Title: *Global change effects on boreal forests: how will boreal ecosystems respond to climate warming?*

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Summary
This project will test whether boreal latitudes are undergoing tipping point transitions that restructure ecosystems due to warming and feedbacks between nutrient cycling and vegetation.

Project Background
Climate is changing most rapidly at high latitudes. This PhD will investigate the climate sensitivity of boreal ecosystems, addressing the question: How and on what timescales will boreal ecosystems respond to changing climate? The focus will be on resolving the complex feedbacks in plant-soil interactions, the role of fire, and how soil nutrient availability limits plant responses. A novel process model of carbon-nutrient interactions, including theorised plant optimisation for growth and allocation, will be combined with a range of experimental and observational data from high latitudes to address the key question.

Figure 1. Boreal ecosystems are dominated by evergreen and deciduous assemblages, linked to fire dynamics and permafrost distributions.

The NERC funded CYCLOPS project has generated comprehensive data from paired sites across thaw boundaries and fire boundaries in the Yukon and North West Territories of Canada. These data quantify the stocks of carbon and nitrogen in evergreen and deciduous ecosystems, in their trees, shrubs, mosses and soils, and the fluxes among these ecosystem components.
However, adaptation of ecosystem processes and structures to alterations in climate and resource limitations, and to disturbances such as fire, is not well understood. We lack basic understanding of key sensitivities and trade-offs, particularly in how vegetation adjusts carbon/nitrogen (C/N) allocation, and thereby structure and function, when relative C/N resource limitations shift. In this regard, we have developed a relatively simple, but complete, dynamic model of ecosystem carbon-nitrogen interactions (ACONITE). The model builds on and links theory related to plant economy and optimisation. Hence, plant investment decisions are based on marginal returns on C and N investment.

Key Research Question
In this thesis, CYCLOPS data will be analysed and synthesised using ecosystem modelling of carbon and nitrogen cycles through ACONITE to address the overarching question: What is the sensitivity and evolving response of nitrogen cycling to climate change and to fire disturbance? The modelling analysis will make use of data assimilation methods that optimally combine simulations with observations, and allow for regional analyses by making use of satellite data on fire burned areas, biomass distribution, leaf trait maps, and canopy phenology.

Methodology

Using abundant data collected from the CYCLOPS project and other boreal studies, the student will calibrate and evaluate the ACONITE model. The student will investigate, and attempt to explain, observed patterns of ecosystem structure, and test theories of N limitation across boreal landscapes with varying fertility. After appropriate training, the critical steps will involve:

(i) Accumulating key data. Working with international and national collaborators, the student will first draw together key datasets for the test sites in Alaska, Canada and Sweden, including climate data, biogeochemical data, plant trait data. Key data gaps will be identified, and filled, with limited field campaigns if necessary (year 1).

(ii) Initial model calibration and evaluation. The model will be applied across a range of test sites developed in (i), and model mismatches identified (year 1).

(iii) Exploration of boreal steady state conditions. Using a single parameterisation of the model, is it possible to explain observed patterns on the basis of climate forcing (year 2)?

(iv). Modelling the transient response of boreal forests to warming and fire. Experiments undertaken over multiple years provide information on biogeochemical responses of boreal ecosystems to perturbation (Figure 2). Can the model resolve the timing of vegetation response to disturbance? What alterations to model structure and/or parameters are required to match observed response patterns (year 3)?

A series of scientific papers will result from these activities and form the basis of the thesis.

Figure 2. A fire in the Yukon 15 years before this picture was taken shows the long term and significant effects on ecosystem structure.

Training and Facilities

A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The student will receive advanced training in ecosystem biogeochemistry, simulation modelling, statistics for model evaluation, and model optimisation approaches. The studentship is linked to CYCLOPS, a NERC funded project with UK and international partners, investigating carbon cycle linkages with permafrost processes. The student is likely to undertake some field work, to collect ancillary data for model evaluation and calibration. Williams' group of post-doctoral researchers and PhD students provide a supporting environment for model-data fusion activities linked to global change ecology.

Requirements

A background in ecological and/or environmental science, or related biological discipline is favoured, but transfers from physical sciences are possible. Strong quantitative skills are vital, and experience or interest in simulation modelling would be helpful.