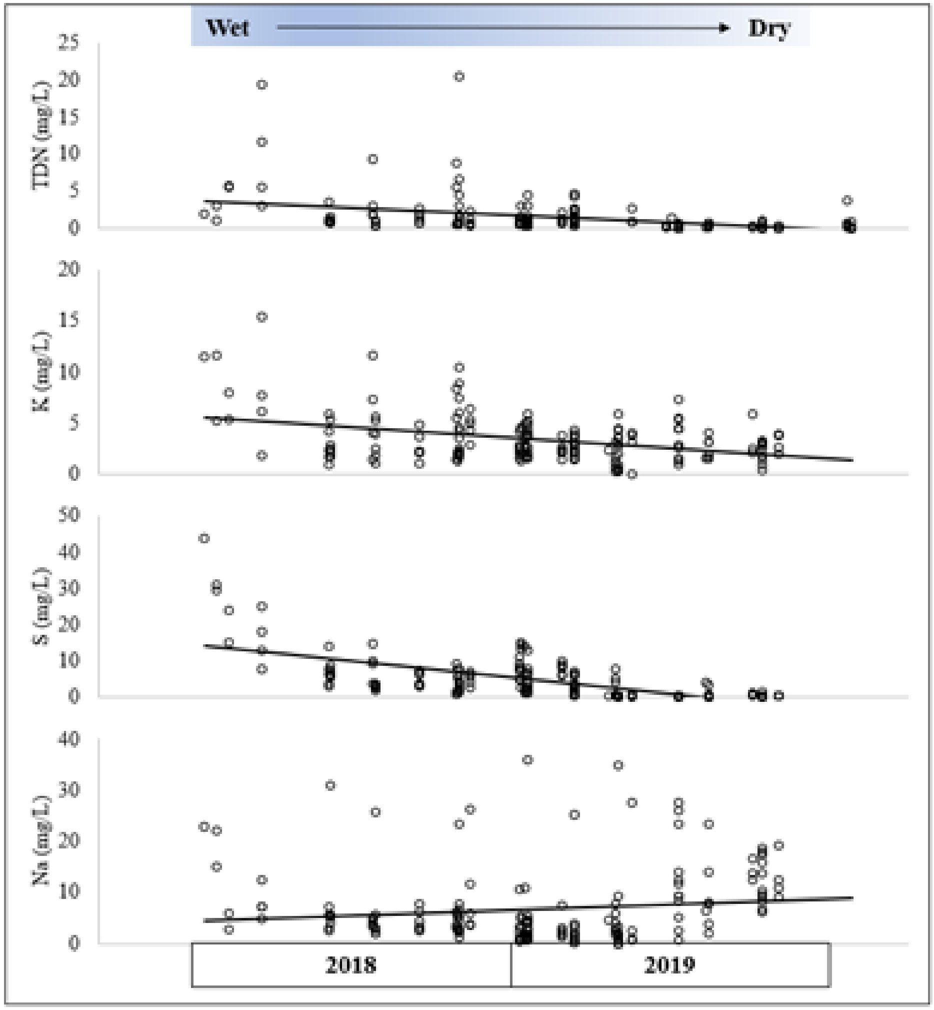
Wood et. al. (In Review)



