FOREST GROWTH ORGANIZATION OF WESTERN CANADA

FGrOW

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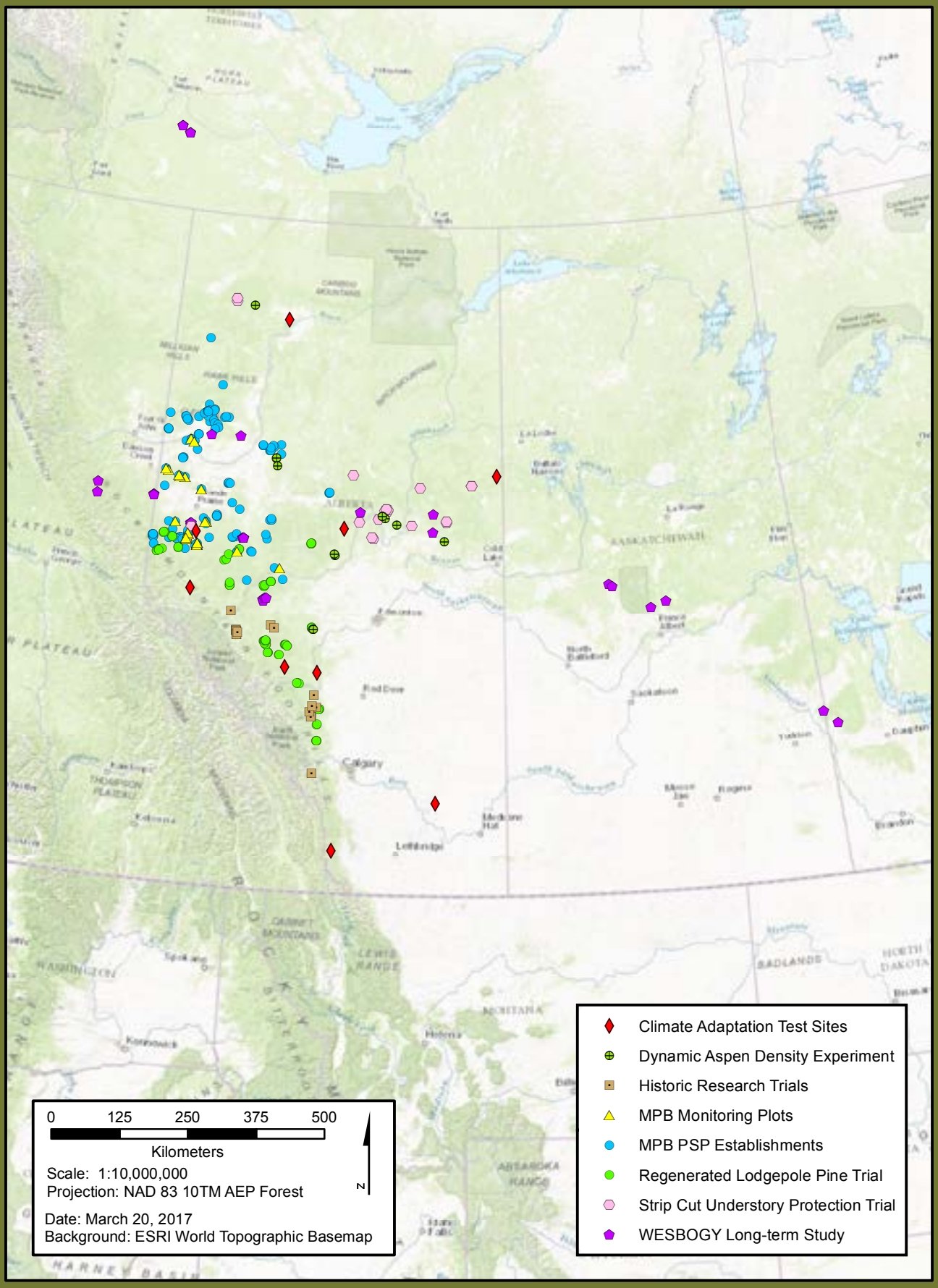
FGrOW Research Trial Locations



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Message from the Chair

Growth and yield has been an exceptionally dynamic area of forest management over the last decade. The associations that inform the science and policy of growth and yield matched this dynamism.

Four strong growth and yield associations took on the complex task of amalgamating into one unified organization called the Forest Growth Organization of Western Canada (FGrOW). The amalgamation took considerable time and cooperation to achieve. I would like to take this opportunity to recognize the leads of those organizations for their incredible collaboration and drive to the common goal of having one organization with common or complimentary objectives.

I have had the distinct honour of serving as the inaugural Chair of FGrOW. As we have navigated the first several business and technical cycles, I have seen FGrOW leap from a concept to a mature organization with guiding documents and principles serving the members' objectives.

Kerri MacKay

Message from the Director

When FGrOW started operating in April 2015, it was the culmination of years of effort by several individuals who saw opportunities to accomplish more and stop duplicating efforts by working together. These people were committed to an efficient and coordinated growth and yield sector, but it wasn't always easy to make others see this vision. The first two years as a united growth and yield association have been, in part, a time for members to understand how they can work effectively together.

