Climate impacts of greenhouse gas emissions in forested landscape of southern Ontario

Summary of Proposed Research Activities

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INTRODUCTION

Temperate forest ecosystems in eastern United States and Canada, and in particular the Great Lakes region are a large sink of carbon. These forests are well-suited to hotter and dry summers, since they sequester much of their carbon in the early growing season. However, our research work at Turkey Point conifer forests suggests that the simultaneous occurrence of spring/early summer drought events along with heat waves may considerably impact the net ecosystem productivity of these forests, through the reduction in photosynthesis. We do not fully understand the response of these forests to climate variability and extreme weather events.

The proposed research will create "Turkey Point Integrated Flux Station (TIFS)" to explore greenhouse gas (H2O, CO2, CH4) exchanges in deciduous (upland Oak) and conifer (White Pine) forests growing in close proximity to each other in southern Ontario. It will establish the first Upland Oak Forest site in Canada at the St. Williams Conservation Reserve, Norfolk County, Ontario.

Ecosystem responses to seasonal climate variations (e.g., droughts and heat waves) and their timing as well as associated phenological changes may vary among deciduous and coniferous forests. Therefore, a careful examination of drought and warming effects and ecophysiological feedbacks in both deciduous and conifer forests, growing in same climatic and geographic region are needed, before drawing generalized conclusions for a region. Establishment of proposed deciduous forest site would provide this opportunity.

OBJECTIVES

(i) to make continuous measurements of energy, water, carbon and methane fluxes, and other meteorological variables over a deciduous (Upland Oak) forest and two coniferous (White Pine) stands in southern Ontario.

(ii) to determine the effects of seasonal and inter-annual climate variability and extreme weather events on net ecosystem productivity (NEP) of these forests and to determine their carbon sequestration potential.

(iii) to determine vegetation composition/diversity and plant and soil nutrient status to evaluate their impact carbon cycling and growth, health, adoptability and conservation of these forests to future climate change.

(iv) to improve process-based photosynthesis and respiration sub-models of Canadian Land Surface Scheme (CLASS) and the Canadian Terrestrial Ecosystem Model (CTEM) by validating them with data from deciduous and coniferous forests.

(v) to provide a comprehensive data set to develop the next-generation ecosystem models and use them with future climate projections to determine impacts of climate change on forest ecosystem structure and function, and help to formulate Canadian climate change policies.

SPECIFIC RESEARCH ACTIVITIES

(A) FIELD MEASUREMENTS

A1. Eddy covariance fluxes and meteorological variables:

Year-round continuous measurement of energy, H2O, CO2, and CH4 will be made at both flux stations (conifer and deciduous forests) using eddy covariance (EC) systems over the next five years. We will maintain our existing closed-path eddy covariance system at the conifer flux station, comprising 70- and 35-year old white pine (conifer) stands in continuous operation over the next five years. These closed-path eddy covariance systems consist of a CSAT3 sonic anemometer and a LI-7000/Li-6262 gas analyzer that are housed in climate-controlled boxes at the top of scaffolding towers. The data logging set-up, including a computer, are housed in a trailer or hut at the base of the towers.

At the proposed deciduous forest site, a closed-path EDDY COVARIANCE SYSTEM would be installed at a mature Upland Oak forest at St. Williams. This eddy covariance system will include a CSAT3 sonic anemometer and a LI-7200 (CO_2 and H_2O) and Li-7700 (CH_4) gas analyzers. The site will also have an AUTOMATIC WEATHER STATION, a SOIL CO2 EFFLUX CHAMBER SYSTEM and a SAPFLOW SYSTEM. A WALK-UP SCAFFOLDING TOWER will be used to install sensors. Systems computer and calibration set-up will be housed in a TRAILER equipped with A/C POWER and PHONE LINE. All eddy covariance flux systems and weather stations will be continuously operated to capture annual cycles of energy water and carbon at all both flux stations.

