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An assessment of the nutrient status of sugar maple in Ontario

-indications of phosphorus limitation-

オンタリオ州におけるサトウカエデの栄養状態の評価

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Environ Monit Assess

Introduction

Sugar maple
(*Acer saccharum* Marsh.)

Introduction

- Historically high S and/or N deposition has reportedly caused soil acidification in some parts of eastern North America.

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- Soil acidification may lead to deficiencies of nutrient (cf: Ca, P, Mg, K…).

(Likens et al. 1998; Watmough and Dillon 2003)

養分バランスに影響

Introduction

- Recent study have linked low P concentrations in soil to reduced radial growth of sugar maple

  in central Ontario. (Gradowski and Thomas 2006, 2008)

 【リン濃度低下がサトウカエデの成長低下に関係している】

  ⇒widespread phenomenon in Ontario?

- There are a number of factors that determine the availability of soil P to plants in the lower soil pH.

 【リン利用能力に与える要因は多い】

  ex) Metallic element, organic matter cycle,

  mycorrhizal fungi…

Purpose and hypothesis

Purpose

in Ontario sugar maple forests

①identify specific nutrients of concern

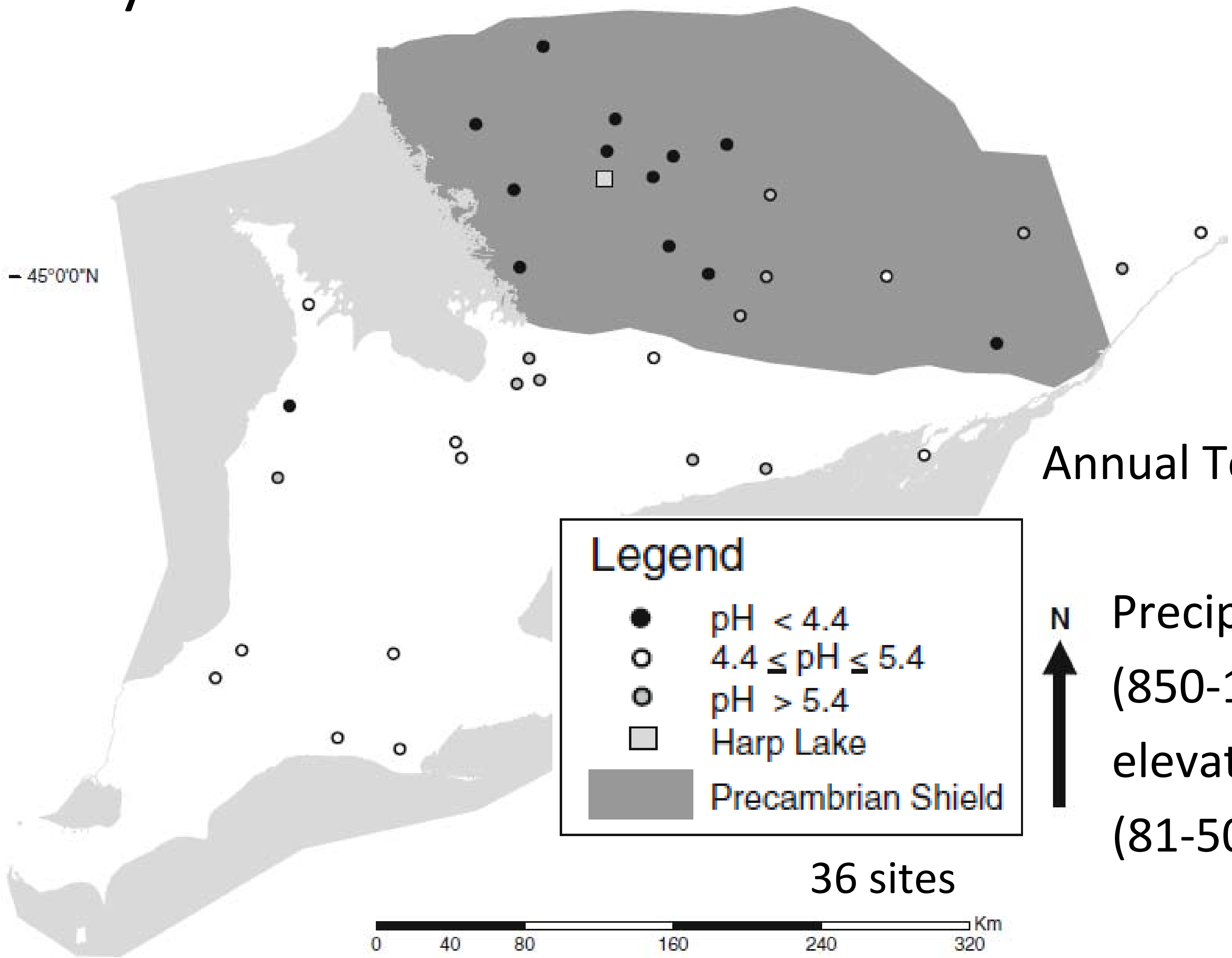
②assess the potential for widespread nutrient deficiencies（どれがヤバい?）

Hypothesis

Declines in soil pH would limit P availability through interactions with organic matter and/or metals in soils.（リンじゃね?）

Materials and methods

Study area



36 sites

Annual Temperature (5-8℃)

Precipitation (850-1060 mm)

elevation (81-507 m a.s.l.)

