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Adaptive Silviculture for Climate Change

An Experimental Installation at the Petawawa Research Forest

PROJECT NUMBER: 301013655/301013553

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Table of Contents

List of Figures

List of Tables

INTRODUCTION

Climate change is anticipated to have significant impacts on Canadian forests. There is currently a need for more information on what these impacts will be and how management intervention can influence, guide and mitigate these impacts. Empirical studies in Canadian forests, demonstrating adaptive forest management interventions, would be especially helpful.

To address this need, the Canadian Wood Fibre Centre (CWFC), Natural Resources Canada (NRcan)[1] has started the process of developing a large adaptive silviculture research study at the Petawawa Research Forest (PRF) in Chalk River, Ontario. This study, called the Adaptive Silviculture for Climate Change (ASCC) project, is led by Natural Resources Canada: Trevor Jones (Research Scientist), Michael Hoepting (Silviculture Research Forester), Jeff Fera (Forest Innovation Research Officer) and Melissa Vekeman (Petawawa Research Forest (PRF) Operations Manager). See Table 2 for contact information for the study leaders. It will become part of the larger ASCC Network of study sites and the first ASCC research site outside of the United States.

As a kickoff of this effort, NRCan hosted a three-day collaborative workshop in Pembroke, Ontario, from July 16 to 18, 2019, called the *Adaptive Silviculture for Climate Change Workshop – Great Lakes St. Lawrence Forest* (Figure 1). The workshop was coordinated, promoted and financially supported by the Canadian Institute of Forestry, the Canadian Institute of Forestry Algonquin Section, the Friends of the Petawawa Research Forest and FPInnovations.

The ASCC Network, Colorado State University and the Northern Institute of Applied Climate Science (NIACS) facilitated the workshop and provided the intellectual contextualization of the ASCC Network site development and experimental design.

Figure 1. Jeff Fera and Micheal Hopeting of NRCan introduce the workshop and the Petawawa Research Forest. (Photo: Courtney Peterson)

[1] The Canadian Wood Fibre Centre (CWFC) is a centre within the Canadian Forest Service (CFS), and the CFS is a sector of Natural Resources Canada (NRCan). NRCan is used to denote the CWFC and CFS throughout the rest of the document, except in direct citations from other sources.

The primary goals of the workshop were to:

(1) Engage local and regional forestry professionals in a climate adaptation training and workshop session, and
(2) To initiate the development of a new adaptive silviculture research study at the Petawawa Research Forest in Chalk River, Ont.

The workshop was facilitated by forestry and climate change specialists from Colorado State University, the Northern Institute of Applied Climate Science (NIACS) and NRCan. Those from the United States were the project leads and principal investigators of the existing ASSC Network. The ASCC Network leads (Figure 2) provided much of the structure of the workshop proceedings based on an engagement model they use when providing training and development of new ASCC Network study sites (Nagel et al. 2017).

Figure 2. Linda Nagel (left) and Coutney Peterson (centre) both of Colorado State University and Maria Janowiak (right) of the Northern Institute of Applied Climate Science and USDA Forest Service.
(Photo: Courtney Peterson)

The three-day workshop was divided into two parts. The first day, July 16, 2019, was designed as a knowledge exchange session on climate change impacts for local forest conditions and adaptation options. Including presenters and facilitators, this session was attended by 37 individuals representing academia, industry, community forest managers, research organizations and federal and provincial researchers. The second part was held on July 17th and 18th, and the attendees (21) were a smaller subset of the first group. Over the two days participants developed a draft plan and designed the silvicultural treatments for the ASCC study at the PRF.

This document provides a summary of the workshop proceedings and its outcomes including an overview of the draft plan for the new ASCC research study site at PRF. It will be useful for understanding the development process for the new research installation and for other organizations who wish to collaborate on this project.

PRIMARY PROJECT PARTNERS

Canadian Wood Fibre Centre

The following description of the Canadian Wood Fibre Centre is from Natural Resources Canada (2019a):

"The Canadian Wood Fibre Centre (CWFC) is part of the Canadian Forest Service (CFS), [Natural Resources Canada] with employees located across the country. Part of the CWFC's mandate is to work closely with FPInnovations and other stakeholders in the development and uptake of end-user relevant wood fibre research.

Linking the three organizations – CWFC, CFS and FPInnovations – this way brings the federal government's priorities together with the Canadian forest sector's research needs. Within this structure, the CWFC's goal is to develop targeted, effective and environmentally responsible solutions to challenges faced by Canada's forest industries."

The CWFC manages and delivers the Developing Sustainable Fibre Solutions Program of the CFS with the following three outputs:

1) Characterize biomass and enhance fibre production for the bioeconomy
2) Model growth and yield of trees under global change and adapt silviculture
3) Develop innovative solutions for forest management 4.0

Petawawa Research Forest

"The Petawawa Research Forest [is] located northwest of Ottawa in Chalk River, Ontario, Canada. It is 10,000 hectares (24,711 acres) in size and is located in the northern portion of the Department of National Defence's (DND) Garrison Petawawa." Natural Resources Canada (2019c)

The PRF is located within the Great Lakes-St. Lawrence forest region that features white pine (*Pinus strobus*), red pine (*Pinus resinosa*), red oak (*Quercus rubra*), yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*) and red maple (*Acer rubrum*) as common dominant species. Soils are typically sandy loams, and the topography ranges from flat to rolling.

