“ Trees sensitivity to Warming is controlled by Turnover Time of Forest Floor”

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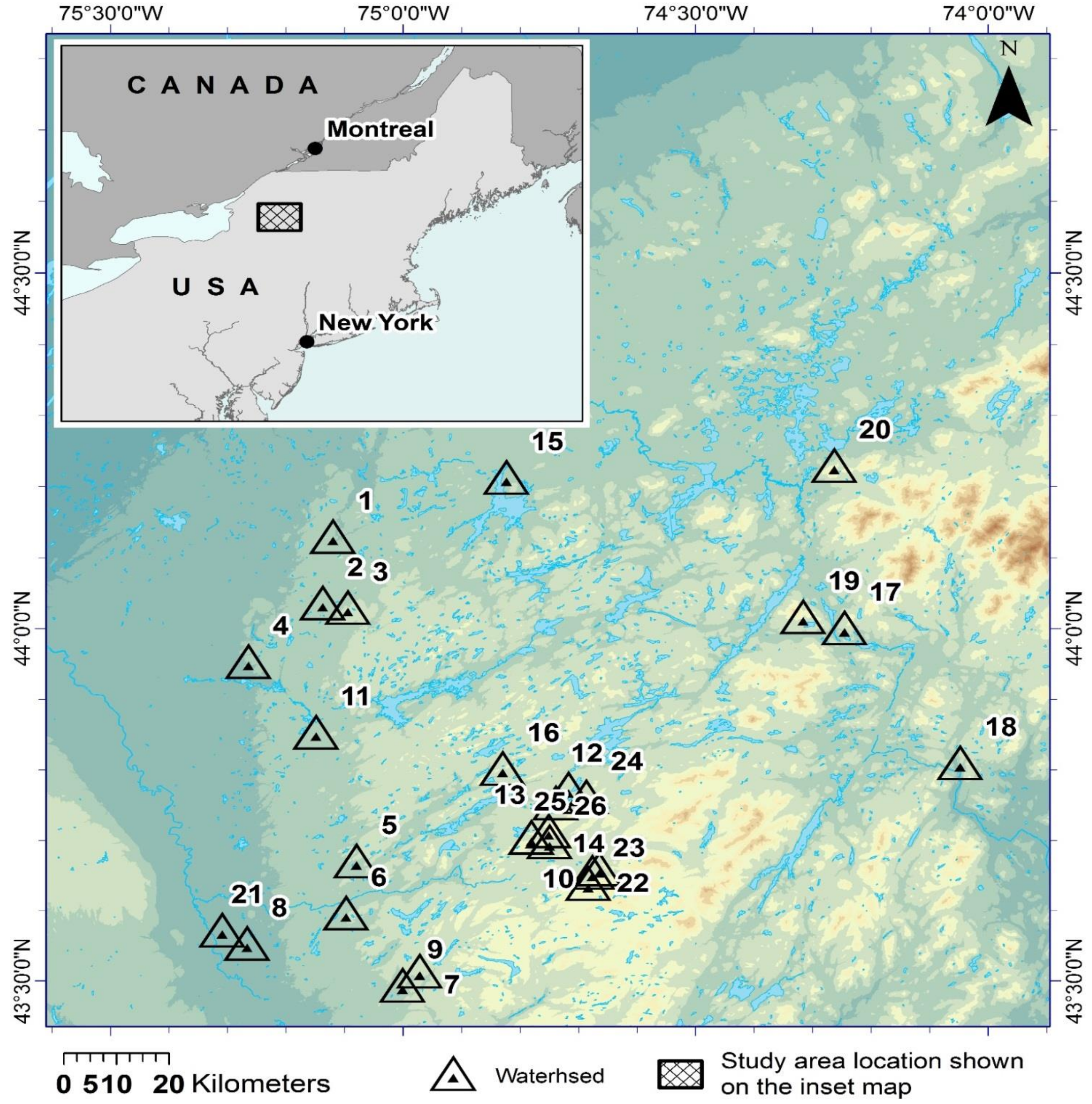
science for a changing world

Reasons for this work

- 1. There are only a few (mostly agricultural) studies about linkage between spring phenology and soil-related variables. Here we had an opportunity to test connection between spring phenology of natural growths with edaphic factors.
- 2. There is no any studies on potential linkage of plants sensitivity to warming with edaphic factors.