A2. Ecological measurements:

Major canopy structural parameters, including the effective LAI, elemental clumping index, needle-to-shoot area ratio, and woody-to-total area ratio all three flux stations will be measured. Downward and upward photosynthetically active radiation (PAR) will also be measured at all sites.

A3. Vegetation composition/diversity and plant and soil nutrient studies:

Under rising atmospheric CO_2 concentrations, limited nutrient availability in the soil in forest ecosystems (e.g., nitrogen, phosphorous, sulphur, etc.) may down-regulate their photosynthetic activity. Furthermore, changes in plant nutrient composition affect litter quality and litter decomposition rates, which will consequently affect the forest growth and ecosystem carbon cycling. Under this initiative, plant species composition and diversity as well as canopy and soil nitrogen and other nutrients (e.g., phosphorous, sulphur, etc.) will be measured and analyzed and their relationship with carbon cycling will be determined at field sites. Canopy and soil samples will be taken from permanent inventory plots (NFI plots) established at all sites. ***A better understanding of interaction between H_2O, CO_2 and CH_4 fluxes and soil nutrient limitations will be crucial to estimate and predict future growth, health, adoptability and conservation of these forest ecosystems.***

A4. Data management and Products:

A central data archive will be established at McMaster University. Raw meteorological and flux data will be analyzed, archived and eventually distributed to the broader scientific community after adopting a data distribution policy. This data set will also be made available on Environment Canada Data Information System (DIS) of Canadian Carbon Program and global Fluxnet data archives.

(B) MODEL DEVELOPMENT WORK

I have incorporated photosynthesis, canopy conductance, and respiration models in the Canadian Land Surface Scheme (CLASS), and plant and soil nitrogen algorithms in the Canadian Terrestrial Ecosystem Model (CTEM), which is a dynamic vegetation model developed at the Canadian Centre for Climate Modeling and Analysis (CCCMa). Both CLASS and CTEM are used in the Canadian global and regional climate models. CTEM includes most of the terrestrial ecosystem processes including photosynthesis, plant and soil respiration, plant phenology, allocation, biomass turnover, litterfall, mortality, fire and competition between plant functional types. Incorporating the nitrogen cycle allows evaluating key climate-vegetation feedbacks. CTEM nitrogen cycle algorithms include biological fixation, soil mineralization, immobilization, nitrification, denitrification, volatilization, leaching, root nitrogen uptake and allocation in plants.

The proposed infrastructure will provide necessary flux and meteorological data to test both CTEM-N+ and CN-CLASS models over conifer and deciduous forests. It will also provide necessary data to develop essential up-scaling algorithms to assess the regional carbon sequestration potential of afforestation. Coupling of CTEM-N+ with the Canadian General Circulation Model (CGCM) will provide an assessment tool to generate scenarios of future climate for policy development and help Canada meet its international obligations.

BENEFITS

The proposed research focuses on fully understanding greenhouse gas exchanges in plantation or afforested forests growing in agricultural landscape. ***Plantation forests or afforestation provides many additional benefits in the form of wildlife and plant species protection, sustained water use, soil erosion protection, improved air and water quality and recreational activities.*** Thus, the disturbance and degradation of forest ecosystem services have important economic and environmental health implications. Information about the carbon sequestration potential of plantation forests or afforestation and afforestation's above mentioned additional benefits will help Canadian and international policy makers to plan and develop realistic strategies to establish and conserve forests ecosystem, not only to offset fossil fuel CO2 emissions but also to improve our environmental quality and health. It will also help to conserve these forests and enhance their biodiversity.

The expected outcome of the proposed research is a more advanced understanding of the potential carbon sink and source strengths of managed forest ecosystems in eastern Canada and an assessment of their vulnerability to future climate change. ***This research will also enhance our knowledge about conservation, sustainability, biodiversity, health and the economic benefits of forests, particularly the planted and managed forests in agricultural landscapes. It will help to manage these forests as planned under St. Williams Conservation Reserve Management Plan.*** This work will assist Canada in meeting its goal of reducing carbon emissions and will help to inform Canadian policy-makers on climate change mitigation and adaptation.