Seasonal variation in soil microbial biomass, bacterial community composition and extracellular enzyme activity in relation to respiration in a Northern Great Plains grassland

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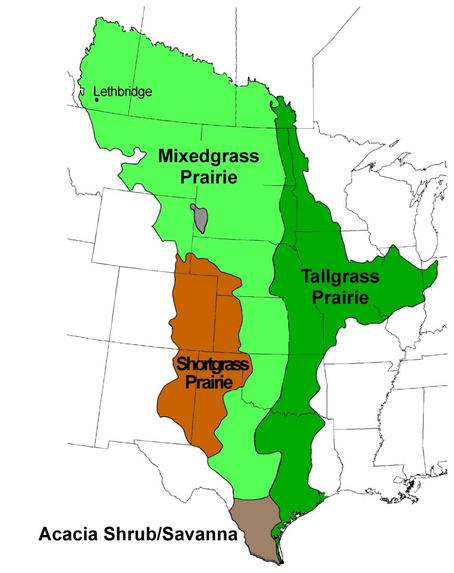
Native grassland study site

Summary

- Seasonal variation in ecosystem CO_2 exchange was compared to analyses of soil microbial biomass, extracellular enzyme activity and the species composition of the soil bacterial community.
- Soil temperature and moisture were shown to have both direct and indirect effects on respiration. Indirect effects were a result of changes to plant and microbial biomass and substrate availability.
- This study indicates that seasonal change in ecosystem respiration is a complex interaction between temporal changes in environmental factors and biological changes in the plant and microbial community that affect respiratory metabolism.



Grasslands of the Great Plains (Ostlie *et al.* 1997)

What factors control respiration?

Respiration rate is determined by R_{10}, Q_{10} and environmental conditions

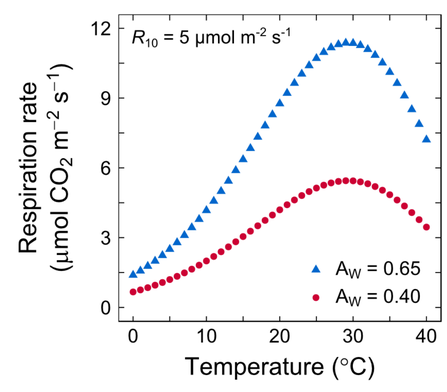
Respiration rate (μmol m^{-2} s^{-1}) = R_{10} x $Q_{10}^{((T-10)/10)}$ x f_{Aw} (Equation 1)

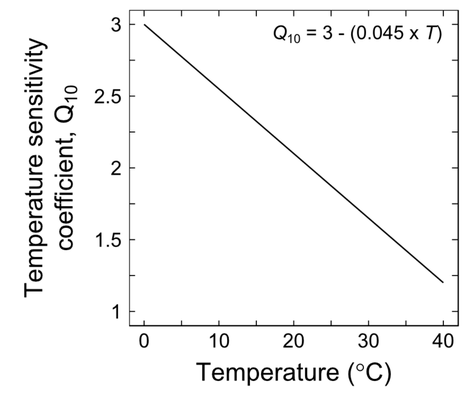
R_{10} is the respiration rate at 10°C (respiratory capacity of the ecosystem)
Q_{10} is the temperature sensitivity coefficient
T is temperature (°C)
f_{Aw} is a relative water stress function (varies 0-1), where A_w is available water

$f_{Aw} = e^{-((Aw-Opt)/\Omega)^2}$, where *Opt* is the optimum water content, Ω is a scalar

Direct controls on respiration:

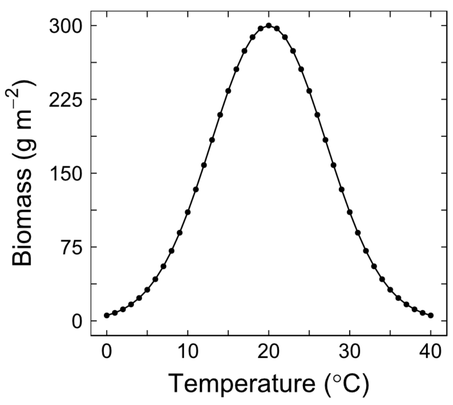
Temperature and soil moisture are variables in equation 1.
Q_{10} is also directly affected by temperature (Tjoelker et al. [2001] Global Change Biology 7:223-230).