26 small, deciduous watersheds. Sampled: 2004, 2009

Exchangeable chemistry, C_{org}, N, Oa thickness, bulk density

Remote sensing data : Start of Season (**SoS**), End of Season (**EoS**), **NPP**. Source: Moderate Resolution Imaging Spectroradiometer MOD13Q1, MOD17A3.

Scope of the work

- 1. Investigated potential linkage between SoS (first greenup dates during 2001-2009 period) and soil-related variables.
- 2. Estimated plants sensitivity to warming (β) as regression coefficient of SoS to spring (April or March) temperature during 2001-2009 period [days of SoS advance/retreat per 1 ^{o}C]
- 3. Investigated potential linkage of statistically significant estimates of β and soil-related variables.

Climatological variables

- Mean Annual Temperature (**MAT**), Annual Precipitation (**P**), Daily Maximum Temperature, Mean Daily Temperature.
- "Biological Temperature" (**BT**=5^{o}C) and the Start of the Thermal Growing Season (**STGS**).
- In addition to STGS we did estimate $\boldsymbol{\beta_T}$ (sensitivity of thermal season to changes in spring temperature): regression coefficient between STGS and spring temperature : days of STGS advance/reatreat per 1^o C.

IMPORTANT

β and $\boldsymbol{\beta}_T$ have the same dimension: [days per 1 ^oC.]

Additional, soil-related variable: Turnover time of Soil Organic Matter (SOM) in forest floor

- $\tau[yr] = \frac{Stock\ of\ Corg\ in\ forest\ floor\ layer\ [\frac{kg}{m^2}]}{Litterfall\ \ [\frac{kg}{m^2 yr}]}$ **(1)**

- $\boldsymbol{Stock\ of\ Corg\ in\ forest\ floor\ = C_{org} \times h \times \rho}$ **(2)**
- Where *h*, - the thickness, and, ρ, - bulk density of forest floor.
- The litterfall was estimated as function of NPP:
  - $\boldsymbol{Litterfall = \alpha \times NPP}$ **(3)**
- Where α is the litterfall fraction of NPP which varies with forest type and age within the range from 20 to 60%. In old-growth, hardwood stands of Great Lake region, this parameter equals to about 40% (Tang and Bolstad, 2005).
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RESULT #1
SoS

- SoS correlates with *Al*, CEC, *pH* at $p<0.05$ and with MAT and thickness of Oa layer (*h*) at $p<0.01$.
- **Covariance:** *Al* with exchangeable chemistry is causal!
- MAT with the elevation above sea level and with thickness of Oa layer (*h*),
- MAT is controlled by the elevation above sea level (the slope is close to the laps rate at 6.2 oC /km);
- MULTIPLE REGRESSION MODEL reviles **0.37** days per 1 [meq/100g] of *Al*; **5.1** days per 1 ^{o}C of MAT, and **1.7** days per 1 cm of forest floor.
- **Covariance of MAT and the thickness of Oa layer can be causal!**

