High-frequency monitoring of nitrate in ground- and streamwater reveals variant C-Q relationship in a forest catchment

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Introduction

+ High-frequency monitoring sensors are applied worldwide.
  On the other hand, this study is the first attempt in Japan.
+ Large part of Japan is covered by forest with steep slope and rivers.
  Extreme stome events are increasing....

How Japanese forest respond to the climate change?
Especially, hydrochemical response are unknown.

Here, we discuss about stream- and groungwater nitrate dynamics and C-Q relationship with traditional and sensor monitoring

Site

Kiryu Experimental Watershed (KEW), Japan

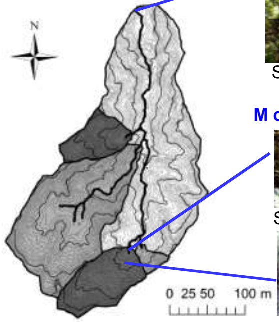
K catchment (5.99 ha)

Streamwater (Manual + Sensor)

M catchment (0.68 ha)

Streamwater (Manual)

Ground water (Manual + Sensor)

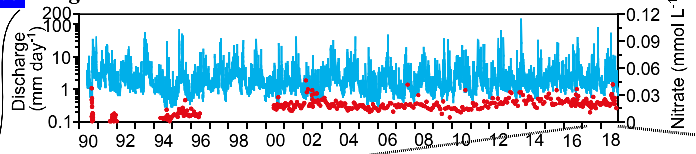


Prep.: 1650mm/yr Mean Temp.: 13.5°C
Vegetation: Japanese cypress (*Chamaecyparis obtusa*) planted around 1960
Bedrock: Weathered Granite

Nitrogen Saturation in KEW (e.g., Ohte et al. 2003 HP)
Forest disturbance occurred in 1990's at M catchment.
Recently, weak 60-yr-old cypress trees are dieback by self-thinning.

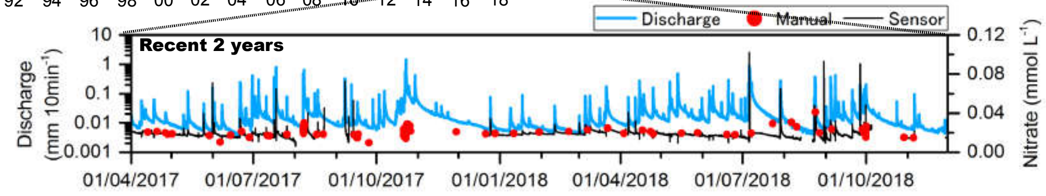
Results

Long-term streamwater Nitrate at K catchment



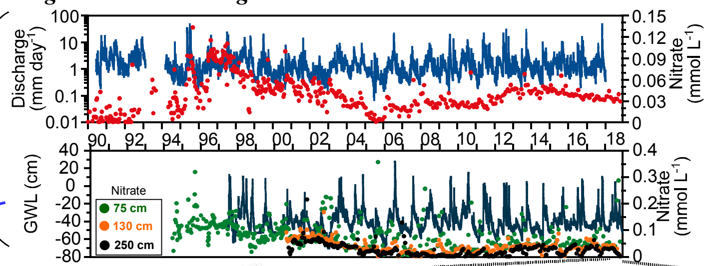
Long-term variation
+ No clear seasonality
+ Stable concentration
+ Since 2011, increasing
'90s < 0.01, '00s = 0.01, '10s = 0.02

→ **Nitrogen Saturation**



Short-term variation
+ Responded to rain storms
  Generally increased,
  but decreased during spring
+ No seasonality
  Base concentration = 0.02 mmol L^{-1}

Long-term stream- and groundwater Nitrate at M catchment

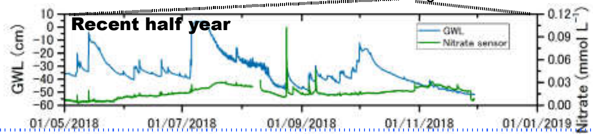


Long-term variation
in Streamwater
+ No clear seasonality

→ **Nitrogen Saturation**

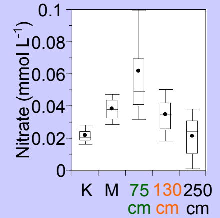
+ Higher than K catchment (> 0.03 mmol L^{-1})
  by Past (1990's) and Current (2010's) dieback

in Groundwater = Synchronize with Stream
+ Upper (75 cm deep) layer:
  Always higher concentration, unclear seasonality
+ Middle (130cm deep) and Lower (250 cm deep) layer:
  Clear seasonality, lower concentration in winter



Short-term variation in Groundwater
+ Responded to rain storms
+ Base conc. increased after GWL peaks
+ Higher in Summer ?
Need more longer data!

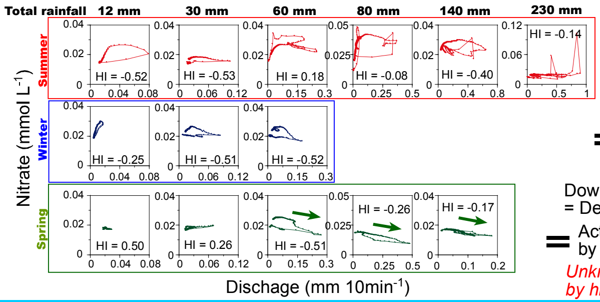
Nitrate conc. range since 2011



Higher conc. in M stream is supported by GW from upper layer (75/130 cm).
K stream, confluence of subcatchments, reflects disturbance within the site.

Discussions

C-Q Hysteresis loop



Generally, counterclockwise regardless of season
*HI: Hysteresis Index
(Lloid et al. 2016 Sci. Total Environ.)
-1 <HI < 1
Negative = Counterclockwise
Positive = Clockwise

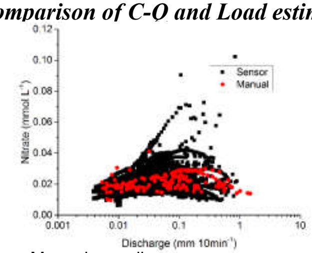
= GW contribution with higher conc. after peak flow

Downward to the right in Spring season
= Decrease of conc.

= Active N uptake by weed expansion ?

Unknown responses are firstly observed by high-frequent sensor data!

Comparison of C-Q and Load estimates



Manual sampling
Range of Q = OK
Range of C = NG
C-Q cannot be expressed by one line.

Method 1 = *True value*
Σ (Sensor C × Discharge)

Method 2
Regression of (Sensor C vs Discharge)
$C = 0.025Q^{0.072}$ ($r^2 = 0.13$)

Method 3
Regression of (Manual C vs Discharge)
$C = 0.022Q^{0.025}$ ($r^2 = 0.02$)

Estimates	kgN ha^{-1}
Method 1	2.83
Method 2	2.85
Method 3	2.99

(Apr. 2017-Aug. 2018)

However, estimates were similar because of small seasonal variations

C-Q does not reflect the mechanisms;
What are occurring within the catchment?
(= Nitrogen saturation in this site)

Conclusions

High-frequency monitoring...
+ can reveal Unknown, overlooked response of conc. to discharge
+ will be powerful tool to detect the responses to increasing Extreme events

On the other hand, long-term manual sampling...
+ can reveal slow, gradual changes of forest condition
+ Nitrogen saturation, caused by long-lasting effects of past and current tree dieback

Changing Environment

Long-term, High frequency monitoring is our future direction!!