The following is from Natural Resources Canada (2019c):

"Established in 1918 by the Canadian Forest Service (CFS), the PRF brings the Government of Canada together with stakeholders to contribute to the protection, sustainability, innovation and economic development of Canada's vast forest resources. As this 'living laboratory' enters its second century of operation, the PRF continues to inform forest research and management practices in Canada and around the world.

The forest is managed by the Canadian Wood Fibre Centre (CWFC) and is available to scientists and collaborators from across federal and provincial departments, academia and industry.

The PRF's mandate is to:

- Facilitate ongoing forest research and maintain long-term research installations

- Showcase the results of experimental trials to forest management end-users and to other researchers
- Carry out sustainable forest management to maximize the forest's future research potential"

Adaptive Silviculture for Climate Change Network

The following description of the Adaptive Silviculture for Climate Change Network is from Adaptive Silviculture for Climate Change (n.d.):

"The Adaptive Silviculture for Climate Change (ASCC) project is a collaborative effort to establish a series of experimental silvicultural trials across a network of different forest ecosystem types throughout the United States and Canada. Scientists, land managers, and a variety of partners have developed five initial trial sites as part of this multi-region study to research long-term ecosystem responses to a range of climate change adaptation actions.

Each trial is focused on understanding and evaluating management options designed to enable forests to respond to a changing climate. Site-specific treatments are developed according to local conditions and tailored to meet site-specific management objectives, while at the same time aligned under a common framework for answering questions about how different forest types will respond to future climate.

In using this two-tiered design, ASCC provides a means for evaluating adaptive management strategies across distinct forest types, allowing researchers to ask broad questions about climate change adaptation across all study sites, while also addressing on-the-ground management needs specific to individual sites.

Two of the primary objectives of the ASCC Network include efforts to:

- Create a multi-region study with locally-suited climate change adaptation treatments, using input from an expert panel of regional scientists and local managers
- Introduce natural resource managers to conceptual tools and approaches that help integrate climate change into resource management and silvicultural decision making"

The ASCC experimental installation at PRF would be the seventh site in the ten-year-old network and first site outside of the United States.

Additional information on the ASCC Network can be found on the ASCC website (https://www.adaptivesilviculture.org/) and Nagel et al. (2017).

Natural Resources Canada Climate Change Adaptation Research

Natural Resources Canada has been undertaking forest-related climate change research for many years. General examples include: research on climate change impacts and forests, impacts of climate change on the forest industry, modeling potential future forest condition scenarios, developing adaptation tools for land managers and undertaking climate change risk assessments and adaptation plans for forests. More information on this work can be found at Natural Resources Canada's *Forest Change* website (Natural Resources Canada, 2019b).

Through this work, NRCan researchers became aware of the ASCC network in the United States. As early as 2017, NRCan started a discussion with their American counterparts leading to research collaboration and knowledge sharing. It was through this relationship that the idea to include a Canadian site in the ASCC Network was developed. Fitting with PRF's mandate and because of the NRCan connection to the PRF, the PRF was ultimately chosen as the site for this new research installation.

WORKSHOP DAY 1

The first day of the workshop was a knowledge exchange and training session held on July 16, 2019 focussed on forests and climate change adaptation. This session was attended by 37 individuals from academia, industry, community forest managers, research organizations and federal and provincial researchers.

The objectives of day 1 were to provide:

- An introduction to conceptual tools and resources designed to help integrate climate change considerations into natural resource management planning and decision-making
- Discussion of regional climate change projections, impacts and ecosystem vulnerabilities (Figure 3)
- An opportunity to apply concepts from the workshop in a scenario-based breakout activity (Figure 4)

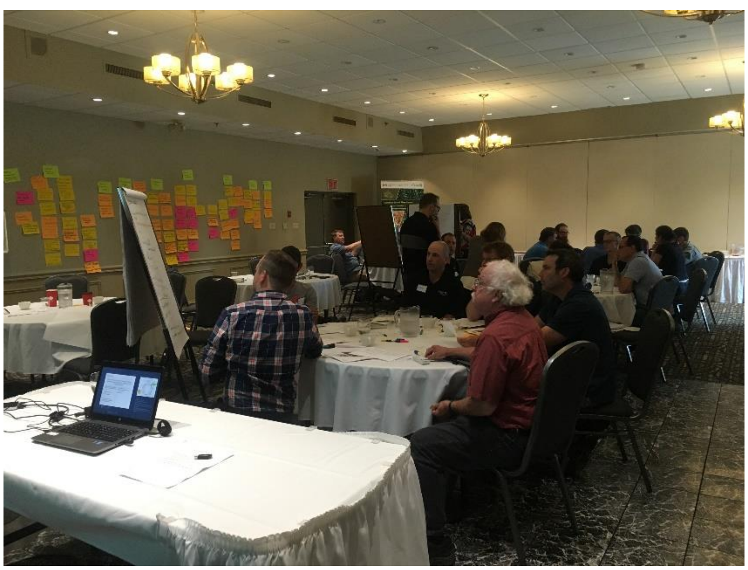

Figure 3. Participants from the day 1 workshop brainstormed and discussed impacts of climate change on forests Sticky notes on the walls are climate change impacts developed by the group. (Photo: Courtney Peterson)