Thermal diffusion model of Oa layer

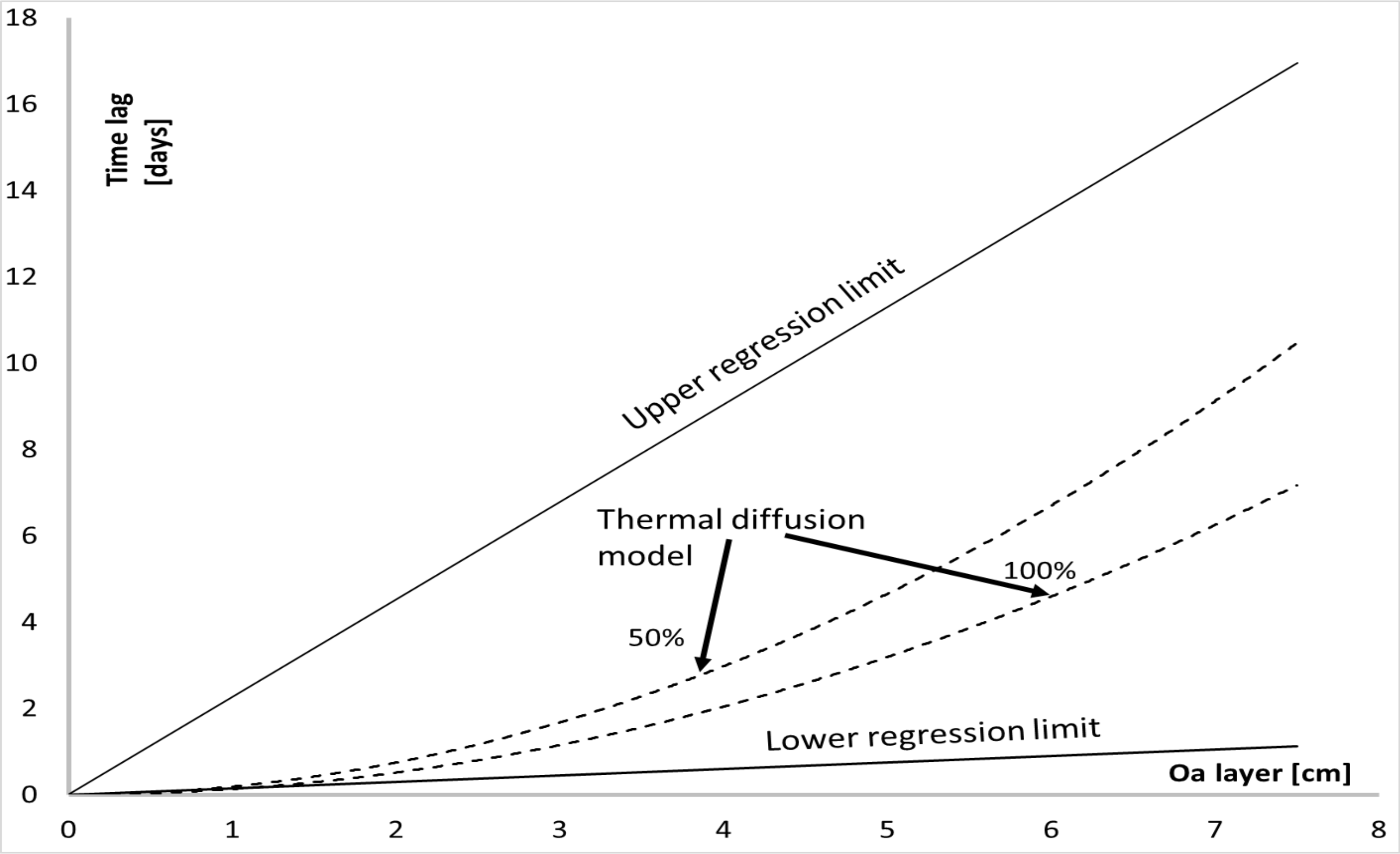
Delay (phase shift) of transmittance of the thermal signal from near surface atmosphere into the soil can be described as (Van Wijk, 1963; Jury, Horton, 2004):

- $\Delta t = h/\omega d$ (5)
- where ω is the angular frequency of surface temperature; *d* is the damping depth; and *h* is soil depth in forest floor. The *d* term can be calculated as a function of ω and the coefficient of thermal diffusivity (*K*) (Jury, Horton, 2004):
- $d = \sqrt{\frac{2K}{\omega}} = \sqrt{\frac{K\tau}{\pi}}$ (6)
- where τ is the time period (1 year). *K* values of the forest floor depend on bulk density and the proportion of organic matter relative to water and air.