Measurement

These sites are OFBN(Ontario Forest Biomonitoring Network).

So, crown condition (Decline Index) at each site has been assessed almost every year since the mid-1980s.

$$DI = DB + \frac{100 - DB}{400} \times \left(UL + ST + \frac{SL}{2} \right)$$

DI : Decline Index
DB: percent dead branches
UL : percent undersized leaves
ST : percent strong chlorosis
SL : percent slight chlorosis

DI<21 : healty
DI>26 : decline

Sample collection

During summer of 2005

- soil(A-horizon, B-horizon)
- litter, fibric, humus(LFH)
- foliage→DRIS
- tree increment core→ Basal area index

$$\mathrm{BAI} = \pi(R_{2004}^2 - R_{2000}^2)$$

What is DRIS?

DRIS is index for assess the nutrient sufficiency status of an individual nutrient in plant tissue.

植物内の個々の栄養素を比較しどれが一番不足しているかを評価する指標

More negative index indicates that nutrient is more lacking relative to other nutrients under consideration.

一番低い値を示すものが一番不足している栄養素

DRIS Calculation

$$A \text{ index} = \frac{[f(A/B) + f(A/C) + f(A/D) + f(A/E)]}{z} \quad (3)$$

where when $A/B \geq a/b$ (Eq. 4):

$$f(A/B) = \left(\frac{A/B}{a/b} - 1\right)\frac{1,000}{CV}$$

or when $A/B < a/b$ (Eq. 5):

$$f(A/B) = \left(1 - \frac{a/b}{A/B}\right)\frac{1,000}{CV}$$

A-E : foliar concentration of elements (P, N, Ca, K, Mg)

If I want to know DRIS of P, A is foliar concentration of P and B-E is others.

CV & a/b : norm (Lozano and Huynh (1989))

z :number of functions in the nutrient index

Results (soil chemistry)

	pH<4.4 n=13	4.4≤pH≤5.4 n=11	pH>5.4 n=12
	A-horizon		
Water-extractable P (μg/g)	9.44±6.8 a	6.39±8.39 ab	3.88±5.10 b
Mehlich-3 extractable P (μg/g)	21.1±16.6 a	43.2±41.1 a	27.8±23.3 a
Fe (μg/g)	4.54±2.23 a	4.13±1.49 a	3.47±0.74 a
Al (μg/g)	2.07±2.14 a	2.21±1.29 a	1.59±0.48 a
Mn (μg/g)	0.44±0.39 b	1.09±0.63 a	0.79±0.50 ab
K (mg/kg)	63.9±47.3 a	56.7±63.0 a	39.7±29.0 a
Na (mg/kg)	12.4±3.35 a	10.3±4.57 a	9.47±4.29 a
Ca (mg/kg)	387±732 b	780±584 ab	2,010±1,750 a
Mg (mg/kg)	66.7±138 a	62.5±45.2 a	235±349 a
	B-horizon		
Water-extractable P (μg/g)	0.69±1.24 a	0.92±1.45 a	0.87±0.73 a
Mehlich-3 extractable P (μg/g)	7.48±4.78 a	33.8±37.1 a	20.4±23.6 a
Fe (μg/g)	7.48±4.04 a	4.25±1.77 ab	3.60±1.45 b
Al (μg/g)	7.37±3.39 a	3.63±1.40 ab	2.32±1.54 b
Mn (μg/g)	0.28±0.33 a	0.40±0.26 a	0.40±0.17 a
K (mg/kg)	22.5±20.3 a	11.62±7.40 a	27.9±24.3 a
Na (mg/kg)	10.9±3.05 a	9.01±1.80 a	9.81±3.22 a
Ca (mg/kg)	170±425 b	199±138 ab	1,370±1,330 a
Mg (mg/kg)	28.2±83.9 b	18.0±29.6 ab	134±219 a

higher

lower

Results　(LFH chemistry)

	pH<4.4 *n*=13 約2倍厚い	4.4≤pH≤5.4 *n*=11	pH>5.4 *n*=12
Depth (cm)	4.02±1.36 a	3.11±1.33 a	2.64±1.76 a
Mass (g/m^2)	2,300±950 a	1,870±684 ab	1,250±531 b
K (mg/kg)	1,020±280 ab	918±277 b	1,320±388 a
Na (mg/kg)	82.8±12.5 a	80.1±23.4 a	105±24.7 a
Ca (mg/kg)	8,980±3,510 b	17,400±7,320 a	17,800±3,970 a
Mg (mg/kg)	890±303 b	1,200±497 ab	1,880±749 a
P (mg/kg)	821±184 a	672±266 ab	608±117 b