Speakers and topics from day 1 workshop included:

- Linda Nagel, Colorado State University: Introduction to ASCC
- John Pedlar, NRCan: Canadian climate science overview
- Trevor Jones, NRCan: Great Lakes-St. Lawrence Forest ecology and silviculture
- Samuel Royer-Tardif, NRCan: Climate change impacts and vulnerabilities of Great Lakes-St. Lawrence Forest
- Jason Edwards, NRCan: Climate change adaptation work at the Canadian Forest Service
- Jeff Fera and Michael Hoepting, NRCan: Vulnerability assessment for climate change at Petawawa Research Forest
- Linda Nagel, Colorado State University: Climate change adaptation strategies for forest managers
- Maria Janowiak, NIACS and the USDA Forest Service: Planning forest adaptation

Interactive sessions included:

- Brainstorm and discussion: What do forest managers need to consider in the face of climate change? (Figure 3)
- Development of forest adaptation strategies for a real local forest stand (Figure 4)

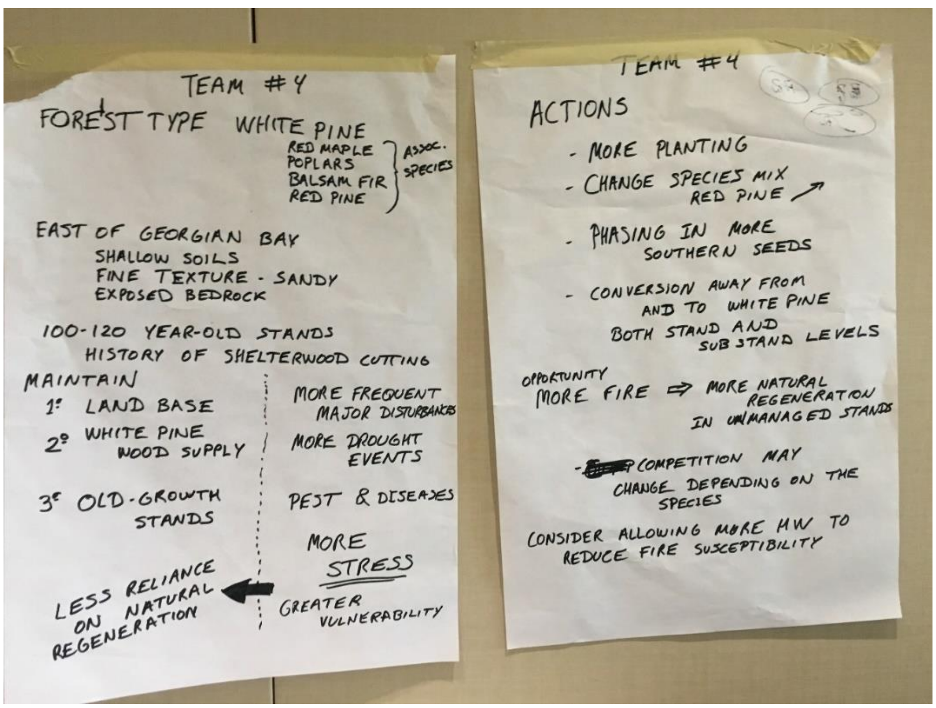

Figure 4. In groups, participants brainstormed adaptation strategies for forests they manage (Photo: Courtney Peterson)

WORKSHOPS DAYS 2 AND 3

Days two and three of the workshop consisted of a planning session held on July 17th and 18th. The 21 attendees were a smaller subset of the first group. See Appendix A for a list of participants and their affiliations. Over the two days participants developed a draft plan for the ASCC study site at the PRF.

The objectives of day 2 were to:

- Engage local managers and scientists in the Adaptive Silviculture for Climate Change (ASCC) co-development framework through the co-creation of locally relevant climate change adaptation strategies
- Introduce natural resource managers to conceptual tools and approaches that help integrate climate change into on-the-ground planning and decision-making processes
- Use an adaptive planning process to design specific climate change adaptation experimental treatments for a set of white pine stands that will be part of a long-term study to be implemented at the Petawawa Research Forest
- Develop specific management, research and monitoring questions that can be addressed through this project

Speakers and topics from days 2 and 3 workshop included:

- Jeff Fera and Michael Hoepting, NRCan: Field tour at PRF of the Cartier Lake Silviculture Area to discuss possible experiment locations
- Linda Nagel, Colorado State University: Facilitation of the development of a draft experimental plan for an ASCC site at the PRF

To ensure that treatment plans would be operationally feasible, organizers ensured that there were local industry forest managers at the planning session that are familiar with the forest conditions of the PRF.

More details on the background and development of the PRF ASCC trial development is provided below.

ASCC EXPERIMENTAL DESIGN

The ASCC project draws heavily on tools created through a management-focused effort called the Climate Change Response Framework (Janowiak et al. 2014) but couples the management tools with a rigorous scientific design. ASCC provides training opportunities for natural resource managers to learn about climate change impacts relevant to local management goals and develop appropriate adaptation actions to address those impacts, while at the same time, the different sites collectively make up an international, statistically robust study with ecosystem-specific climate change adaptation treatments. Manager-scientist partnerships are the core of each new ASCC Network site.