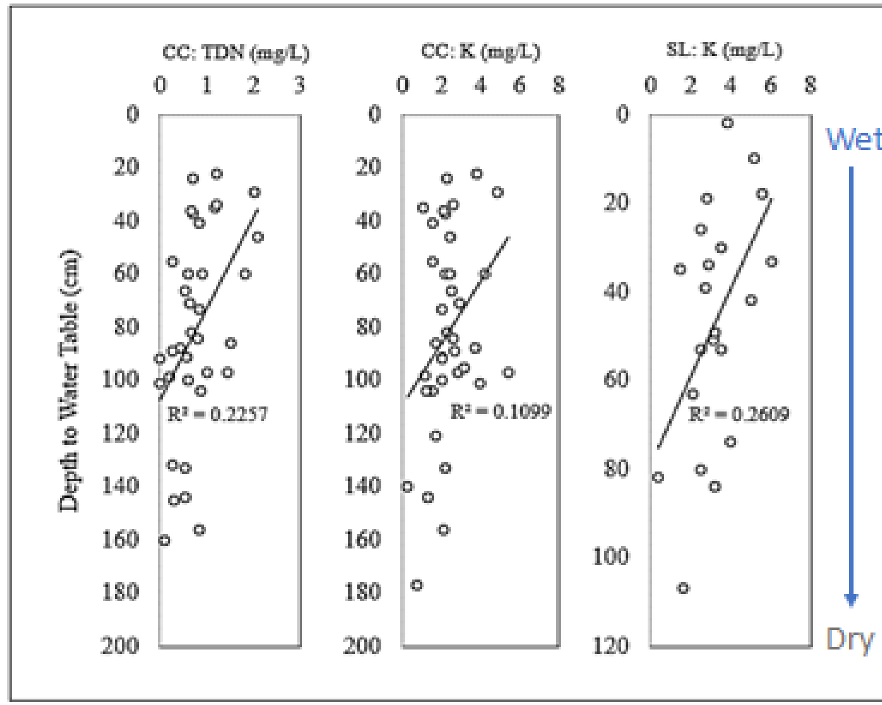


Nutrient concentrations peaked after restoration/tree removal and then declined with ecosystem recovery and riparian tree growth.

Wood et. al. (In Review)



Plant Nutrient and Carbon Concentrations Decreased from Wet to Dry Conditions



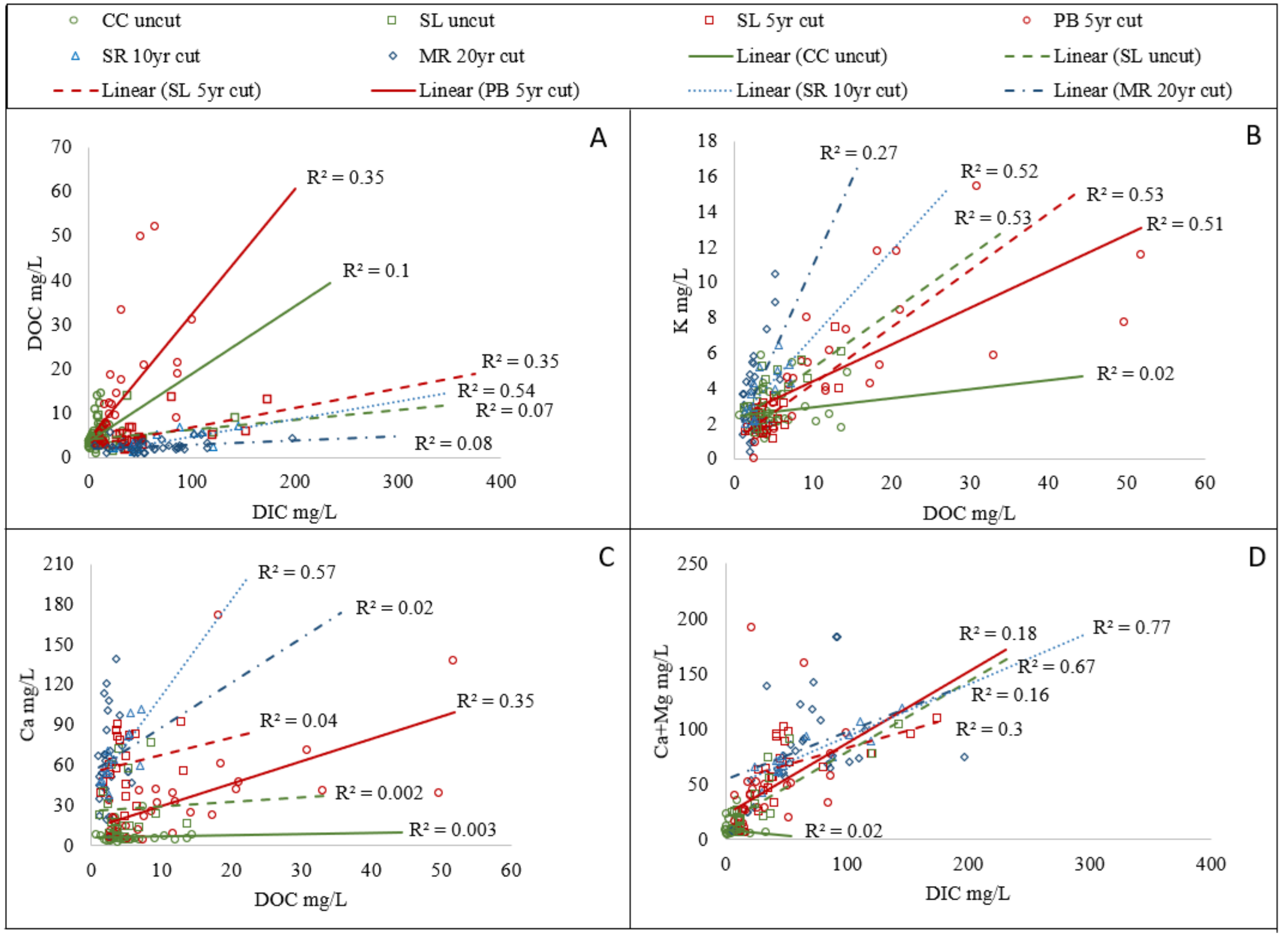
Wood et. al. (In Review)