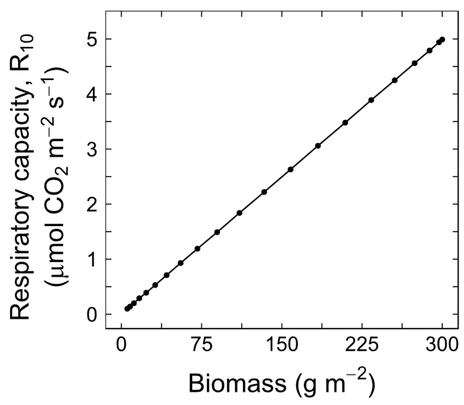


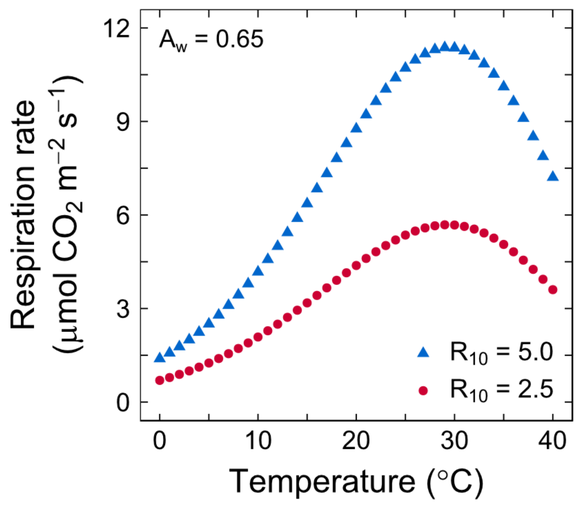


Indirect controls on respiration:

Any change in the ecosystem that affects R_{10} will cause variation in respiration.
Variation in R_{10} may primarily involve changes to biomass (plant and microbial) and substrate availability.
The conceptual graphs shown below for biomass could also be applied to substrate availability.