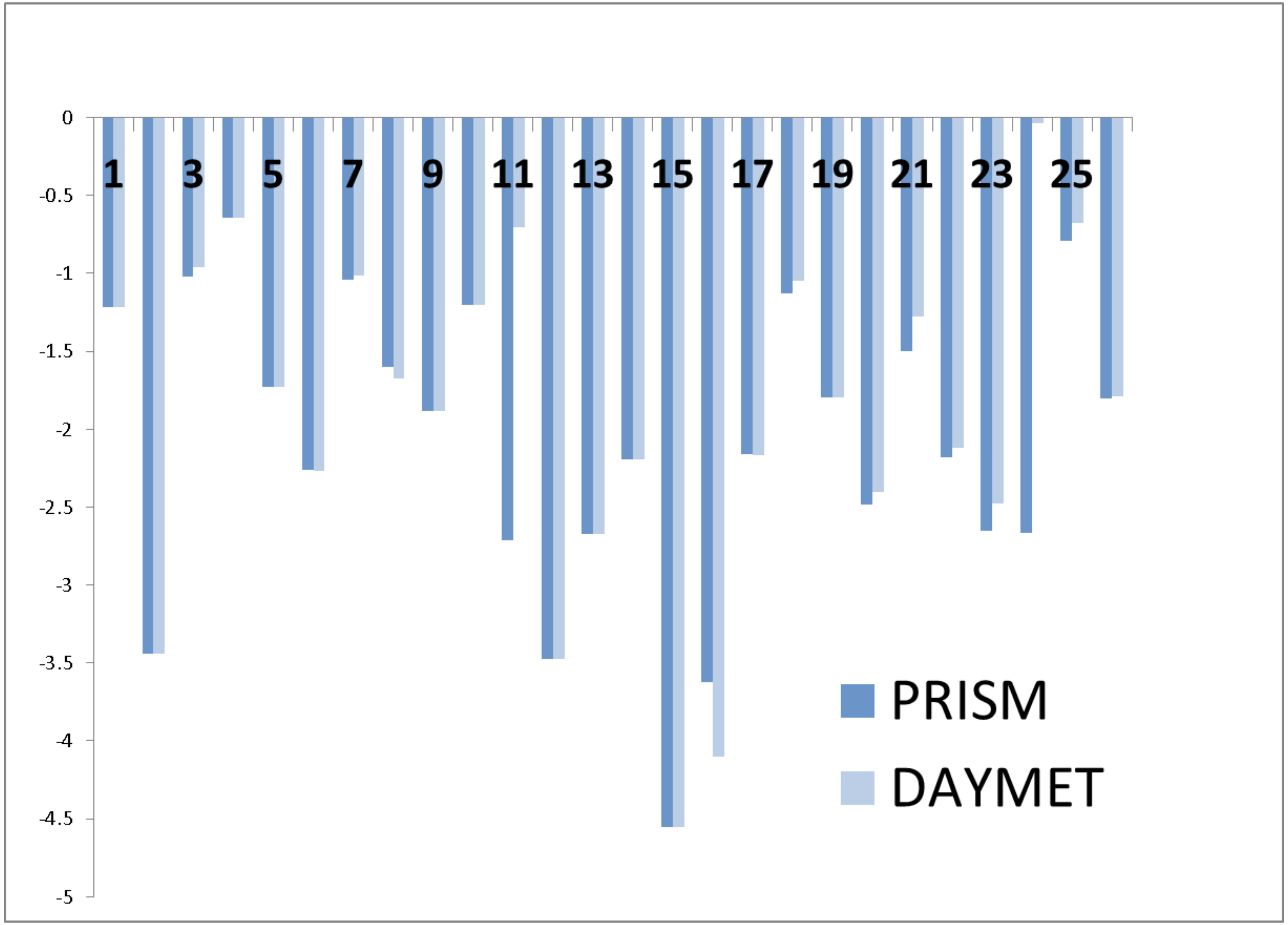
Calculations of thermal diffusion coefficient

- Derived *K* values are about 5-fold smaller than the typical thermal diffusivity of snow (Oldroyd et al., 2013).
- According to our calculations, insulating capacity of the 10 cm of forest floor equals approximately to 0.5 meter of snow depth.

Experimental (95% confidence level) regression slopes and the thermal diffusion model results (100 and 50% saturation) of the delay of SoS relative to the thickness of forest floor (*h*).



