Influence of permafrost degradation on foliar mineral element cycling upon changing subarctic tundra vegetation

Elisabeth MAUCLET[1], Yannick AGNAN[1], Catherine HIRST[1], Arthur MONHONVAL[1], Justin LEDMAN[2], Meghan TAYLOR[2], Edward A. G. SCHUUR[2], Sophie OPFERGELT[1]

1. Earth and Life Institute, Université catholique de Louvain, Louvain-la-Neuve, Belgium (elisabeth.mauclet@uclouvain.be, yannick.agnan@uclouvain.be, catherine.hirst@uclouvain.be, arthur.monhonval@uclouvain.be, sophie.opfergelt@uclouvain.be)
2. Center for Ecosystem Society and Science, Northern Arizona University, Flagstaff, AZ, USA (justin.ledman@gmail.com, meghan.taylor@yale.edu, ted.schuur@nau.edu)

Climate warming strongly affects the Arctic region by creating soil subsidence, increasing thaw depth and modifying water table depth. Thawing permafrost unlocks deeper soil mineral nutrients that may boost plant growth, and generates microtopography that may induce contrasted local soil moisture conditions. According to soil subsidence and drainage capacity, shift in vegetation through the Arctic and sub-Arctic region may vary, with sedges (as part of graminoids) expanding through wetter lowlands and shrubs expanding through drier uplands. Consequently, changes in the composition of Arctic tundra vegetation may influence local mineral element cycling through litter production, but this remains poorly constrained. In order to evaluate the influence of permafrost degradation on litter composition, we determined foliar mineral element stocks and annual litterfall fluxes from a typical Arctic tundra. We measured foliar elemental composition (Al, Ca, Fe, K, Mn, P, S, Si, and Zn) of leaf samples from 7 vascular species and 6 non-vascular species (mosses and lichens) from two contrasted Alaskan sites, i.e., under experimental (CiPEHR) and natural (Gradient) warming. We found that foliar composition is specific to the species and independent of the permafrost degradation. Therefore, the shift in the tundra vegetation related to climate change is expected to mostly influence the change in litter mineral element composition.

Upon sedge expansion, foliar mineral element stocks largely increased for elements highly concentrated into sedge leaves, such as Si (i.e., Si foliar stock increased ~4 times over 8 years of warming experiment and related sedge expansion). Upon shrub expansion, foliar mineral element stocks increased for elements highly concentrated into shrub leaves, such as Ca and Mn (i.e., Ca and Mn foliar stocks were ~1.5 times higher upon shrub- than sedgeland). As a cascade reaction, changes in foliar mineral element stocks related to the shift in vegetation led to changes in their annual litterfall fluxes, with an increase in Si annual foliar fluxes upon sedge annual litterfall, and an increase in Ca and Mn annual foliar flux upon shrub annual litterfall (Figure 1). Consequently, sedge and shrub expansion led to contrasted litter elemental composition, and thereby contrasted nutrient cycling, with implications for further vegetation succession across the Arctic tundra.

References

Schuur, E.A.G., Crummer, K.G., Vogel, J.G., Mack, M.C., 2007. Plant species composition and productivity following permafrost thaw and thermokarst in Alaskan tundra. Ecosystems 10, 280–292. https://doi.org/10.1007/s10021-007-9024-0

Schuur, E.A.G., Mack, M.C., 2018. Ecological response to permafrost thaw and consequences for local and global ecosystem services. Annu. Rev. Ecol. Evol. Syst. 49, 279–301. https://doi.org/10.1146/annurev-ecolsys-121415-032349

Figure: Changing element cycling upon shift in subarctic tundra vegetation from shrub to sedge upon permafrost degradation.