We're now seeing tangible results from working collaboratively. Researchers from different project teams have been discussing their work and giving and receiving valuable feedback. Member companies and project teams are beginning to share data to support projects, which will in turn answer important questions such as how managed stands are regenerating and responding to treatments.

For as long as I've worked in Alberta, I've heard talk about the need for a better bridge between research findings and how they can or should be applied by practitioners. I believe that for FGrOW's long term survival and relevance, it will be critical to build that bridge. Communicating with practitioners about our research and how it can be applied will be a major part of FGrOW's work as we move forward. Almost as important will be ensuring that the body of growth and yield research is not lost and forgotten as those who were involved continue to retire.

To be successful we must build on the great research that was completed through the founding organizations, which continues through FGrOW. We need to focus on strengthening the link between research results and potential changes to forest management practice that is so often missing. We must continue the successes we've had in holding workshops and expand that practice. We need to get better at writing extension notes and summaries of research findings and applications so that our work is accessible to practitioners.

It's an exciting time to be working for FGrOW. The organization is still evolving and growing, highlighted by Tree Improvement Alberta joining in 2016. I'm honored to be able to guide FGrOW as it adapts to its members changing questions to give them the science and tools that they need.

Sharon Meredith

What is Growth and Yield?

Growth and yield can seem intimidating; it is broad and encompasses a lot of things. We won't lie to you. It's complicated and it does involve a lot of math. Luckily, the math can be left in the hands of a select few and the rest is pretty easy to understand.

At its simplest, growth and yield can be broken down into its two components. Growth means how forests, measured at the tree or stand level, change over time. Yield is how much of something, most often volume of wood, exists in a stand or tree at a specific point in time.

To measure both growth and yield, sampling is important. Sampling has traditionally been done by establishing plots on the ground and measuring the trees in them, but there is an increasing trend towards using remote sensing technologies like LiDAR. The key is to sample enough to provide accurate estimates, as cost effectively as possible. Sampling is tied closely with forest inventory, which is essential for determining amounts and locations of plots.

Growth measurements, obtained through permanent sample plots, can be used to understand response to treatments, outcomes of tree improvements, or simply stand growth. They are used to develop growth models, which are a critical forest management tool, linked to regeneration standards and foundational to allowable cut calculations.

Temporary sample plots provide a "snapshot" of forest conditions at a specific point in time, which we refer to as yield. Individual measurements from permanent sample plots can be used in the same way. These data can be used as inputs to growth models to create yield curves, to develop estimates of yield for similar stand types, or to check yield estimates from models.

One of the most important things the science of growth and yield does is allow us to make better estimates of how trees and stands change over time, so that we can develop better predictions for how much volume can be expected to be present over the life of a stand. The resulting yield curves are essential to forest management. They let us make more accurate annual allowable cut calculations, help rationalize investments in silviculture and tree improvement, and increase understanding of ecosystem productivity and response to disturbance.