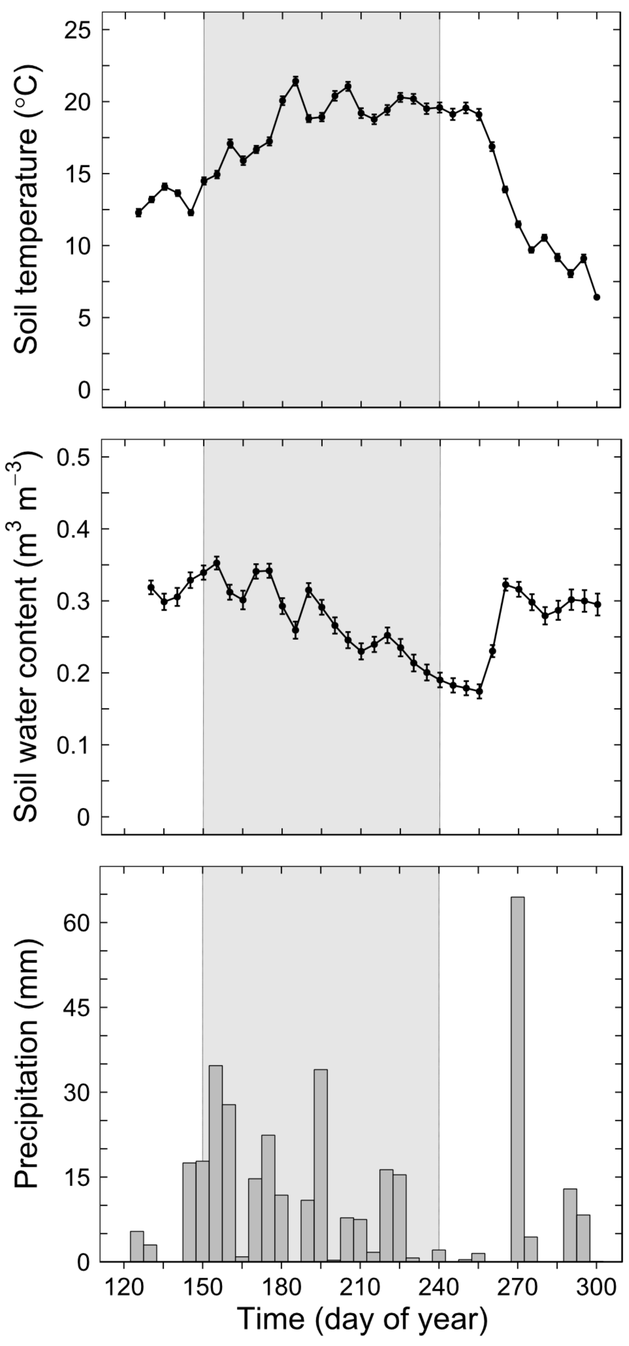




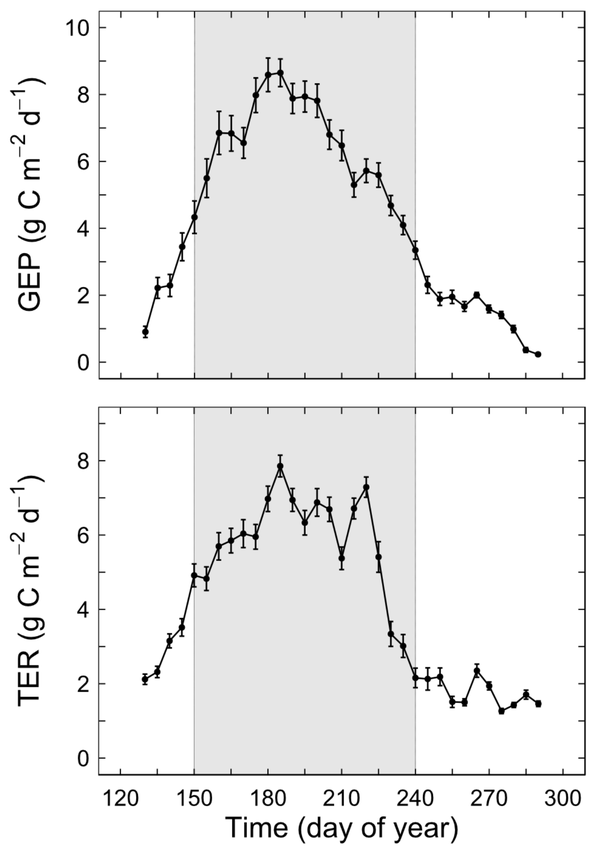


Respiration rate varies with temperature, but this can be amplified or reduced by changes to the respiratory capacity (R_{10}) of the ecosystem.

