FP Project Description

Return to Full Proposal #: Y092200

Title: Assessing ecosystem vulnerability to climate change from the tree- to stand- to landscape-level

Project Description: Achieving sustainable forest management (SFM) has many requirements, which differ from region to region, however one common aspect is the assumption of environmental stasis. This is an illogical assumption since changes in the environment have always occurred and will continue to do so in the future. Currently, projected changes in climate include increasing temperatures, changes in precipitation, and increased frequency and intensity of extreme climatic events. These changes will influence ecosystems directly and indirectly via changes in the frequency and intensity of fires, pests and diseases [1]. Ambiguity in predicted changes along with the conventional management philosophy has created a situation where resource managers often simply ignore climate change. However, the recent linking of the mountain pine beetle epidemic and the dothistroma outbreak in northwest BC to climate change [2, 3] and the predicted increases in fire season length and severity [4] has made climate change an increasingly salient issue with forest managers.

Climate change is a stressor that will directly or indirectly influence the processes that impact ecosystems. Ecosystems are the basic units of nature on earth and are created from the interaction between the biotic and abiotic components of its environment [5]. Changes in any biophysical component can alter the stable dynamic equilibrium that exists between biotic and abiotic components leading to creation of new ecosystems [5]. Ecosystems provide the foundations for SFM, any process that results in a restructuring of controlling variables and processes will destroy or weaken the foundation from which current ecological services are provided. A restructuring of controlling variables and processes can shift an ecosystem to a new stable state [6]. The ability of an ecosystem to recover from disturbances and persist under changes in climate is referred to as ecological resilience [7]. Management actions that maintain or expand the resilience of an ecosystem to shifts in climate are required if ecosystem functionality is to be sustained. To determine how to maintain ecosystem resilience an understanding of ecosystem vulnerabilities is required. Gaining this understanding is an important step if we are to determine where and what adaptation strategies are to be incorporated into long-term forest planning and to providing guidance on how to manage for the risks associated with climatic change. The ability to achieve a sustainable forest industry will rely on our understanding of ecosystem vulnerability to climate change.

Gaining an understanding of how climate change may influence ecosystem resilience is also an essential foundation for determining how climate change will influence forest health and condition and growth and yield from the stand to the landscape-level. We propose to address this important principle by: (1) applying a tree and climate assessment model, TACA [8], to assess species and ecosystem resilience to climate change in the Sub Boreal Spruce zone near Smithers, BC; (2) apply TACA to assess how climate change will impact a site's moisture regime (site type); (3) link the results of TACA to a stand-level forest dynamics model, SORTIE-ND, to predict how changes in site type and species resilience will affect stand-level competition, development and growth and yield under climate change; and, (4) use the results from TACA and SORTIE-ND to investigate the impact of climate change and disturbances (e.g. mountain pine beetle, dothistroma fungus, root rot fungus and fire) at the landscape-level.

References:

[1]: Gitay, H., et al. 2002. Climate Change and Biodiversity. Intergovernmental Panel on Climate Change Technical Paper V.

[2]: Carroll, A.L., et al. 2004. Effects of climate change on range expansion by the mountain pine beetle in British Columbia. Pp 223-232, In: T.L. Shore, et al. (Eds.); Mountain Pine Beetle Symposium: Challenges and Solutions. Natural Resources Canada Information Report BC-X-399.

[3]: Woods, A., et al. 2005. Is an unprecedented Dothistroma needle blight epidemic related to climate change? Bioscience 55: 761-769.

[4]: Flannigan, M., et al. 2003. Fire regimes and climatic change in Canadian forests. In: Fire and Climatic Change in Temperate Ecosystems of the Western Americas. Ecological Studies 160, Springer.

[5]: Tansley, A.G. 1935. The use and abuse of vegetational concepts and terms. Ecology 16: 284-307.

[6]: Gunderson, L.H., et al. 2002. Resilience of large-scale resource systems. In: SCOPE 60: Resilience and Behaviour of Large-Scale Systems. Island Press, Washington, USA.

[7]: Holling, C.S. 1996. Engineering resilience versus ecological resilience. In: Engineering with Ecological Constraints. National Academy Press, USA.

[8]: Nitschke, C.R. 2006. Integrating Climate Change into Forest Planning: A Spatial and Temporal Analysis of Landscape Vulnerability. PhD dissertation, University of British Columbia, Canada.

FP Project Objectives

Return to Full Proposal #: Y092200

Title: Assessing ecosystem vulnerability to climate change from the tree- to stand- to landscape-level

Project Objective: Long-term Objectives:
(1)To gain an understanding of the impacts climate change will have on ecological resilience and stand dynamics in the Sub Boreal Spruce (SBS) zone;
(2)To further develop TACA and expand the use of SORTIE-ND; and,
(3)To develop a meta-model framework that allows for a cost-effective and reliable method for evaluating stand and landscape vulnerability to climate change that can be used in other parts of British Columbia and elsewhere.