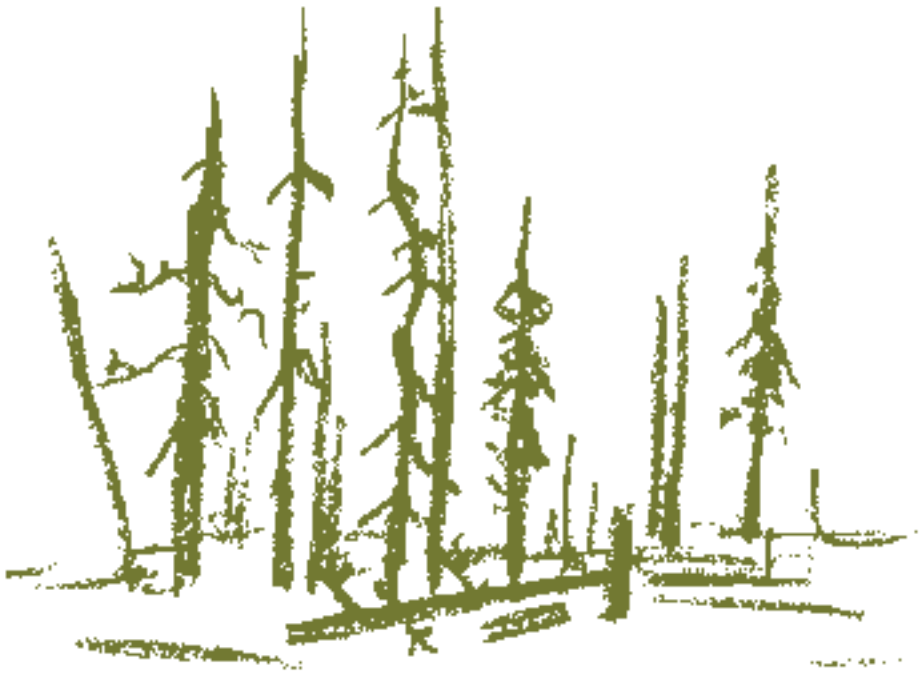
Origins

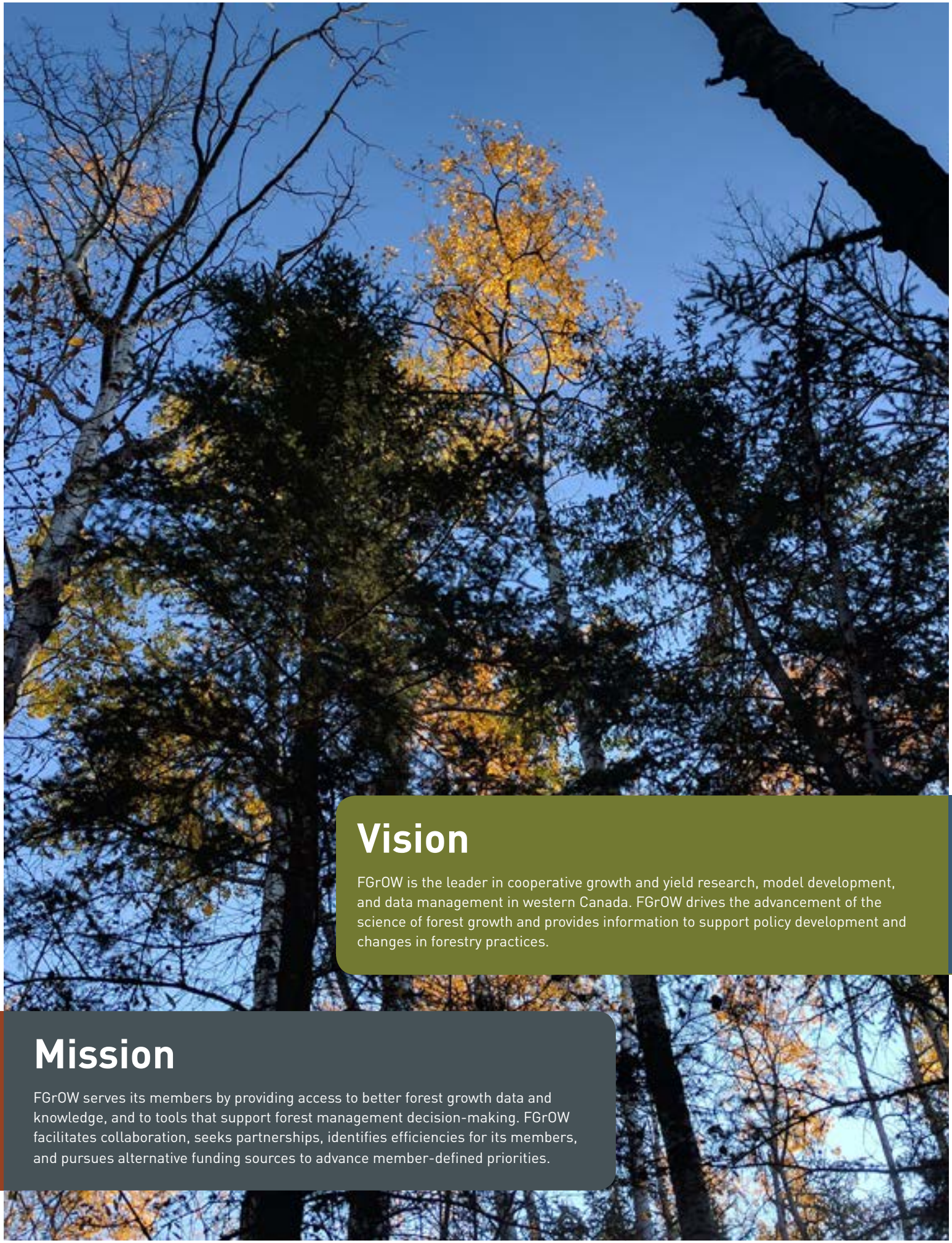
Forestry practitioners in western Canada have long realized the importance of collaborative growth and yield research; the first Alberta-based growth and yield association, the Western Boreal Growth and Yield Association (WESBOGY), began meeting in the mid-1980s. The early 2000s saw the formation of two more growth and yield associations in Alberta: the Foothills Growth and Yield Association (FGYA) and the Mixedwood Management Association (MWMA). Soon afterwards, members of the three associations began to discuss the need for a more coordinated growth and yield sector. This need was recognized in the formation of the Alberta Forest Growth Organization (AFGO) in 2008. This led to more formal discussions about restructuring the growth and yield associations, and eventually to the development of a single new association—FGrOW.

Throughout the discussions that led to the formation of FGrOW, members of the associations placed a high value on continuing existing projects and research, but also recognized the potential advantages of coordinating efforts to increase opportunities for funding and to raise the profile of growth and yield in western Canada. Finding a way to realize the advantages that would address the needs of all members took time and would not have been possible without champions advocating for change, including Richard Briand (Hinton Wood Products) and Gitte Grover (formerly of Alberta-Pacific Forest Industries).

FGrOW began operating in April 2015. It was an amalgamation of the four Alberta-based growth and yield associations: AFGO, FGYA, MWMA and WESBOGY, which joined January 1, 2016. The intent of the amalgamation was to increase efficiencies, facilitate collaboration, and attract more funding to growth and yield in Western Canada. As of April 1, 2016, Tree Improvement Alberta (TIA) became a project team under FGrOW.