Result #2
β



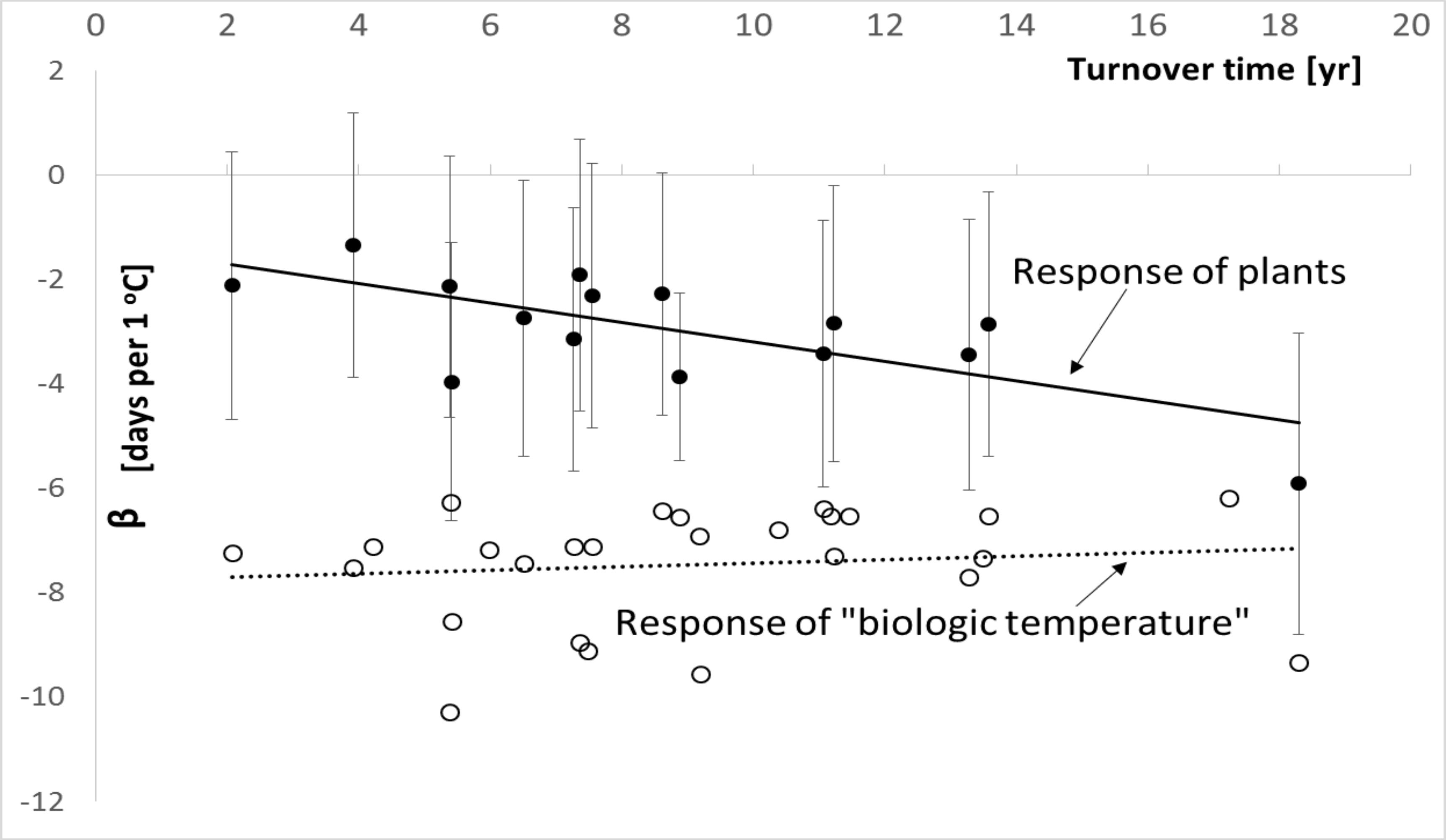
RESULT#3, β

- We did build 3 multiple correlation models of **β and soil-related variables :**
- **1.** PRISM mean daily temperature data (τ**,** EoS); r>0.5, p<0.05, n=17
- **2.** PRISM maximum temperature data (τ); r>0.8; p<0.01, n=17
- **3.** DAYMET maximum temperature data (τ**,** MAT); r>0.7, p<0.01, n=17

B increases with turnover time at the rate of about 0.1 days per 1^{o}C per each 1 yr of turnover time.