The ASCC study is designed to maintain key experimental design elements that are consistent across all study sites while allowing individual sites to tailor treatments to their unique, local contexts. All ASCC sites followed the same co-development process involving both managers and scientists, with each site utilizing the same experimental approach and study design structure for treatment types and spatial/temporal factors. In that context, ASCC sites are testing silvicultural systems along an adaptation gradient including no action, resistance, resilience and transition using definitions modified from Millar et al. (2007) (Table 1). “By designing, implementing, and monitoring a spectrum of treatments across this adaptation gradient, managers and scientists will be able to learn how well various adaptation options accommodate a range of potential future climate change conditions, at an operational spatial scale, and across a variety of ecosystem types and geographic regions” (Nagel et al. 2017, p. 169).

A component of the ASCC experimental design is the Climate Change Response Framework’s Adaptation Workbook developed by the Northern Institute of Applied Climate Science. “The Adaptation Workbook is a structured process to consider the potential effects of climate change and design land management and conservation actions that can help prepare for changing conditions. The process is completely flexible to accommodate a wide variety of geographic locations, ownership types, ecosystems and land uses, management goals, and project sizes.” (Northern Institute of Applied Climate Science, n.d.)

The strength of the Adaptation Workbook is to take the predicted climate change outcomes (e.g. temperature change, precipitation change) that are often reported at a national or regional scale and translate those outcomes into forest stand-level impacts. By translating regional impacts to local impacts, forest managers can make practical decisions about how to manage their forests in the face of climate change.

The Adaptation Workbook is available as an online decision support tool (https://adaptationworkbook.org/) or in the book *Forest Adaptation Resources: Climate Change Tools and Approaches, 2nd Edition* (Swanston et al., 2016). These documents are recommended reading for those who want more information on the adaptation model incorporated into the ASCC work at the PRF.

The Adaptation Workbook guides users through the process shown in Figure 5. Part of the process requires that land managers make practical management decisions to adapt to climate change. These fall into one of four treatment definitions and goals modified from Millar et al. 2007 as shown in Table 1: Resistance, Resilience, Transition and No Action (Nagel et al. 2017). These treatments and goals can vary from stand to stand within the same forest. Managers are not restricted to only one treatment option.

Following the decision of which treatment type to use (see Table 1) managers have a comprehensive list of “strategies” and “approaches” to help guide management actions. See Appendix B for a list of these “strategies” and “approaches”. Final management decisions/prescriptions are always made by the forest manager based on local conditions and knowledge.

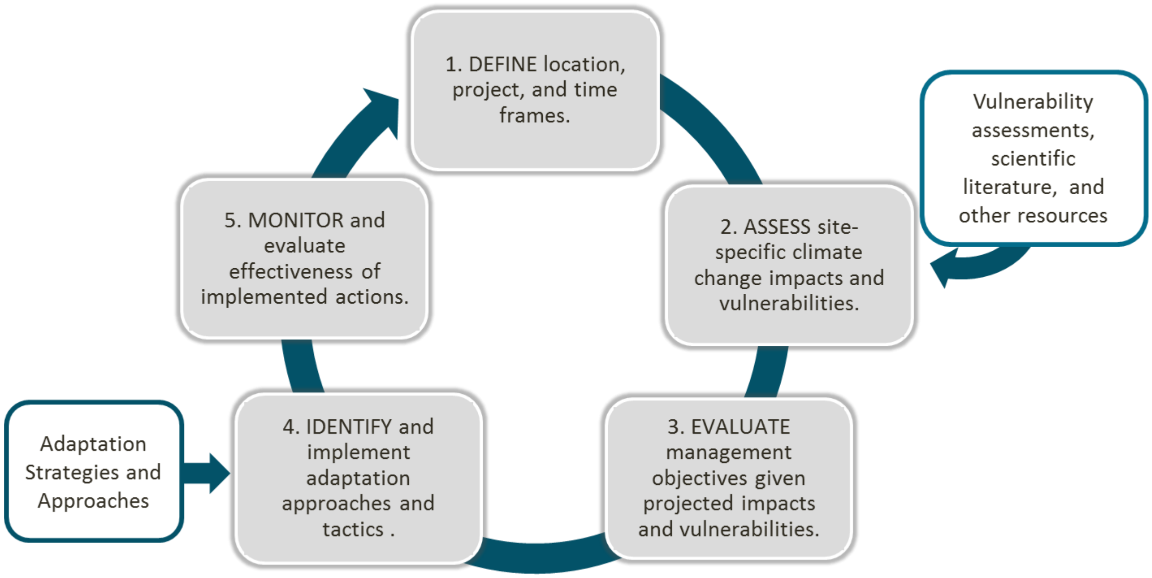

Figure 5. Adaptation Workbook Process
(Swanston et al., 2016)

Table 1. Adaptation Treatment Definitions and Goals

	Adaptation Treatment Definition	Adaptation Treatment Goal
Resistance	Actions that improve the defenses of the forest against anticipated changes or **directly defend the forest against disturbance** in order to **maintain relatively unchanged conditions.**	Maintain relatively unchanged conditions over time.
Resilience	Actions that accommodate some degree of change but **encourage a return to a prior condition or desired reference conditions following disturbance.**	Allow some change in current conditions but encourage an eventual return to reference conditions.
Transition	Actions that intentionally accommodate change and enable ecosystems to **adaptively respond to changing and new conditions.**	Actively facilitate change to encourage adaptive responses.
No Action	Since climate change impacts all forests globally, we cannot maintain a true "control." With this in mind, we consider an approach in which forests are allowed to respond to climate change in the **absence of direct silvicultural intervention** as an appropriate baseline for many questions.	Allow forests to respond to climate chance without direct management intervention.