FGrOW is an association under fRI Research (formerly the Foothills Research Institute) which acts as a coordinating agency, providing accounting and administrative support.





Vision

FGrOW is the leader in cooperative growth and yield research, model development, and data management in western Canada. FGrOW drives the advancement of the science of forest growth and provides information to support policy development and changes in forestry practices.

Mission

FGrOW serves its members by providing access to better forest growth data and knowledge, and to tools that support forest management decision-making. FGrOW facilitates collaboration, seeks partnerships, identifies efficiencies for its members, and pursues alternative funding sources to advance member-defined priorities.

Goals

1) **Improve practice through the development of best practices and tools.**

- Develop minimum standards and recommended best practices for sampling programs and data collection.
- Support forest growth model development.
- Support the development of tools that will accurately reflect forest growth in natural and managed stands under a range of conditions and in response to management activities.
- Help members realize investments in silviculture and tree improvement by ensuring that growth response is accurately reflected in approved growth models.
- Assist in producing guidelines for development of growth and yield plans, yield curves, or other practices of interest to members.

2) **Facilitate discussion among members on forest management practices related to growth and yield policy and provide input on growth and yield policy.**

- Strike working groups to develop recommendations for addressing areas of concern identified by members.
- Provide technical review of proposed policy changes when invited by government or other agencies.
- Engage members in discussions that encourage collaboration.

3) **Provide a venue for members to collectively prioritize, pursue, and implement forest growth research and related analysis.**

- Identify existing gaps and emerging topics and their linkages to the science of forest growth.
- Develop and support proposals for external funding.
- Support the implementation of projects that receive funding, including publication of results in peer reviewed journals.

4) Coordinate collaborative solutions in forest growth data collection and management.

- Centrally manage programs for data management and/or field measurements where it is the most efficient means of implementation.
- Enable collection of data suitable for growth model validation, development and enhancement and allow members to achieve cost-savings in their growth and yield programs through collaborative data collection.

5) Deliver and facilitate training and extension for practitioners.

- Build extension materials, including reports and research summaries or QuickNotes.
- Hold sessions to communicate findings and train practitioners on the use of tools and models.
- Conduct field tours to enhance on-the-ground experience for members and partners.
- Ensure that research is communicated to practitioners and government in a way that enables implementation of relevant results and facilitates associated changes in policy.
- Support development of qualified practitioners in the field of growth and yield.

6) **Raise the profile of growth and yield.**

- Meet with senior managers of member organizations to discuss FGrOW's results and members' priorities for research.
- Communicate with managers in the energy and other natural resources sectors about the value of FGrOW's work.
- Maintain an FGrOW presence at select conferences or meetings, such as the AFPA or CIF AGMs.
- Maintain a website that highlights FGrOW's work and which makes reports available.

FGrOW Members

Organization	Project Team Affiliation				
	Foothills Pine	Mixed-wood	Policy and Practice	TIA	WESBOGY
Alberta-Pacific Forest Industries Inc.		√	√	√	√
Alberta Agriculture and Forestry	√*	√	√	√	√
Alberta Plywood Ltd.		√	√	√	√
Alberta Newsprint Company	√			√	
Blue Ridge Lumber Inc.	√		√	√	
Canadian Forest Products Ltd.	√		√	√	√
Daishowa-Marubeni International Ltd.		√	√	√	√
Edson Forest Products	√		√	√	
Hinton Wood Products	√		√	√	
LP Canada, Ltd.					√
Manning Forest Products				√	√
Millar Western Forest Products Ltd.	√	√	√	√	
Norbord Inc.				√	
Northland Forest Products Ltd.				√	
Saskatchewan Environment					√
Spray Lake Sawmills	√			√	
Sundre Forest Products	√		√	√	
Tolko, High Level		√	√	√	
Vanderwell Contractors**					
Weyerhaeuser Company, Alberta Forestlands	√	√	√	√	√

*Non-voting member

**FGrOW Member with no Project Team affiliation

The University of Alberta and the Canadian Wood Fibre Centre of the Canadian Forest Service are associate members of FGrOW

Executive Council

Kerri MacKay, Chair, Weyerhaeuser (2015–2017)

Darren Aitkin, Alberta Agriculture and Forestry (2015–2017)

Bob Held, Sundre Forest Products (2015–2017)

Tim McCready, Millar Western Forest Products (2015–2017)

Shane Sadoway, Blue Ridge Lumber (2016–2018)

Sharon Meredith, FGrOW Executive Director, non-voting

Project Team Chairs

Foothills Pine Project Team
Matt Denney, Spray Lake Sawmills

Mixedwood Project Team
Dave Swindlehurst, Weyerhaeuser

Policy and Practice Project Team
Tim McCready, Millar Western Forest Products

TIA Project Team
Shane Sadoway, Blue Ridge Lumber

WESBOGY Project Team
Phil Comeau, University of Alberta

Current Projects

Foothills Pine Project Team
Regenerated Lodgepole Pine (RLP) Trial

Cooperative Management of Historic Research Trials (HRT)