Results (foliar chemistry)

	pH<4.4 n=13	4.4≤pH≤5.4 n=11	pH>5.4 n=12	
Concentrations (%)				Critical foliar concentrations[a]
P	0.10±0.01 b	0.12±0.03 ab	0.16±0.06 a	0.08–0.18
N	1.93±0.21 a	1.78±0.26 a	2.11±0.46 a	1.6–2.23
K	0.78±0.10 a	0.77±0.22 a	0.83±0.23 a	0.55–1.04
Na	0.07±0.02 a	0.06±0.03 a	0.13±0.14 a	0.001–0.008
Ca	0.97±0.18 b	1.41±0.21 a	1.47±0.31 a	0.5–2.19
Mg	0.16±0.02 b	0.20±0.02 a	0.21±0.05 a	0.11–0.4
Ratios				DRIS norms[b]
P/N	0.05±0.01 b	0.07±0.02 ab	0.08±0.03 a	0.01
P/K	0.13±0.02 b	0.17±0.06 ab	0.20±0.06 a	0.18
P/Ca	0.11±0.02 a	0.09±0.02 a	0.11±0.05 a	0.17
P/Mg	0.64±0.13 a	0.64±0.18 a	0.77±0.30 a	0.83
DRIS indices				
P	−15.4±9.2 b	−10.1±5.18 ab	−6.48±7.57 a	
N	9.09±4.55 a	2.96±5.81 ab	3.76±6.37 b	
K	−3.62±3.14 b	−11.6±9.75 ab	−12.7±7.59 a	
Ca	−2.55±5.59 b	4.68±3.89 a	2.86±7.25 ab	
Mg	12.5±7.18 a	14.0±5.74 a	12.5±7.38 a	

P is the most limiting nutrient in lower soil pH

Results (catchment mass balance)

		In–out (mg m^{-2} $year^{-1}$)						Molar ratio in stream water		
		Ca	Mg	K	Na	P	N	Ca/Na	Mg/Na	K/Na
Harp-3A	1980–1989	−1,560±353	−494±106	−212±74	−346±80	14.3±4	652±155	2.57±0.23	1.24±0.10	0.41±0.05
	1990–1999	−1,200±324	−375±101	−110±56	−334±106	10.1±3	777±133	2.11±0.17	1.01±0.08	0.26±0.05
	2000–2005	−1,020±211	−314±69	−18.5±33	−350±93	15.0±5	684±118	1.71±0.10	0.81±0.04	0.14±0.04
Harp-6A	1980–1989	−1,160±286	−339±76	−81.9±58	−254±56	14.3±5	872±79	2.59±0.37	1.14±0.15	0.28±0.04
	1990–1999	−886±152	−265±42	−75.0±52	−286±86	9.31±3	830±122	1.88±0.37	0.85±0.15	0.23±0.06
	2000–2005	−653±261	−200±77	−0.96±58	−270±100	14.9±5	720±122	1.49±0.22	0.68±0.10	0.15±0.07

P and N is accumulating!

P	N
14.3±4	652±155
10.1±3	777±133
15.0±5	684±118
14.3±5	872±79
9.31±3	830±122
14.9±5	720±122

Results (Sugar maple health)

	pH<4.4 n=13	4.4≤pH≤5.4 n=11	pH>5.4 n=12
Cumulative basal area index	41.8±12.7 a	41.2±12.7 a	46.9±18.2 a
Decline index	8.40±4.14 a	7.60±4.80 a	7.42±2.49 a