Plant biomass and organic matter can be a source or sink of nutrients.

Respiration

Decomposition

Dead biomass



Limiting nutrient uptake

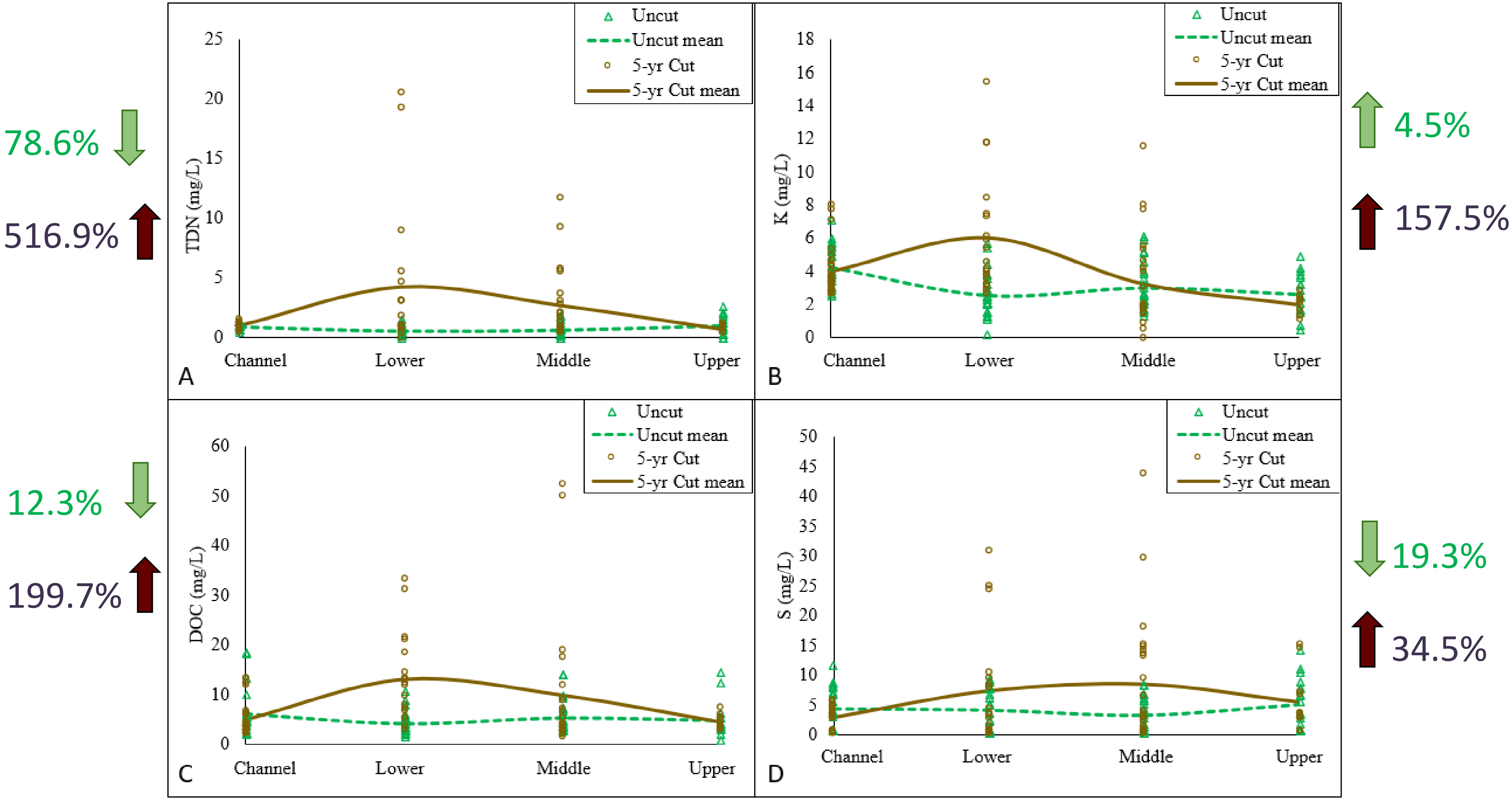