Stand Dynamics after Mountain Pine Beetle Attack

Establishment of PSP Network to Monitor Stand Dynamics and Establish Yield Curves for Stands Killed by MPB

Mixedwood Project Team
Strip Cut Understory Protection (SCUP) Trial

Dynamic Aspen Density Experiment (DADE)

Silviculture Guide

Policy and Practice Project Team
Cutblock Inventory Classification Subcommittee

Provincial Growth and Yield Initiative (PGYI)

Tree Improvement Alberta Project Team
Realized Gain Trials (RGT)

Expanded Provenance and Progeny Trials for Climate Change Adaptation in Alberta

WESBOGY Project Team
Mixedwood Growth Model (MGM) Development

Long-term Study (LTS)

FRIAA Open Funds Projects
Empirical Post-Harvest Stand Assessment, sponsored by Millar Western Forest Products

Stand Dynamics Following Canopy Removal and Release of Advance Regeneration in Aspen and Lodgepole Pine Dominated Stands, sponsored by Weyerhaeuser

Improved Estimation of Tree Mortality and Stand Breakup, sponsored by Alberta Plywood

Improving Site Index Estimation for Alberta, sponsored by Millar Western Forest Products

Partnership with University of Alberta

The University of Alberta (UofA) has a long history of collaborating with the forest industry to answer growth and yield questions. As an associate member of FGrOW, the UofA continues to play a crucial role through conducting research that is of interest to forest managers. The University's programs are also important for developing new practitioners.

In addition to its excellent undergraduate program, the University runs a graduate program that is training growth and yield analysts. Professors, including Dr. Steve Titus (retired), Dr. Phil Comeau and Dr. Vic Lieffers, have trained most of the analysts working in growth and yield in the province. Many are now employed with consultants and the Alberta government.

The University's contribution to growth and yield goes beyond training new practitioners. Since its inception in the 1980s, WESBOGY has been housed at the UofA. WESBOGY continues to operate as an FGrOW project team at the University, with Dr. Phil Comeau acting as Project Team Chair. Central to WESBOGY Project Team is the funding for a Research Associate at the University; Dr. Mike Bokalo has been in this role since 2001. Dr. Comeau and Dr. Bokalo have provided long-term consistency to the WESBOGY programs: driving advancements of the Mixedwood Growth Model, overseeing design and implementation of the Long-term Study, and carrying-out other member priority research initiatives.

The MWMA was housed at the UofA for 10 years, prior to the formation of FGrOW. The University continues to be a non-voting member of the Mixedwood Project Team contributing expertise to study design and implementation.

The Tree Improvement Alberta (TIA) Project Team is closely linked with the University through Dr. Barb Thomas. Dr. Thomas, an NSERC Industrial Chair in Tree Improvement and Forest Genetics, was instrumental in forming TIA and continues to sit on its Board.

The importance to FGrOW of collaborating with the University is seen in the number of projects conceived by FGrOW that are being carried out on campus. The most recent examples are projects that are supported by FRIAA Open Funds and sponsored by FGrOW members. The UofA played a lead role in proposal development for projects that were identified as priorities by FGrOW members.

FGrOW appreciates the contributions the University makes to its program and looks forward to continuing this collaboration.

Knowledge Transfer

An important mandate of FGrOW is to ensure that its findings are communicated to its members and that they are able to use the results being produced. To date, FGrOW's most successful knowledge transfer activities have been workshops and field tours.

Field tours provide an informal opportunity for members to see the research that's being done on the ground and to discussion its implications. Tours often result in unique generation of ideas and discussions that wouldn't happen indoors. Some recent examples of FGrOW field tours include:

- WESBOGY annual fall tours not only look at work done by the project team, but also visit other sites of interest to its members.
- TIA has hosted field tours that give members more exposure to tree improvement practices and report on findings of projects like the Climate Adaptation Project.
- The FGrOW Sundre fall tour in 2015 was an opportunity to discuss issues faced by FGrOW and its members while looking at integrated resource management challenges and successes.

Workshops are an important way to help practitioners gain a more in-depth understanding of research results. They can also be used to give feedback to researchers on their work and help set direction for new or continued research. FGrOW's workshops include:

- In June of 2016, the Foothills Pine Project Team invited experts and practitioners to give feedback on its research on lodgepole pine regeneration and stand dynamics after MPB attack. Workshop participants helped decide the next steps for several aspects of the projects.
- TIA's annual workshops are well attended and provide participants with technical details of current TIA projects as well as an opportunity to learn about other relevant, ongoing research.
- When the Provincial Growth and Yield Initiative (PGYI) database app was nearing completion, the Policy and Practice Project Team held a workshop to provide practical, hands-on training on how to format data and load it into the app.

WESBOGY Long-term Study

Background

Mixed stands of trembling aspen and white spruce are a prominent component of our western boreal forests. Despite the fact that aspen can slow the growth of white spruce, there are a number of advantages to managing mixedwoods, as compared to converting to monocultures. Advantages can include: higher total yields, reduced incidence of frost damage to spruce, reduced vigor of understory competitors, and higher spruce wood quality. Long-term site productivity may also be enhanced by the presence of aspen, which takes up nutrients and retains them on site. Maintaining mixed stands in landscapes where they are naturally common also contributes to sustainable management objectives such as preserving biodiversity, protecting wildlife habitat, and preserving visual characteristics in the landscape.