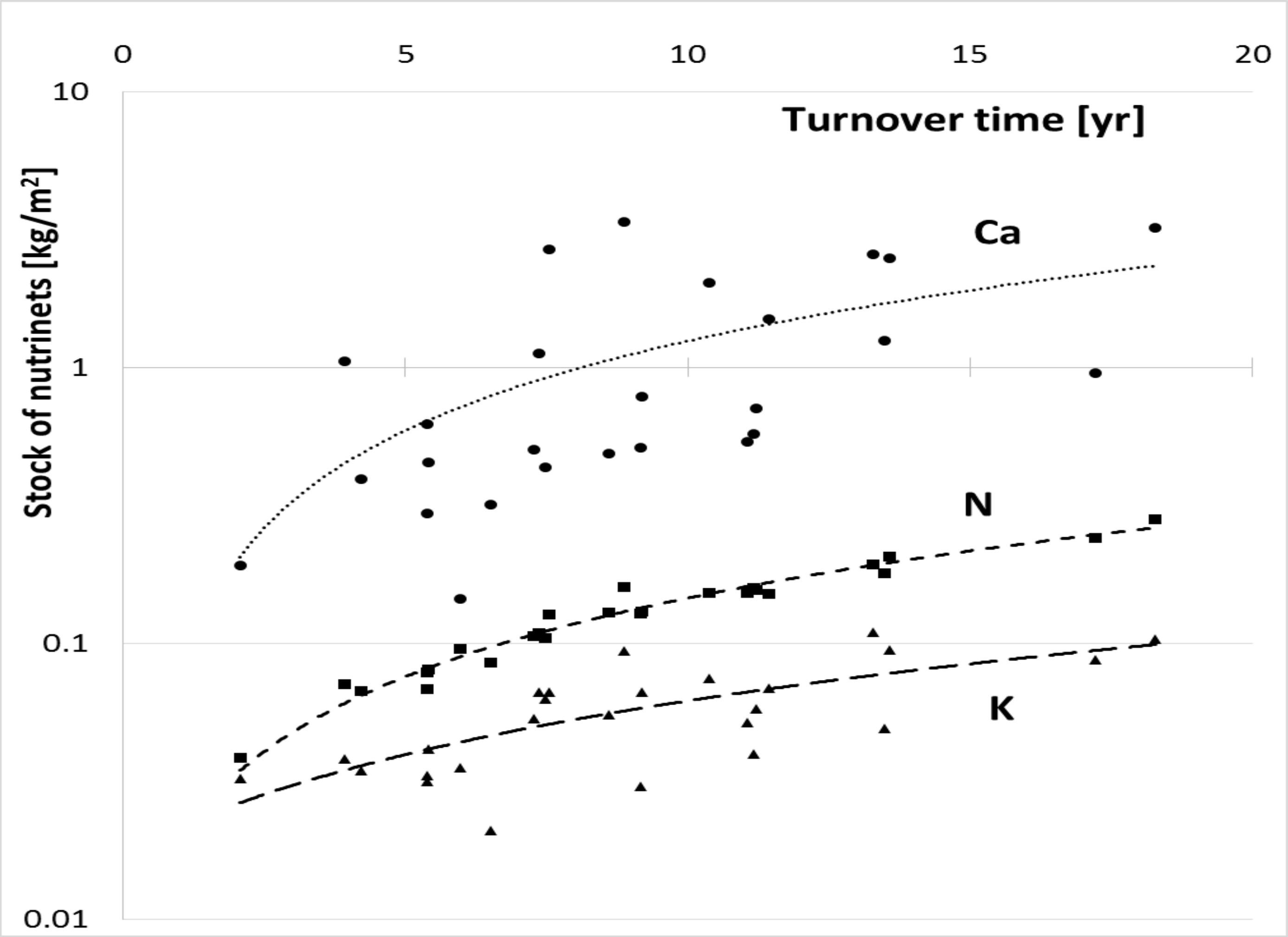
(The whole range of turnover time estimates is from 3 to 20 years. The average of 9 years is very close to other independent estimates of turnover time in maple and oak hardwood stands).

RESULT#3, β



0
2
4
6
8
10
12
14
16
18
20
Turnover time [yr]
2
0
-2
-4
-6
-8
-10
-12
β [days per 1 °C]
Response of plants
Response of "biologic temperature"

HYPOTHESIS 1: Soil Nutrients Limit Plants Response to Warming
HYPOTEHSIS 2: Thick forest floor (slow turnover time) protects fine roots from late winter-early spring frost .



Conclusions

- 1. Spring phenology of similar hardwood stands in Adirondacks, in the region with relatively uniform climatic conditions, is controlled by soil acidification (Al^{3+}) as well as by MAT and/or by the thickness of forest floor which acts as a very good thermal insulator, thus, delaying the spring thermal signal propagation into the soil.
- 2. Plants sensitivity to warming in Adirondacks is typical for deciduous forest ecosystem: 1 to 5 days advance of SoS per 1^{o}C of spring warming.
- 3. The dominant factor controlling plants sensitivity to warming is turnover of forest floor. Most likely forest floor acts here as source of extra nutrients to supply extended growing season and/or as the last defense from late winter-early spring frost as snow thickness declines with the warming.