Environmental conditions

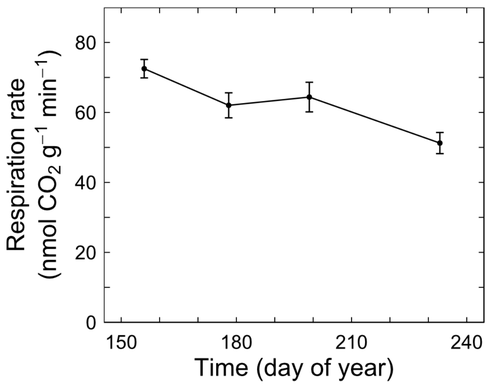


Ecosystem CO_2 exchange

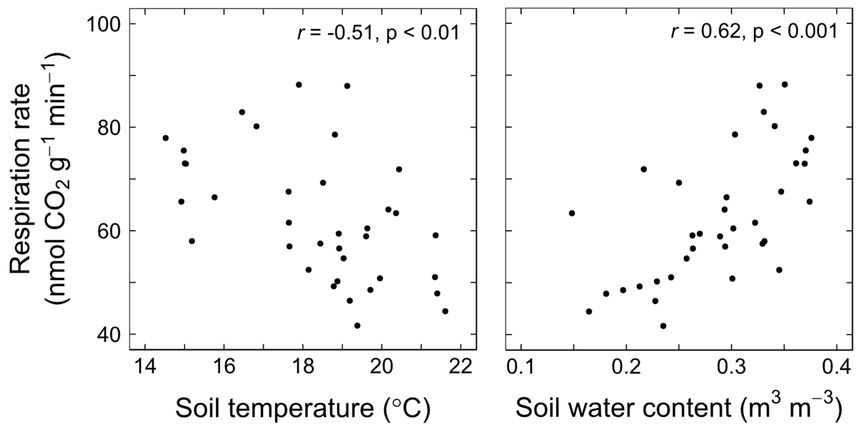


GEP = gross ecosystem productivity
TER = total ecosystem respiration

Substrate-induced respiration



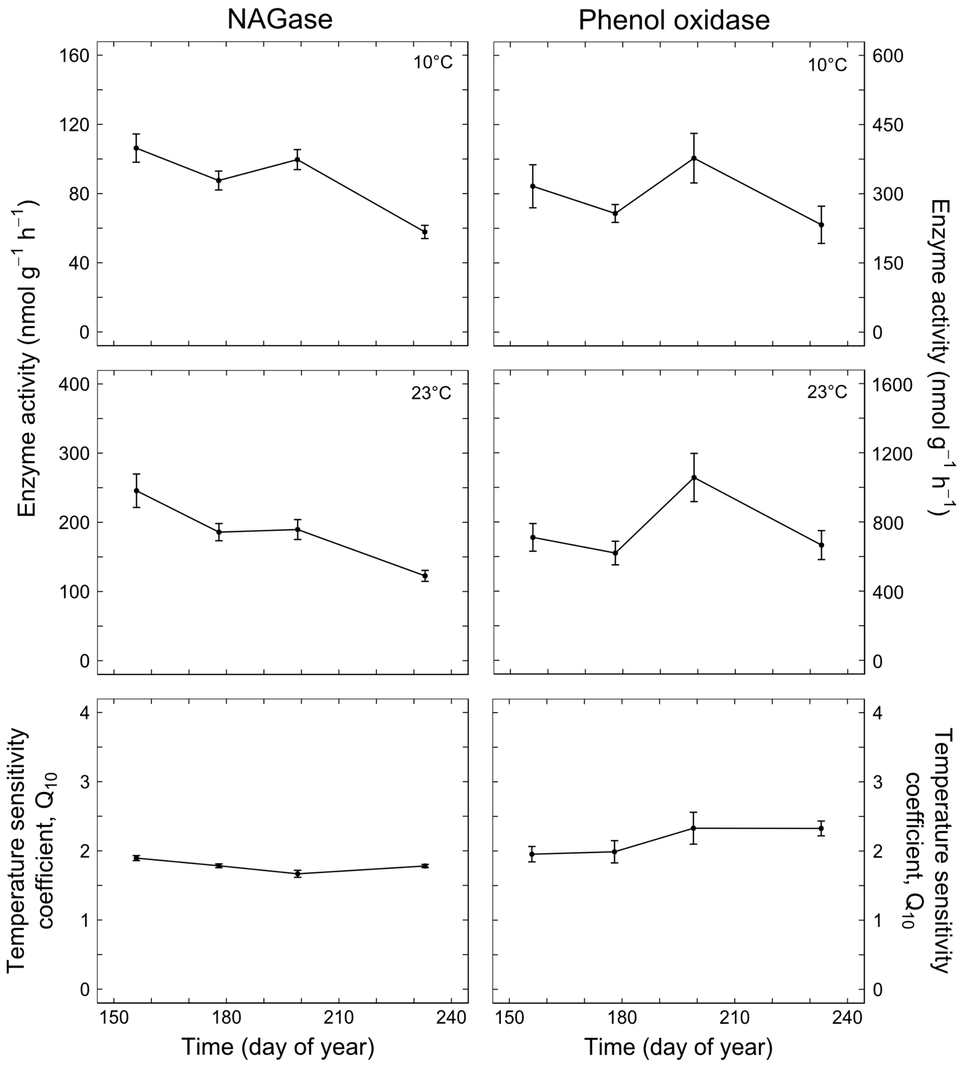
Substrate-induced respiration is a proxy measurement for living microbial biomass in the soil. It declined over the growing season in strong correlation with reductions in soil moisture.