Despite the advantages to managing for mixed stand types, this does involve added complexity. Improving our understanding of stand dynamics and growth in these complex stand structures is important to accurately forecasting outcomes from mixedwood management practices. The Western Boreal Growth and Yield Association, now the WESBOGY Project Team of FGrOW, recognized this need and began to established a Long-term Study (LTS) in 1990 to advance our understanding of the dynamics of spruce/aspen mixedwood stands. Today, the study includes a total of 615 plots established across British Columbia, Alberta, Saskatchewan, Manitoba and the Northwest Territories.

Overview

This study involved planting white spruce seedlings in recently clearcut areas where aspen regeneration had already been established. At age 5 spruce and aspen were thinned to desired treatment densities. Each installation consists of two replications of 15 treatments.

WESBOGY Long-term Study Locations

Treatment numbers for the 15 spruce and aspen density combinations created in the WESBOGY LTS.

		Aspen Density (sph)					
		0	200	500	1500	4000	Natural
Spruce Density (sph)	1000	1	2	3	4	5	6
	500	7	8	9	10	11	12
	0	x	x	x	13	14	15

Measurement plots are 20m by 20m (0.04 ha) with a 5–10m wide treated buffer on each side of the measurement plot. Trees are measured annually for the first 10 years of the study, every 2 years between ages 10 and 20, and then every three or four years. Collected data are all stored in a database that is maintained on a secure server at the University of Alberta.

Results

Eight installations have measurements covering more than 20 years and some interesting results are emerging. At age 20, aspen are at least one meter shorter in the natural unthinned compared to the other densities, while aspen diameter declines with increasing aspen density. White spruce are also shorter in the

natural unthinned compared to the other treatments at age 20 and root collar diameter of spruce declines with increasing aspen density.

The figure below shows Mean Annual Increments (MAI) calculated by the Mixedwood Growth Model for these plots. These results indicate that increasing aspen densities will lead to reduced spruce MAI, but that mixtures having at least 1500 sph of aspen, with 1000 sph of spruce, will have higher total MAI.

The WESBOGY LTS has provided the data necessary for several peer reviewed publications, a few of which are listed below. A publication of 20 year LTS results is under development.

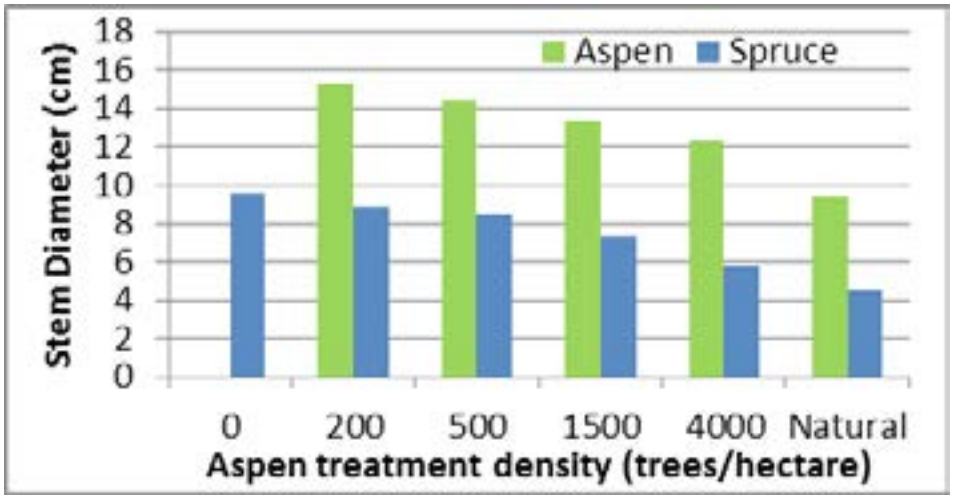
Bokalo, M., P.G. Comeau and S. J. Titus. 2007. Early development of tended mixtures of aspen and spruce in western Canadian boreal forests. Forest Ecology and Management 242: 175–184.