ASCC SILVICULTURAL TREATMENT DEVELOPMENT PROCESS

The ultimate goal of the workshop was to design site-specific desired future conditions (DFCs), identify management objectives and develop silvicultural tactics to meet the overarching goals of the resistance, resilience and transition treatments for the new ASCC site at the PRF. This draft was to include as much details as possible. Linda Nagel, Colorado State University and principal investigator of the ASCC Network, facilitated an interactive process to achieve this goal. The workshop participants were split into groups of approximately six people each. Each group had representatives from industry (representing sustainable forest licence holders), academia and NRCan. Linda Nagel facilitated each group through the Adaptation Workbook process described above to develop prescriptions for the treatments.

The forest type that will be the focus of the ASCC research site at the PRF was pre-determined by NRCan prior to the workshop. The study will be situated in stands with dominant and co-dominant components of white and red pine and mid-canopy components of red oak, aspen (*Populus spp*.), white birch (*Betula papyrifera*), red maple, balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) (Figure 6). In these stands, the understory is predominantly hazel (*Corylus spp.*) and ferns, with a limited herbaceous layer. Soils are well-drained sandy loams that vary in depths between shallow and deep. Reflecting the topographical heterogeneity of the region, study sites will represent level to upper slope positions.

Figure 6. Participants toured and discussed the pine (Pinus spp) stands that were being considered for study sites (Photo: Courtney Peterson)

The standard ASCC experimental design has four silvicultural treatments: Control (untreated reference conditions), resistance, resilience and transition. Each treatment is replicated four times across a 200-hectare (500-acre) area.

For each treatment the groups had to draft/define the following:

1. Desired future condition
2. Management objectives
3. Tactics to achieve 1 and 2 above
4. Timeframes for tactics to be implemented
5. Benefits of the treatment that are being managed for

6. Drawbacks and barriers to implementation
7. Technical feasibility/ability to implement

Groups reported back their progress at various milestones throughout the day and a consensus was achieved between the groups at each milestone before continuing. In this way a common prescription was developed for each treatment (Figure 7).

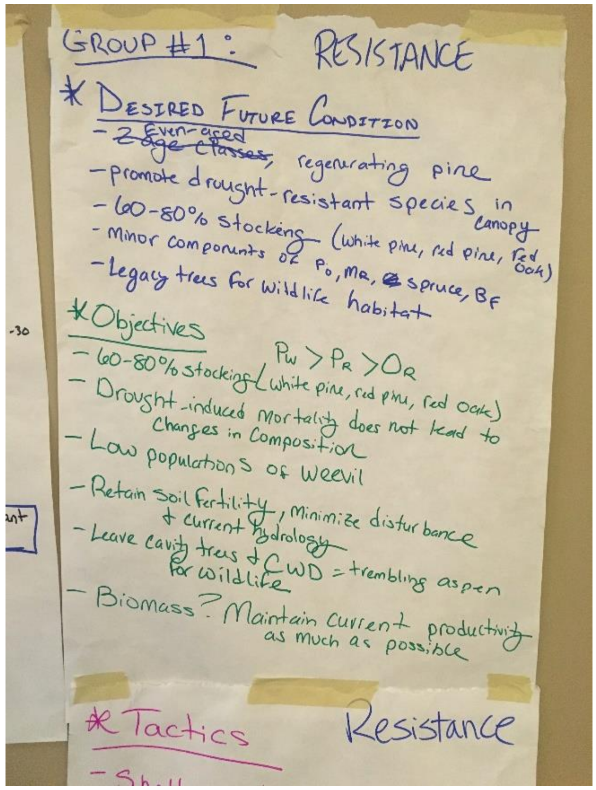

Figure 7. An example of a "resistance treatment" developed by one of the breakout groups
Each group shared their draft treatments and a common draft treatment was developed through consensus.
(Photo: Courtney Peterson)

CLIMATE CHANGE IMPACTS AT PETAWAWA RESEARCH FOREST

Participants considered and discussed the anticipated climate change impacts to the PRF, and the challenges and opportunities these impacts will present.