The negative correlation with soil temperature was likely due to a strong negative correlation between soil temperature and soil moisture (r = -0.78).

Variation in active soil microbial biomass with changes in soil moisture indicated possible indirect effects of soil moisture on soil respiration.

Measured extracellular enzyme activity



Modeled extracellular enzyme activity

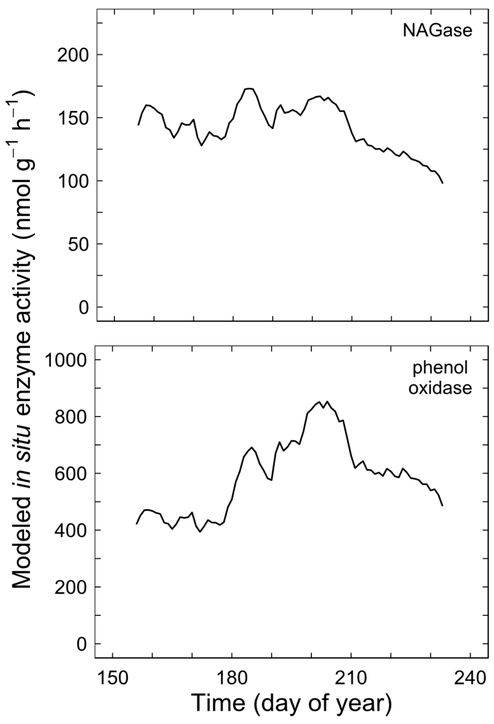
Measured enzyme activity was used to model *in situ* enzyme activity for the growing season:

Enzyme activity (nmol g^{-1} h^{-1}) = R_{10} x $Q_{10}^{((T-10)/10)}$

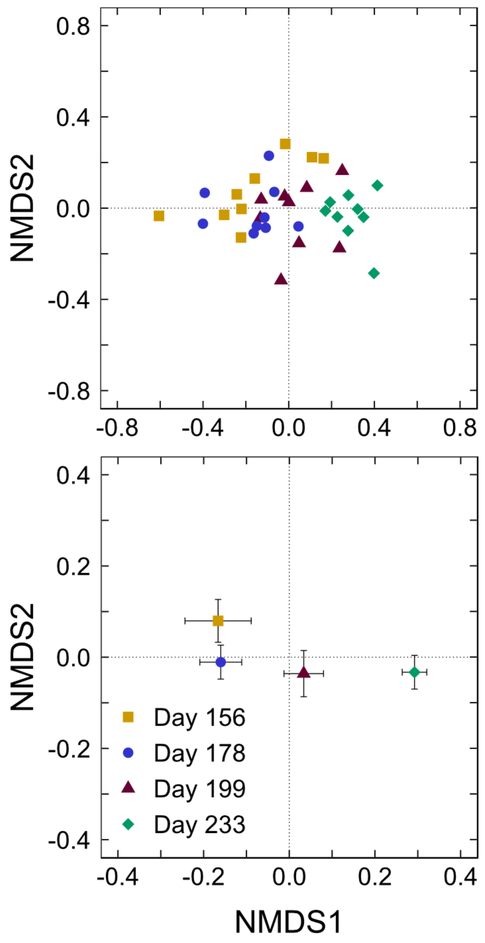
R_{10} is the measured rate at 10°C

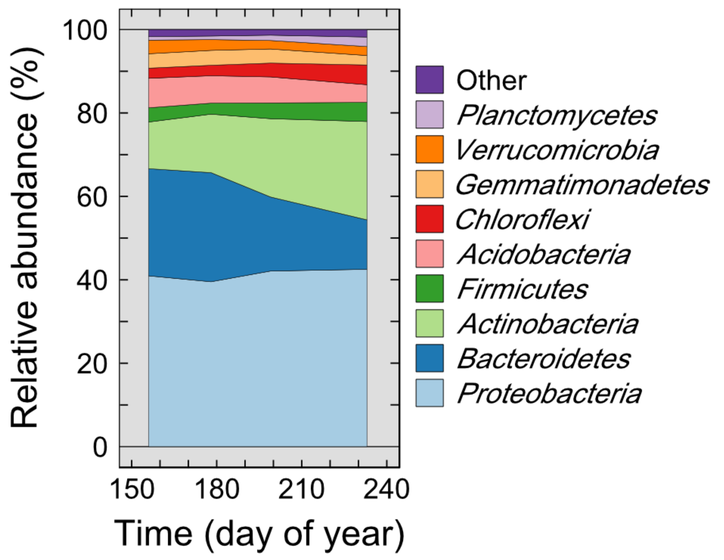
Q_{10} is the calculated temperature sensitivity coefficient