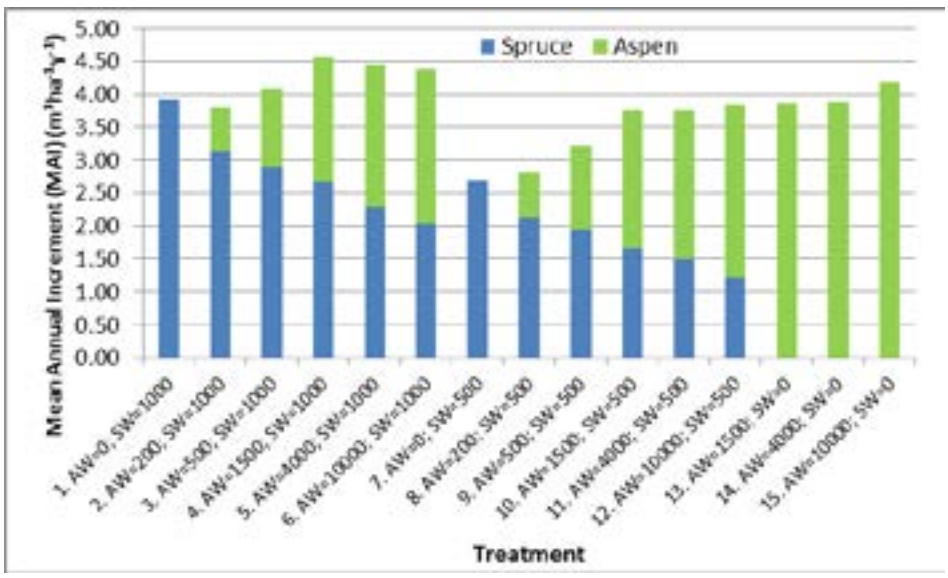
Cortini, F., P.G. Comeau and M. Bokalo. 2012. Trembling aspen competition and climate effects on white spruce growth in boreal mixtures of Western Canada. Forest Ecology and Management 277: 67–73.

Oltean, G., P.G. Comeau and B. White. 2016. Linking depth-to-water topographic index to soil moisture on boreal forest sites in Alberta. Forest Science 62: 154–165.

For additional information on WESBOGY LTS please contact Phil Comeau (phil.comeau@ualberta.ca) or Mike Bokalo (mike.bokalo@ualberta.ca).

Effects of aspen density on diameter of aspen and white spruce at age 20 (Values are averages for the four oldest LTS installations).



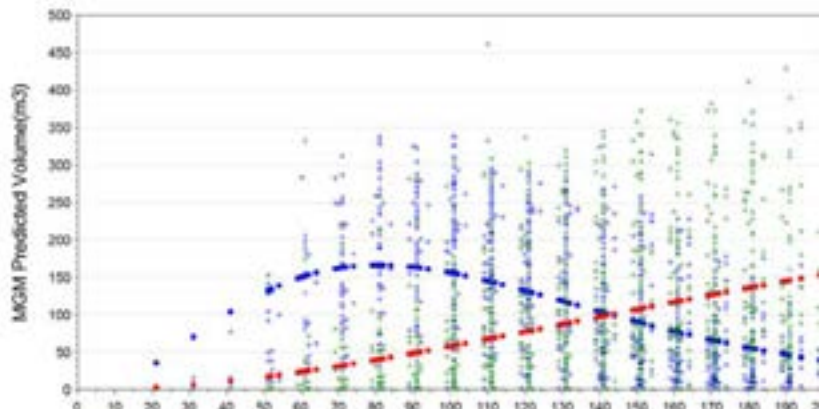


Predictions of effects of the 15 treatments on Mean Annual Increment based on Mixedwood Growth Model (MGM) simulations to age 90 starting with age 10 measurements.

Mixedwood Growth Model

The Mixedwood Growth Model (MGM) is a deterministic, distance-independent, individual tree growth model developed by the University of Alberta for the western Canadian boreal forest. MGM simulates the growth of five major boreal species—white spruce, lodgepole pine, trembling aspen, black spruce, and jack pine—in pure or mixed stands. The model starts with a tree list or stand summary data. MGM then uses growth and survival functions to project the list of trees into the future. Outputs include yield tables and charts portraying averages and totals for the conifer and hardwood components including estimates of above ground tree biomass. The Stand Visualization System (SVS) can also be used to provide visual snapshots of the stand structure at specific points in time.

Conifer and deciduous composite yield curves for understory protection harvesting,



MGM is well suited for modeling both natural and managed stands including simple, even-aged stands, mixed species stands, as well as more complex (multi-age/multi-cohort/vertically structured) stands created through partial harvesting practices such as understory protection or other tending practices.