Geologic influence

Ion exchange

Wood et. al. (In Review)

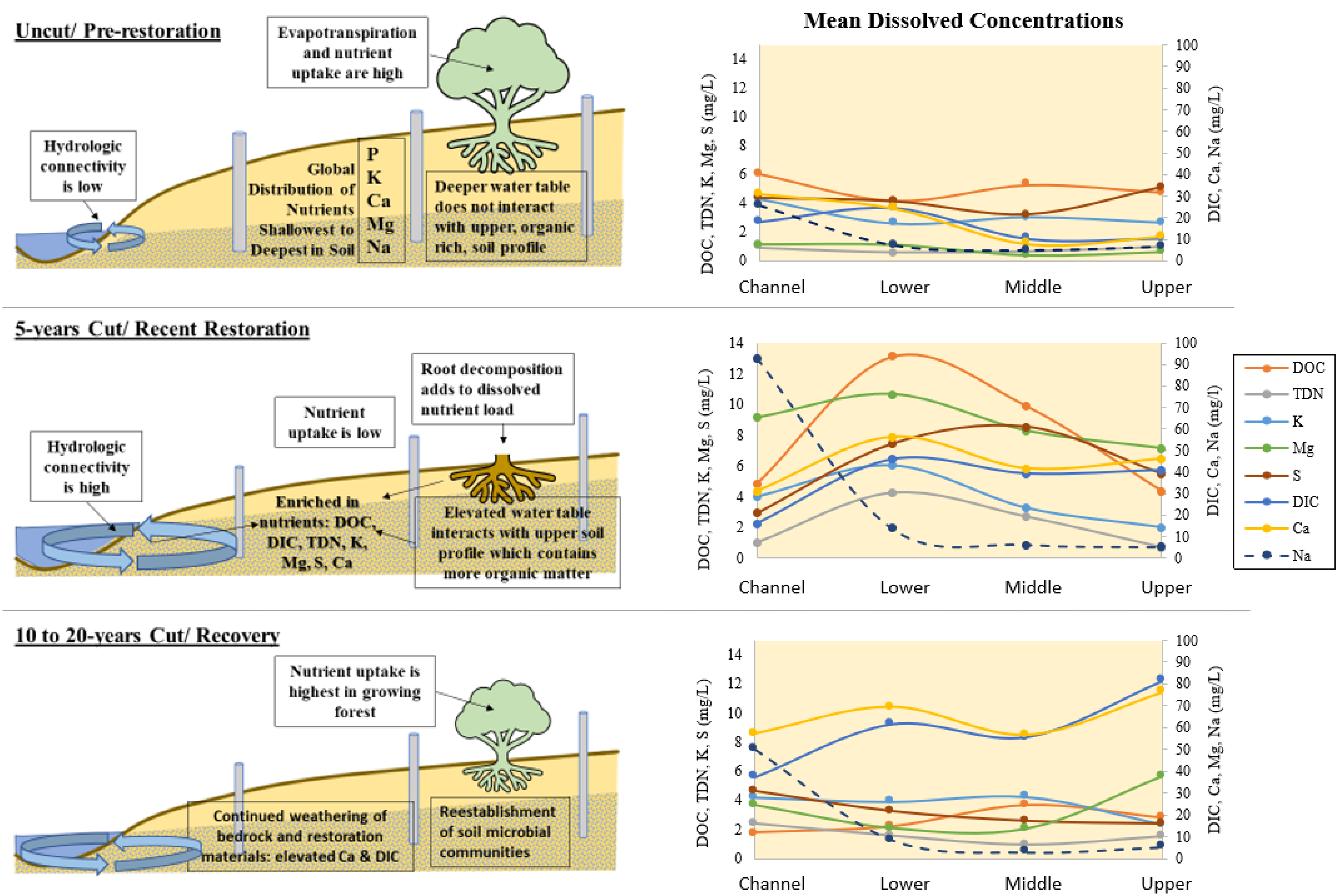
Riparian zones are sources or sinks: restored/cut sites *vs.* uncut sites