Key projected climate change impacts include:

- Increasing summer moisture stress due to expected reduced summer precipitation coupled with higher temperatures
- Increased potential for wildfire
- More irregular seed production necessitating a reduced reliance on natural regeneration
- More frequent snow and ice storms leading to crown damage and snow loading on seedlings

- Warmer winter temperatures and increased evapotranspiration
- Rain on snow events leading to rapid snow melt and fluctuating water tables

Challenges resulting from these projected impacts may include:

- Important forest types to the PRF, including white pine, red pine, oak and hardwood forest units will be exposed to increased drought stress, which could slow growth of established trees and increase mortality in regeneration
- Changes in seasonality and shorter, milder winters could lead to challenges with the timing of vegetation management and harvest
- Infrastructure on the PRF could be taxed by large storm events and heavy rains
- Changes in precipitation patterns and increased drought could increase stress and lead to increases in losses from forest insects, diseases and wildfire

Opportunities resulting from these projected impacts may include:

- Warmer temperatures and longer growing seasons could potentially increase tree productivity and enhance timber production
- White pine, the most dominant and economically important tree species at the PRF, is generally expected to adapt better to the various possible ranges of future climate conditions than many other local species
- Some tree species currently found on-site are expected to have expanded ranges or expansion of suitable growing sites, including red oak, which may create opportunities to diversify forest composition and forest product offerings

DRAFT EXPERIMENTAL DESIGN

The outcome of the two-day workshop was a draft experimental design for each of the four treatments: No action control (untreated reference conditions), resistance, resilience and transition. However, because the PRF ASCC trial will be focused on the renewal of white pine dominated forests, which is typically achieved using the uniform shelterwood system, a second control treatment was added after the workshop. Control 2 (business as usual) will be the implementation of a standard uniform shelterwood system renewal strategy. This treatment will provide a more direct comparison against traditional stand renewal practices for the resistance, resilience and transition treatments.

The sections below summarize key aspects of the *draft* treatments. NRCan researchers will continue to refine this design. The first harvests/entry of the stands to implement the treatments are tentatively scheduled for fall and winter 2020/21. Each of the adaptation treatments will be replicated four times across a 200-hectare (500-acre) area on the Petawawa Research Forest.

No Action Control 1 (Untreated Reference Conditions) Treatment Summary

ASCC No Action Treatment Goal: *Allow forests to respond to climate change without direct management intervention*

Since climate change impacts all forests globally, we cannot maintain a true "control." With this in mind, we consider an approach in which forests are allowed to respond to climate change in the absence of direct silvicultural intervention as an appropriate baseline for many questions.

The first control is an untreated stand that will be used for reference. The treatment will be passive with no harvesting or manipulation taking place. Fire suppression will continue.

Control 2 (Business As Usual) Treatment Summary

PRF ASCC "Business as Usual" Treatment Goal: *Standard strategies and approaches to achieve the Desired Future Condition (DFC) at the PRF*

Control treatment objective: Manage the forest with no change to current uniform shelterwood practices used for pine management (business-as-usual) at the PRF

Control management goals:

- Species Composition: White pine dominated with other target species being red pine, red oak and white spruce; minor species: Trembling aspen (*Populus tremuloides*), white birch, red maple and balsam fir
- Structural Diversity: Generally even-aged at maturity and two-aged during the uniform shelterwood renewal phase
- Manage for typical pests and wildlife values
- Fire Adaptation: The uniform shelterwood system strives to mimic the light conditions and structure created by low intensity ground fires

Control treatment strategies and approaches:

- Two-cut uniform shelterwood with mechanical and chemical site preparation for slash management, understory vegetation management and seedbed creation
- Plant white pine from local seed zones and allow for natural regeneration of white pine, red pine, red oak and spruce
- Tending as needed
- Re-initiate the uniform shelterwood system in 80 to 100 years

Resistance Treatment Summary

ASCC Resistance Adaptation Treatment Goal: *Maintain relatively unchanged conditions over time*

Resistance treatment objective: Achieve the desired future condition with mild deviation from standard strategies and approaches typically employed at the PRF.

Resistance treatment management goals:

- Regenerate a well-stocked, productive, pine-dominated stand (white pine and other drought-tolerant species common to the site)
- Maintain or increase production of high-quality saw logs and other forest products
- Manage for typical pests and for wildlife values
- Increase resistance by incorporating planting stock from southern seed sources, increasing species diversity and reducing the rotation age

Resistance treatment strategies and approaches:

- Two-cut uniform shelterwood with mechanical and chemical site preparation for slash management, understory vegetation management and seedbed creation
- Plant white pine from local and more southern seed zones (e.g. Simcoe, Essex, Ohio/Illinois)
- Plant red pine from local seed source
- Allow for natural regeneration of red oak, white pine and white spruce
- Tending as needed
- Thinning (pre- and/or commercial) to accelerate saw log production
- Re-initiate the uniform shelterwood system in 80 to 100 years *or* use repeated commercial thinning entries to maximize saw log production and extend the rotation in 60 to 80 years

Resilience Treatment

ASCC Resilience Adaptation Treatment Goal: *Allow some change in current conditions but encourage an eventual return to reference conditions*

Resilience treatment objective: Achieve a similar desired future condition with moderate deviation from standard strategies and approaches typically employed at the PRF.

