Carbon storage in boreal forests

Professors Alison Munson and **Sylvie Quideau**, along with a team of talented students, seek a better understanding of how fire severity affects the production of black carbon and orientates tree regeneration and succession

PROFESSORS ALISON MUNSON AND SYLVIE QUIDEAU

To contextualise your research, could you begin by explaining your reasons for joining forces on this project? What expertise do you bring to this work?

SQ: The collaboration began over supper in Asilomar, California, at a meeting on the stabilisation and destabilisation of soil organic matter, with discussions on the gaps in understanding of mechanisms of carbon stabilisation in soils. One of the processes identified as least well understood was fire, the production of so-called black carbon and its subsequent interaction and storage in soils. Does it degrade, does it not? If not, why not?

AM: I have been working in fire-dominated black spruce ecosystems throughout my 25 year career, while Sylvie brought expertise on soil chemistry and the capacity to apply new methods, including Nuclear Magnetic Resonance spectrometry, that help us understand in much greater detail the structure and reactions of material such as black carbon. I knew where, how and with which partners to effectively set up the experiment. We had three exceptional fire years, both in terms of an early season of burn and of the area burnt, so our timing was almost perfect to track vegetation succession and the fate of black carbon after wildfire.

What were the founding objectives of this project and their relevance to Canadian science and society?

SQ & AM: Our overall objective is to measure and model carbon storage in black spruce forests under various fire regimes, particularly varying severity. Our specific objectives are to evaluate the amount and the fate of charcoal in the soil profile according to variable fire severity and to evaluate the stability of charcoal mixed with mineral soil. We also aim to understand how fire severity interacts with environmental factors such as local climate, soil, exposition, etc. to control the regeneration of black spruce, jack pine and understory vegetation species. Finally we will use this soil and vegetation information to model the dynamics of ecosystem carbon storage at the landscape level, under different scenarios of fire regime or climate.

Black carbon in Quebec boreal spruce forests

A new study, based at **Université Laval** is creating predictive models to understand how a changing climate might affect the functioning of boreal forest ecosystems for which Quebec is famed

BOREAL FORESTS PRESENT a fascinating area for ecological and environmental study, playing an important role in both global water and nutrient cycles. Their total carbon stocks are estimated at around 470 gigatonnes, and the soil beneath them accounts for around 17 per cent of terrestrial carbon stores. Canada is charged with the task of protecting and managing a fifth of global boreal forests, an area which constitutes over half of its commercial forest and over a quarter of its terrestrial surface. Given these staggering statistics, it is no wonder that scientists desire a more detailed understanding of the processes and mechanisms that underpin the forests' function. A new study based at the Université Laval in Canada, and led by Professors Alison Munson and Sylvie Quideau, is seeking a better comprehension of the impact of variable fire regime on carbon storage in black spruce forests, in order to reveal the enigmatic nature of this dynamic system.

A COLLABORATIVE EFFORT

Central to the project has been a commitment to collaboration and an ethos that fosters opportunities for both under- and postgraduate students. One example is the research undertaken by Rod Wasylishen, holder of a Canada Research Chair in Physical Chemistry and the team's chief chemist, who works extensively on the interpretation of Nuclear Magnetic Resonance spectrometry (NMR) analyses of various forms of black carbon. As part of this process, Wasylishen has worked both with Quideau and PhD student Laure Soucemarianadin. Further collaboration from Steve Cumming, who holds a Canada Research Chair in Modelling Boreal Ecosystems, and Florent Mouillot, at IRD in France, has been crucial to the integration of results into models of fire disturbance, forest dynamics and carbon storage. Their mentoring is essential to train PhD students Yosune Miquelajauregui and Juliette Boiffin as researchers in a field which has a distinct lack of highly-trained students.

THE RESULTS SO FAR

Already, Munson, Quideau and their team have produced some exciting results, with several transcripts currently under review for scientific publication. Most notably, the study – which was timed shortly after three consecutive fire years – recorded unexpectedly low tree regeneration. Quebec's boreal black spruce is particularly unique due to the variable and often incomplete combustion of deep forest floor layers during fire. As the heat intensifies, black carbon experiences chemical and physical changes, increasing its surface area and its ability to adsorb nutrients and tannins (the latter can restrict the potential for tree growth) concurrently. Munson reveals: "Our results

How is charcoal typically stored in the soil profile? What influences its attenuation?

SQ & AM: Charcoal can be stored either within the surface organic layers or in the mineral horizons. In Quebec boreal black spruce ecosystems (podzols), there is a characteristic subsoil accumulation of iron and aluminium oxides often associated with organic carbon (B horizon). In contrast to drier Siberian Scots pine forests, our results indicate that the majority may be stored in the lower part of the forest floor. In Quebec, the much thicker organic layers are only partially consumed. In mineral horizons of podzols from Quebec, black carbon is concentrated in the B horizons although results do not show any preferential association with oxides.