- No significant differences in cumulative basal area index or Decline Index among soil groups.
- DI values indicate that trees are

  ingenerally good condition

Discussion

Ca & Mg

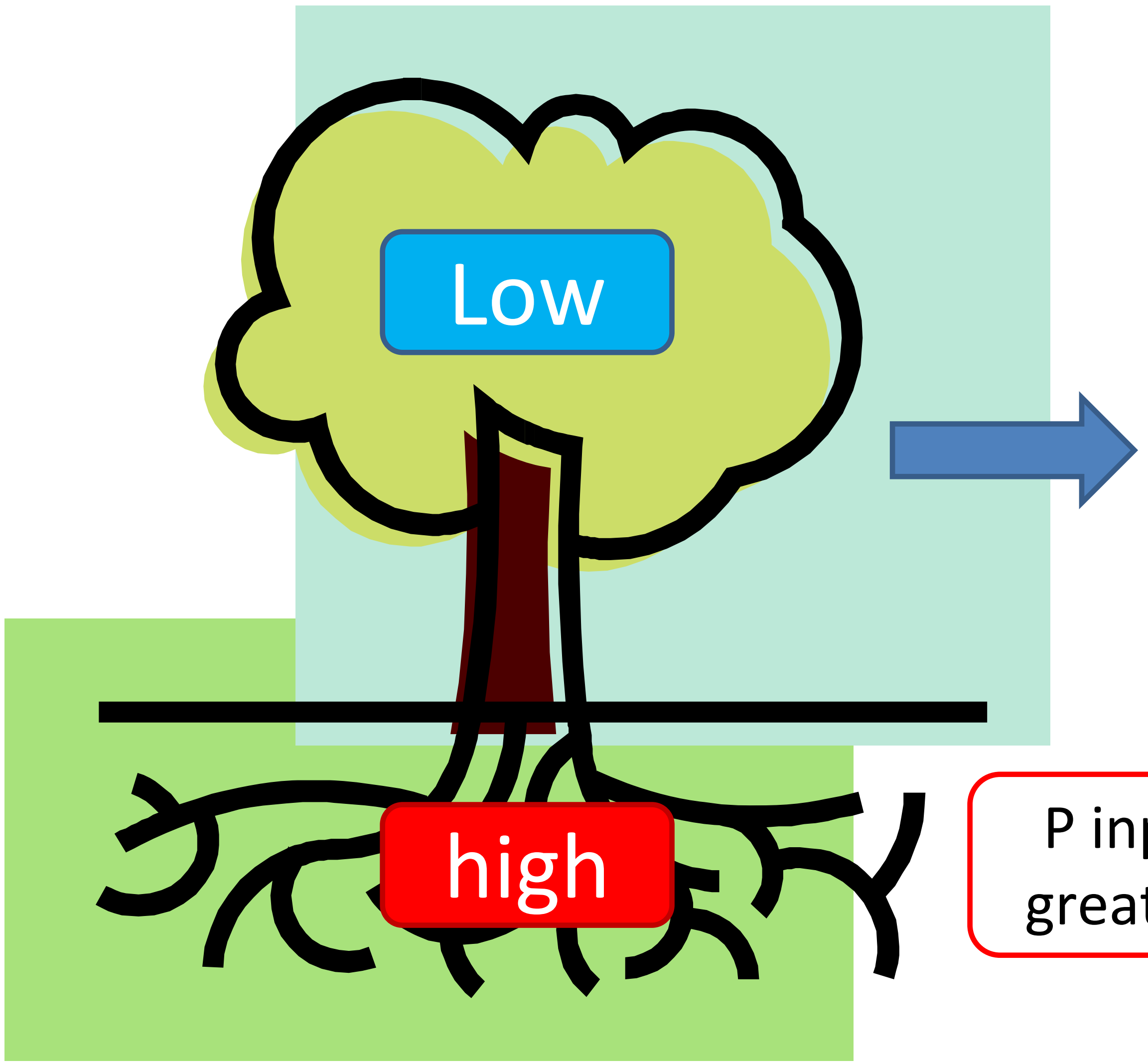
soil & foliar parameter is lower in acidic sites

(Likens et al. 1998; Watmough and Dillon 2003)らの結果に一致

Because of historically high S deposition

Discussion（P）

The most limiting nutrient to sugar maple by DRIS.



due to low P availability of trees

P input from deposition is greater than stream export

Discussion（P Unbalance）

Why 樹木がリンを利用できなくなっている？

- Fe and Al (soil chemistry)were higher

  → Reaction with metals

- Low pH sites have thicker LFH layers

  P concentrations and pools were significantly higher

  → slower rates of decomposition and mineralization

- No data but in the literature (ex: Hutchinson et al. 1998)

  → Decreases in mycorrhizal activity

Discussion

No difference in crown condition (decline index)

and radial growth (basal area index)

➢P concentrations 0.1% at acidic sites,

P/N ratio was 0.05

→barely(>_<)problem in near future

※foliar P concentrations of decline tree below 0.1%

P/N ratios ranged from 0.025 to 0.04

conclusion

In Ontario sugar maple forests

①specific nutrients of concern is P（リン）

②the potential for widespread nutrient deficiencies is not yet having a widespread detrimental effect on tree health.（まだ広域的には起こっていない）

Declines in soil pH would limit P availability through interactions with organic matter and/or metals in soils.