Nutrient uptake along flowpaths (sink) at uncut sites and accumulation along flowpaths (source) at 5-year cut sites.



Wood et. al. (In Review)

Riparian zones shift from sink to source of carbon and nutrients based on tree removal



Wood et. al. (In Review)

Other studies have shown increased nutrient concentrations after tree removal in watersheds

streams

groundwater

Study	Water Chemistry Response after Tree Removal	Location
Löfgren et al. (2009)	Increased concentrations of Na, K, N, Cl, etc. in streams	Sweden
Martin and Pierce (1980)	Increased concentrations of Ca and N in streams	Northeastern U.S. /New England
(G. E. Likens et al. 1970))	Increased concentrations of N, Ca, K, Na, Mg, etc. in streams	New Hampshire, USA
Aubertin and Patric (1974)	Increased concentrations of nitrate and phosphate in streams	West Virginia, USA
Hewlett, Post, and Doss (1984)	Increased concentrations of N, K, Na, Ca, Mg, etc. in streams	Georgia, USA
Burns and Murdoch (2004)	Increased concentrations of nitrate in streams	Catskills, New York, USA
Swank, Vose, and Elliott (2001)	Increased concentrations of nitrate, K, Na, Ca, Mg, S, and Cl in streams	Southern Appalachian Mountains, North Carolina, USA
Feller and Kimmins (1984)	Increased concentrations of N, K, Mg, Ca, etc. in streams	Vancouver, British Columbia
Rusanen et al. (2004)	Increased concentrations of nitrate in groundwater	Finland aquifers
Kubin (1998)	Increased concentrations of nitrate in groundwater	Finland aquifers
Williams, Fisher, and Melack (1997)	Increased concentrations of nitrate, potassium, sodium, and chloride in groundwater	Amazonian rainforest in Brazil

Wood et. al. (In Review)

Tree-Tradeoff: Take Home Points

- Significantly increased concentrations in riparian groundwater for at least 5 years following tree removal then subsequent recovery
- Increased concentrations during wet periods and decreased concentrations during dry periods
- Strong relationships with DOC (organic matter) across sites suggesting the importance of plant uptake and biomass (organic matter) as sources and sinks of nutrients
- Significant increases in concentrations along hydrologic flow paths from uplands to streams in riparian zones where trees were recently cut, and opposite patterns where trees were not cut – riparian zones can be nutrient source or sink

Translation Slides

by Sadie Drescher

What does this mean for me?

- True to the theme of this research project the restoration and short/long-term impacts are a "trade-off" for us to consider
- Now we have some data on this topic which has been long-awaited
- There are impacts after stream restoration and there is a recovery period
- As always, other factors impact the concentrations entering the stream from the groundwater and the recovery, e.g., if it is a wet year or a dry year
- The stream restoration can improve ecosystem function, as intended, and the riparian zone can bounce back after a recovery period of >5 years

What does this mean for me?

What do I take from this if I am a practitioner:

- After restoration when trees are removed there will likely be a period of about 5 years where higher concentrations of nutrients enter the groundwater
- What can I do to lessen the impact?

What do I take from this if I am a regulator:

- After 5 years a “successful” stream restoration that removed trees will be accomplishing the restoration goals and regaining the riparian function (riparian tree growth and ecosystem recovery)

Acknowledgments

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