Why are contributions from industry so valuable?

SQ & AM: Collaboration with industry and government ensures new knowledge is taken up more rapidly and efficiently. It is also an excellent context for training graduate students, demonstrating to them how their projects have a direct application and how the context of the partners could be interesting for future employment. We also learn a great deal of local ecology from discussions with partners.

Additionally, most scientists like to think that their advances in knowledge have a positive impact on practices; in our case, this might be a change in norms or regulations, or a recommendation to change a forest harvest or silvicultural practice to ensure long-term ecosystem integrity.

How will this research benefit land managers and Earth scientists in the future? What challenges lie ahead?

SQ & AM: Our research will contribute to the current reflection on how we manage the forest land base in the context of a changing climate. This is a highly complex situation with huge uncertainties, so any information benefitting this reflection is important. We are trying to understand processes at the stand level and scale these up to the landscape level to understand potential responses in terms of carbon storage. For example, how might an operation like recovering wood after fire have an effect on either vegetation succession or carbon storage in the soil? Large changes at the landscape level can subsequently feedback to climate, for example by changes in albedo of surfaces, or changes in stabilisation or destabilisation of carbon over large territories.

> The research group combines fire disturbance, vegetation succession and biogeochemical variables into one comprehensive model that can predict the changes in carbon storage

support what several scientists have noted recently – that response to unusual or extreme climate events may be more important than the gradual change in climate conditions. This type of study can give us important information about the potential resilience of ecosystems under climate change".

The research group aims to complete their project by using results gathered in modelling exercises at the landscape level, combining fire disturbance, vegetation succession and biogeochemical variables into one comprehensive model that can predict the changes in carbon storage which will result from the shift in vegetation type following fires of various severities. Munson explains the reason for this inclusive method: "We have some new and surprising results from the field, but we need to be able to incorporate these into projections to better understand where we might be going in 100 years, or even 600 years or more".

A FEAT OF LOGISTICS

Besides the complex and little-understood processes, overcoming the sheer practicalities of such a study has been no small achievement. Munson recalls: "One summer alone, the students drove 25,000 km to firstly find, and then take inventory of, all of the sites. On one visit to the field, we were close to a large active fire and woke up with a layer of ash on the vehicles; we even considered evacuation from the field". Munson has been impressed by the work ethic and cooperation of the students (of which three are international) for whom the ecosystem was entirely new. One student, Sylvain Pelletier-Bergeron, was hired by the Ministère des Ressources Naturelles before his MSc was even completed. Munson is confident that both the study itself, and the students who have worked on it, will go on to make a significant contribution to the field and that the results will help us to reconsider the contribution of forest fires to global carbon stocks.

INTELLIGENCE

MEASURING AND MODELLING CARBON STORAGE IN QUEBEC BOREAL BLACK SPRUCE ECOSYSTEMS UNDER VARYING FIRE REGIMES

OBJECTIVES

- To examine the relationship between fire severity and the quantity and quality of charcoal produced and to investigate the fate of this charcoal in the soil profile
- To evaluate fire severity effects on early response of the understory (mosses, herbs and shrubs) and on tree regeneration and identify abiotic factors that may interact with severity to control plant succession, productivity (biomass) and therefore carbon storage
- To integrate data to refine models of carbon dynamics in boreal black spruce forests and to model future scenarios of carbon storage under a changing fire regime

KEY COLLABORATORS

Robert Bradley, Université de Sherbrooke • **Michel Campagna**, Ministry of Natural Resources, Quebec • **Steve Cumming**, Université Laval • **François Dumoulin**; **Denis Villeneuve**, Produits Forestiers Résolu • **Sylvie Gauthier**; **David Paré**; **Vincent Roy**, Natural Resources Canada • **Sylvie Quideau**; **Derek MacKenzie**; **Rod Wasylishen**, University of Alberta, Canada • **Florent Mouillot**, Institut de recherche pour le développement, France

FUNDING

Natural Sciences and Engineering Council of Canada

CONTACT

Professor Alison Munson
Department of Wood and Forest Sciences

Faculty of Forestry, Geography and Geomatics
2405, rue de la Terrasse
Pavillon Abitibi-Price, office 3165
Université Laval
Québec G1V 0A6
Canada

T +1 418 656 2131 x 7669
E alison.munson@sbf.ulaval.ca

ALISON MUNSON focuses on the biogeochemistry of forest ecosystems, with an emphasis on carbon and nitrogen cycling and the links between these two cycles. She also studies feedback of plant functional traits on nutrient cycles.

SYLVIE QUIDEAU focuses on soil carbon fluxes and organic matter processes. She studies soil organic matter chemistry and biodiversity in Canadian boreal forests; the influence of environmental factors on carbon distribution and composition in soils; and organic matter quality in reconstructed soils from oil sands in Northern Alberta.