Current Year Objectives (2008-2009):
(1) To complete development of SORTIE-ND dataset from TACA results;
(2) Develop regeneration potential sub-model in SORTIE-ND;
(3) Model stand dynamics and succession under current climate scenario and validate SORTIE-ND-TACA link to established research plots;
(4)Model the impact of species competition on the vulnerability of species and ecosystems to predicted climate change under various stand modifying treatments;
(5) Compare species vulnerability in their regeneration niche, fundamental niche and realised niche;
(6) To determine the impact of species vulnerability to climate change, from the species to stand-level, on future growth and yield;
(7) Using GIS, scale stand-level response up to the landscape-level to determine ecosystem vulnerability; and,
(7) To start developing a data library of SORTIE-ND-TACA scenarios in GIS to model the landscape-level response of ecosystems to climate-driven changes in disturbance regimes (Objective for 2009-2010).

FP Experimental Design and Methods

Return to Full Proposal #: Y092200

Title: Assessing ecosystem vulnerability to climate change from the tree- to stand- to landscape-level

Experimental Design and Methods: We will use meta-modelling to investigate the potential impact climate change will have on forest ecosystems. Meta-modelling incorporates the strengths of many smaller models into a framework where the outputs of one model become the inputs of another (Luxmoore et al. 2002). A meta-modelling approach is a recommended methodology for assessing community change in response to climatic change and disturbances (Beissinger & Westphal 1998). A meta-model methodology will be used in conjunction with assessments of current and future vulnerabilities to climate change. Vulnerability assessments are recommended as the best method for assessing potential climate change impacts (IPCC 1998; Lemmen & Warren 2004).

A conceptual meta-model framework is presented in Figure 1. The proposed framework will be developed and used to assess the vulnerability of the study area to climate change. The meta-model framework allow for the assessment of climate change vulnerability at both the stand- and landscape-level.

The driving models that will assess climate change vulnerability are TACA and SORTIE-ND. TACA is an individual tree response model that was developed for evaluating the vulnerability of tree species to climatic change within a species fundamental-regeneration niche (Nitschke 2006; Nitschke & Innes in press). The TACA model uses the predicted changes in growing degree days, chilling weeks, bud burst date, frost damage, and a change in water balance (drought stress) on/ across sites to predict tree and ecosystem response. To model stand-level dynamics, we will use the spatial-explicit individual tree growth model SORTIE-ND (www.sortie-nd.org) (Pacala et al. 1996), which over the past 10 years has been significantly developed (e.g. Coates et al. 2004), parameterized (e.g. Wright et al. 1998, Kobe and Coates, Canham et al. 2004, Astrup & Coates in reveiw), and validated (Astrup 2006) as a growth model for northern BC. In SORTIE-ND, individual tree growth and mortality is dependent on competition for both light availability and below-ground resources (represented through a distance-dependent competition index). Our ongoing research, FIA-FSP project Y07-1254, investigates how competition changes across a nutrient and moisture gradient. The integration of this information into SORTIE-ND makes it possible to model changes in competition under climate change scenarios based on actual data rather than assumptions as is generally the case. TACA predicts changes in: (1) regeneration dynamics and (2) site conditions. The changes in regeneration dynamics will be used to drive the regeneration sub-model of SORTIE-ND under climate change. The changes in site conditions will be used as input into SORTIE-ND and will results in changed growth rates and competitive interactions.

To model natural disturbances three models will be used. Two existing models will be used and one will be developed. To model fire, the fire-spread model Prometheus (CWFGM Steering Committee 2003) will be used; for bark beetles, the Canadian Forest Service Mountain Pine Beetle Risk Rating System (CFS MPB RRS) (Shore & Safranyik 1992) will be utilised. The third model will be a Dothistroma Risk Rating System that will be developed as part of this study. The measured variables will include the change in area at risk to all disturbances and for fires the change in mean fire size, maximum fire size and fire frequency. The results of all analysed variables will be statistically analysed and where changes are detected climatic thresholds will be identified.

The modelling of climate will use local climate data and global climate change model (GCM) predictions. At least three different GCM's will be used, including the CGCM2 and HADCM3 models. Local climate data will be represented by local weather station records and by climate data provided by the ClimateBC model developed by Wang et al. (2006). ArcGIS 9.0 will be used this particular framework to integrate the results of each modelling component/analysis into the same spatial information system from which landscape vulnerability can be measured.

Replication will be achieved through multiple scenario analysis. Multiple scenarios of current and future climates will be used to test the range of potential behaviour of natural disturbances and ecosystem response. The incorporation of multiple scenario analyses into a strategic decision-making process has been effectively used by decision makers to address problems with increased uncertainty, interdependence and complexity (Schoemaker 1993). Statistical analysis of modelling results will be used to determine if differences exist between the response of measured variables under current scenarios and future climate change scenarios. Two-sample Student's t-test and Analysis of Variance (ANOVA) will be performed to test for differences in variable responses (Sokal & Rohlf 1995; Tabachnick & Fidell 2001). To provide support to the t-test and ANOVA results, confidence intervals will be calculated to provide both an estimate of the effect and a measure of uncertainty. It is the estimates of the magnitudes of effect with associated errors that are important in these types of studies rather than the statistical significance of a test (Johnson 1999).

The study will utilise models that have been developed and utilised in other studies. The models have all been subjected to peer-review and have their own standards and limitations. The meta-model approach for assessing ecosystem vulnerability to climate change has recently been tested by Nitschke (2006) for a 145, 000 ha landscape in south-central BC. The integration of SORTIE-ND into this established protocol will expand the analytical ability of this framework and increase our understanding of ecosystem response to climate change.