Resilience treatment management goals:

- Create a well-stocked, multi-aged structure
- Promote species composition in order of abundance from most to least: White pine, red oak, red pine, aspen, other species
- Maintain/increase productivity and quality of wood products and diversify wood products, including pine saw logs

- Promote low susceptibility to disturbances, including drought, wildfire, wind, ice storms, insects and diseases
- Enhance species diversity particularly among dominant species (including functional diversity, structural diversity and genetic diversity)
- Increase resilience to low intensity wildfires and reduce susceptibility to stand-replacing wildfires
- Mange for wildlife habitat and mitigation of pests by utilizing expanding gaps to create a multi-aged stand with a gradient of light conditions

Resilience treatment strategies and approaches:

- Irregular shelterwood created by expanding gaps with feathered edges; start with 1-2 tree length diameter gaps
- Site preparation in the gaps for slash management, understory vegetation management, and seedbed creation; aides' early regeneration survival and success
- Capitalize on the onsite species and natural regeneration (i.e., promote oaks on ridgetops, etc.)
- One year after site preparation, plant local and southern seed sources in the gaps
    - Gaps: 40% white pine from southern sources; 40% red oak from southern sources; 20% local red pine
    - Feathered edges: 70% white pine and 30% red oak from southern sources
- Allow for natural regeneration of red oak, white pine and white spruce
- Tending as needed
- Gaps to mature in 80 to 100 years; continue irregular shelterwood system

Transition Treatment

ASCC Transition Adaptation Treatment Goal: *Actively facilitate change to encourage adaptive responses.*

Transition treatment management goals:

- Continue to provide quality wood products
- Promote a diverse species mix that is adapted to drought, wildfire, wind, ice storms, insects and diseases
- Increase the genetic diversity of native species (including white pine and red oak)
- Assisted migration of pine and hardwood species
- Maintain wildlife habitat through structural retention and an increase in mast species

Transition treatment strategies and approaches:

- Clear-cut with aggregate retention (10%-20%) in variable sizes focused on existing white pine and red oak
- Site preparation using mechanical, and possibly prescribed fire and chemical, treatments

- Plant pines and oaks with local and novel future-adapted species, such as:
    - Local red pine
    - Pitch pine (*Pinus rigida*) from US seed sources
    - Red oak from southern seed sources (e.g. Essex, ON)
    - White oak from southern seed sources (e.g. Essex, ON)
    - Small amounts of American chestnut (*Castanea dentata*) from US seed sources (if available)
    - Other species to consider may be jack pine (*Pinus banksiana)*, bur oak (*Quercus macrocarpa*), black cherry (*Prunus serotina*), hickory (*Carya spp.*), virginia pine (*Pinus virginiana*)
- Allow for natural regeneration of red oak, white pine and white spruce
- Tending as needed
- Species mix anticipated to be conducive to commercial thinning or irregular shelterwood management after 80 to 100 years

Monitoring

Monitoring is an essential component of the ASCC study. NRCan will collaborate with research partners from many institutions to work together to investigate the effectiveness of the different silvicultural treatments aimed at creating adaptive ecosystems. Some of the monitoring items include:

- Regeneration of planted seedlings
- Residual tree survival and growth
- Vegetation diversity
- Microclimate conditions
- Hydrology and catchment data
- Operational costs and productivity
- Coarse woody debris
- Carbon and nutrient pools

COLLABORATION OPPORTUNITIES FOR OTHER ORGANIZATIONS

The PRF is a public research forest with many different organizations conducting research there at any given time. Many of the research installations are collaborations between different research organizations. The ASCC installation provides another opportunity for research organizations to collaborate to answer questions about the impact of climate change on forests. While the original goal of the project was to measure climate change effects on tree productivity under different management scenarios, the installation provides an opportunity to measure many other effects at the intersection of climate change and forest management. The ASCC installation will be a fully replicated, stand-alone trial, but because of the underlying design, it will also be linked to the broader ASCC network of sites.

NRCan would welcome other researchers and organizations to collaborate with them to answer other research questions. These research studies would be sub-studies of the larger study and could include impacts on, or adaptation responses of, plants, animals, arthropods, carbon sequestration, fecundity and reproductive success of difference species, as well as many others.

Interested parties can contact any of the people in Table 2 for more information.

Table 2. Main study contacts

Role	Name	Email	Telephone
Scientific Lead	Trevor Jones	trevor.jones@canada.ca	705-541-5610
Scientist	Nelson Thiffault	nelson.thiffault@canada.ca	418-454-1976
Project Foresters	Jeff Fera Michael Hoepting	jeff.fera@canada.ca michael.hoepting@canada.ca	705-541-5616 705-541-5687
PRF Operations Manager	Melissa Vekeman	melissa.vekeman@canada.ca	705-541-5610

NEXT STEPS

Key next steps include:

- Refine and finalize the draft experimental treatments
- Collaborate with key partners to determine potential seed lots for future-adapted seedlings
- Collect pre-treatment forest inventory data in 2019 and 2020
- Implement the treatments (harvests) in winter 2020-21
- Future data collection will focus on tree regeneration, forest growth, forest health and carbon and nutrient fluxes
- Participate in ASCC network-wide analytical initiatives

REFERENCES

Adaptive Silviculture for Climate Change. (n.d.) *About ASCC.* Retrieved from https://www.adaptivesilviculture.org/about-ascc

Janowiak, M.K., Swanston, C.W., Nagel, L.M., Brandt, L.A., Butler, P.R., Handler, S.D., Shannon, P.D., Iverson, L.R., Matthews, S.N., Prasad, A., & Peters, M.P. (2014). A practical approach for translating climate change adaptation principles into forest management actions. *Journal of Forestry, 112*(5), 424-433.