T is the measured temperature (°C) at a soil depth of 10 cm



Bacterial community composition

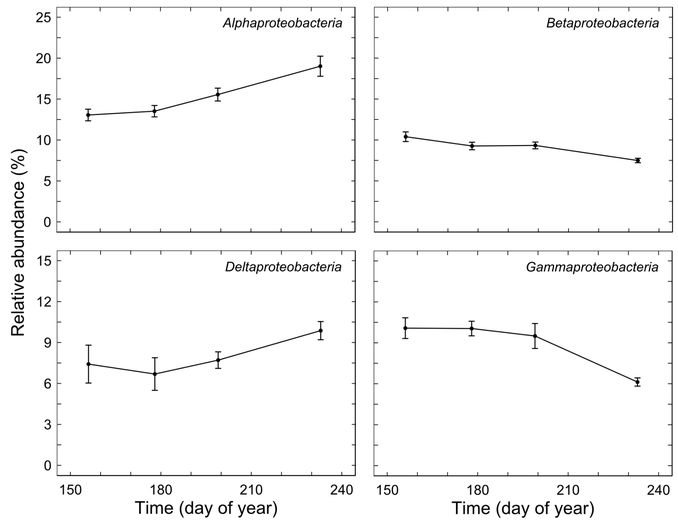




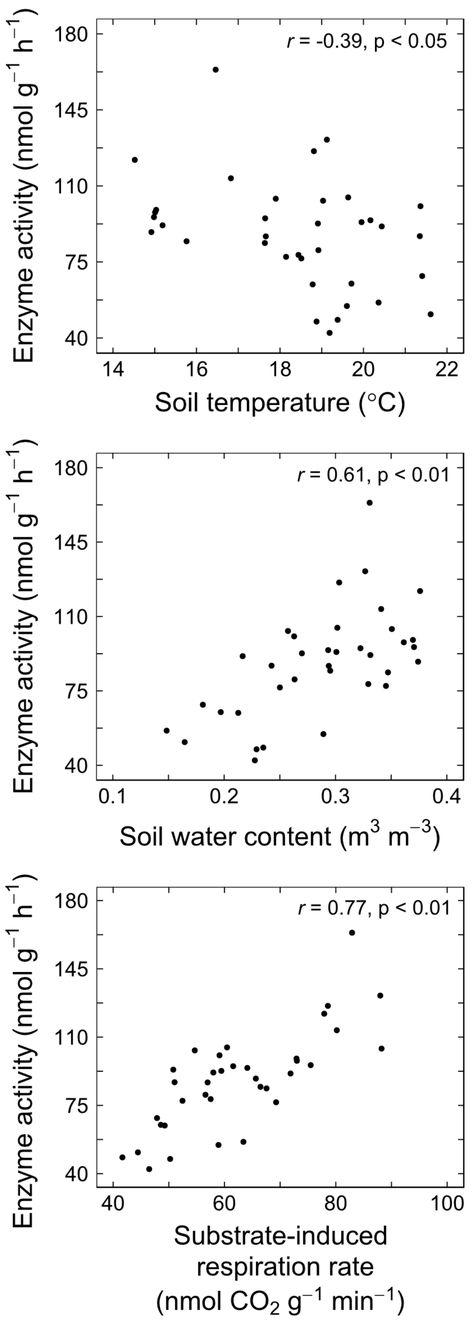
Shifts in Beta diversity (NMDS1) indicated a temporal shift in the species composition, which was also shown by seasonal changes in the abundances of major phyla, as well as the classes of the most abundant phylum, *Proteobacteria.*

Changes in the species composition of the soil bacterial community can lead to changes in extracellular enzyme activity and the decomposition of soil organic matter.

This could cause a shift in substrate availability and therefore affect soil respiration.



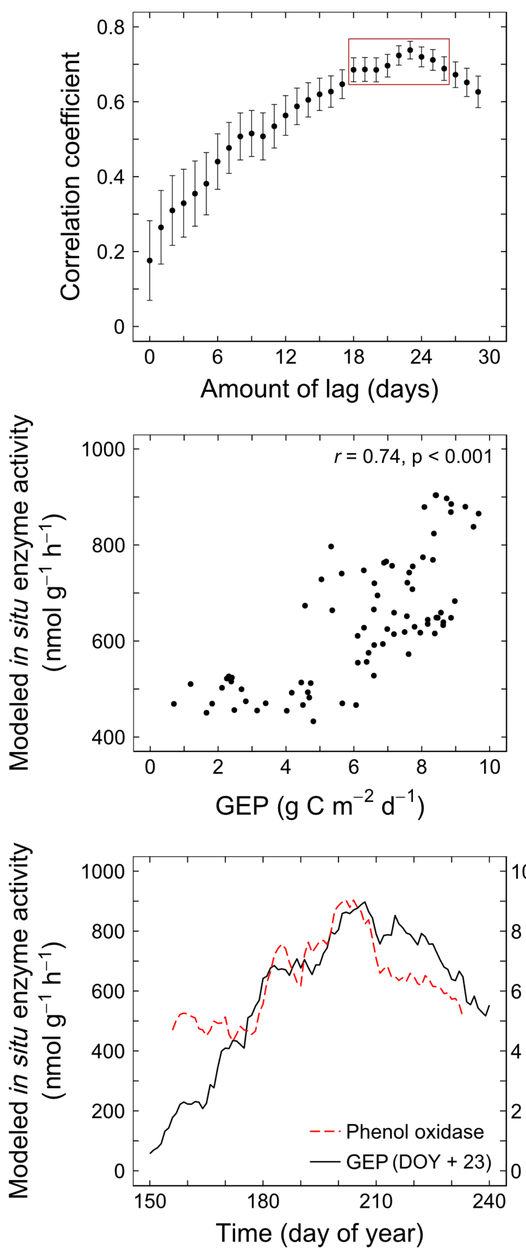
NAGase activity



Correlations used enzyme activity measured at 10°C.

NAGase activity was correlated with soil temperature and moisture, similar to substrate-induced respiration.

Phenol oxidase activity



GEP is a proxy for carbon input by root exudates , which stimulates microbial activity. Phenol oxidase activity is primed by C input and acts to release N from soil organic matter, which can further stimulate plant root and microbial activity and soil respiration.