Miller, C.I., Stephenson, N.L., & Stephens, S.L. (2007). Climate change and forests of the future: Managing in the face of uncertainty. *Ecological applications, 17*(8), 2145-2151.

Nagel, L. M., Palik, B. J., Battaglia, M. A., D'Amato, A. W., Guldin, J. M., Swanston, C. W., Janowiak, M. K., Powers, M. P., Joyce, L. A., Millar, C. I., Peterson, D. L., Ganio, L. M., Kirscbaum, C., and Roske, M. R. (2017). Adaptive silviculture for climate change: A national experiment in manager-scientist partnerships to apply and adaptation framework. *Journal of Forestry, 115*(3), 167-178.

Natural Resources Canada. (2019a). *Canadian Wood Fibre Centre.* Retrieved from https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/canadian-wood-fibre-centre/13457

Natural Resources Canada. (2019b). Climate change impacts on forests. Retrieved from https://www.nrcan.gc.ca/climate-change/impacts-adaptations/10761

Natural Resources Canada. (2019c). *National research forests.* Retrieved from https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/national-research-forests/13171

Northern Institute of Applied Climate Science. (n.d.). *About the adaptation workbook.* Retrieved from https://adaptationworkbook.org/about

Swanston, C.W., Janowiak, M. K., Brandt, L. A., Butler, P. R., Handler, S. D., Shannon, P. D., Lewis, A. D., Hall, K., Fahey, R. T., Scott, L., Kerber, A., Miesbauer, J. W., Darling, L., Parker, L., St. Pierre, M. (2016). *Forest adaptation resources: Climate change tools and approaches for land managers, 2nd Edition.* United States Forest Service, Northern Research Station, General Technical Report NRS-87-2. United States Forest Service: Newtown Square, PA.

APPENDIX A: DAY 2-3 EXPERT PANEL PARTICIPANTS

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Notes: [a] Workshop facilitator; [b] NRCan/CWFC Scientific Lead for PRF ASCC Study		

APPENDIX B: FOREST ADAPTATION STRATEGIES AND APPROACHES

Menu of strategies from Swanston et al. (2016).

1 Strategy 1: Sustain fundamental ecological functions.

1.1. Reduce impacts to soils and nutrient cycling.
1.2. Maintain or restore hydrology.
1.3. Maintain or restore riparian areas.
1.4. Reduce competition for moisture, nutrients, and light.
1.5. Restore or maintain fire in fire-adapted ecosystems.

2 Strategy 2: Reduce the impact of biological stressors.

2.1. Maintain or improve the ability of forests to resist pests and pathogens.
2.2. Prevent the introduction and establishment of invasive plant species and remove existing invasive species.
2.3. Manage herbivory to promote regeneration of desired species.

3 Strategy 3: Reduce the risk and long-term impacts of severe disturbances.

3.1. Alter forest structure or composition to reduce risk or severity of wildfire.
3.2. Establish fuelbreaks to slow the spread of catastrophic fire.
3.3. Alter forest structure to reduce severity or extent of wind and ice damage.
3.4. Promptly revegetate sites after disturbance.

4 Strategy 4: Maintain or create refugia.

4.1. Prioritize and maintain unique sites.
4.2. Prioritize and maintain sensitive or at-risk species or communities.
4.3. Establish artificial reserves for at-risk and displaced species.

5 Strategy 5: Maintain and enhance species and structural diversity.

5.1. Promote diverse age classes.
5.2. Maintain and restore diversity of native species.
5.3. Retain biological legacies.
5.4. Establish reserves to maintain ecosystem diversity.

6 Strategy 6: Increase ecosystem redundancy across the landscape.

6.1. Manage habitats over a range of sites and conditions.
6.2. Expand the boundaries of reserves to increase diversity.

7 Strategy 7: Promote landscape connectivity.

7.1. Reduce landscape fragmentation.
7.2. Maintain and create habitat corridors through reforestation or restoration.

8 Strategy 8: Maintain and enhance genetic diversity.

8.1. Use seeds, germplasm, and other genetic material from across a greater geographic range.
8.2. Favor existing genotypes that are better adapted to future conditions.

9 Strategy 9: Facilitate community adjustments through species transitions.

9.1. Favor or restore native species that are expected to be adapted to future conditions.
9.2. Establish or encourage new mixes of native species.
9.3. Guide changes in species composition at early stages of stand development.
9.4. Protect future-adapted seedlings and saplings.
9.5. Disfavor species that are distinctly maladapted.
9.6. Manage for species and genotypes with wide moisture and temperature tolerances.

9.7. Introduce species that are expected to be adapted to future conditions.
9.8. Move at-risk species to locations that are expected to provide habitat.

10 Strategy 10: Realign ecosystems after disturbance.

10.1 Promptly revegetate sites after disturbance.
10.2. Allow for areas of natural regeneration to test for future-adapted species.
10.3. Realign significantly disrupted ecosystems to meet expected future conditions

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