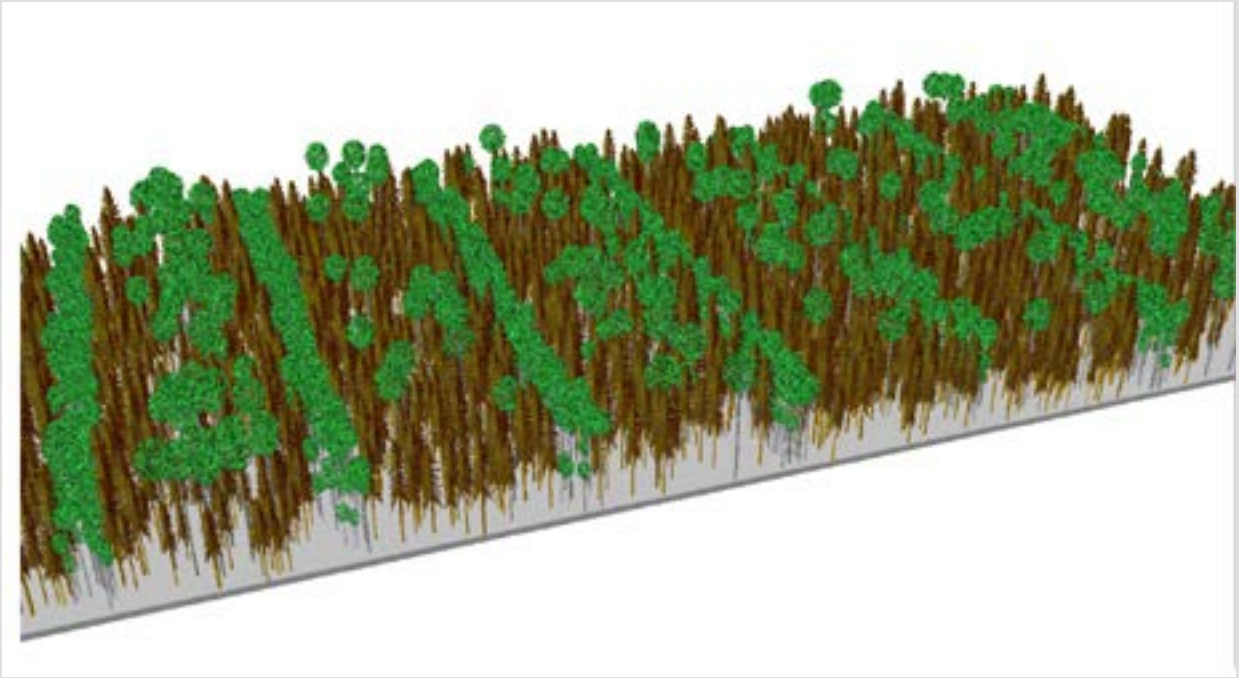
In a paper published in 2013[1], MGM demonstrated unbiased predictions of yield for both pure stands and mixtures of white spruce and aspen. Subsequent publications have shown similar results for lodgepole and jack pine. Other publications[2] have also demonstrated the application of MGM in forest management planning and decision making.

Development of MGM has been supported by industry, provincial and federal governments, and the Forest Resource Improvement Association of Alberta (FRIAA). This work has focused on several key needs:

- The estimation of mean annual increment (MAI) from performance survey data
- Yield estimation in support of forest management plan development (both natural origin and managed stands)
- Developing and evaluating response curves for understory protection and other tending practices
- Rationalizing and understanding the effects of silviculture on managed stand yields

Current work on MGM is focusing on improving the performance and utility of the model supported by better documentation, user guides and training workshops. In 2016, a proposal for a three year project to further enhance the model's utility was awarded by FRIAA. This project will begin in the spring of 2017. The model is publicly available; information on downloading and installing MGM can be found on the MGM website at http://www.mgm.ualberta.ca.

SVS image of MGM projection 40 years after understory protection harvesting.



1 Bokalo et al. 2013. The validation of the Mixedwood Growth Model (MGM) for use in forest management decision making. *Forests* 4(1): 1–27.

2 Pitt et al. 2004. *Forestry Chronicle* 80: 583–597; Comeau et al. 2005. *Forestry Chronicle* 81: 559–574; Grover et al. 2014. *Forestry Chronicle* 90: 35–43; Kabzems et. al. 2016. *Forests* 7: 5; Comeau 2014 *Forestry Chronicle* 90: 479–485.

Regenerated Lodgepole Pine Trial

Overview

After lodgepole pine is harvested and planted, the juvenile stand development is affected by the site's characteristics and any silviculture treatments applied. To assess these effects, the Regenerated Lodgepole Pine (RLP) trial began in 2000. It uses a replicated split-plot design consisting of 102 one-hectare permanent sample plots, each with four sub-plots, distributed throughout the upper and lower foothills natural sub-regions. After clearcutting and either drag scarification, mounding or no further soil treatment, the plots were planted at a range of densities from zero to 4444 trees per hectare. Two of the four sub-plots in each main plot were weeded, and two were later thinned, resulting in four treatment combinations: control, weed only, thin only, and weed and thin. Weeding involved either chemical or mechanical reduction of hardwood, shrub and herbaceous competition during the first six years following planting. Thinning (removal of excess trees) to target densities was undertaken between 2012 and 2014.

Results

The condition and growth of planted and natural regeneration were assessed bi-annually, and mortality checked annually, for the entire regeneration phase of stand development, defined in Alberta as the first 14 years following harvesting. The data have been used to create the Foothills Reforestation Interactive Planning System (FRIPSY) based on the following findings.

- Stand density (live trees per hectare) and percent stocking of planted lodgepole pine at the end of the regeneration phase can be predicted at the stand level (i.e., within individual openings created by clearcutting) from natural sub-region, soil moisture class, climatic risk, and treatment prescription or history (site preparation, time of planting, planting density, and weeding).
- Density and stocking of naturally regenerated lodgepole pine and aspen are more variable and require addition of pine and hardwood stocking indices for reliable prediction at the stand level. These indices can be estimated at the stratum level (i.e., for pine or pine-hardwood regenerated yield strata within forest management areas) from natural sub-region, soil moisture class, and treatments, but prediction at the stand level require's additional stocking information,

normally derived from establishment surveys conducted five to eight years after harvest.

- Tree diameter and height distributions, and hence basal area and top height, can be forecast at the stratum level for planted and naturally regenerated pine providing that information on natural sub-region, soil moisture and nutrient classes, climatic risk, and silvicultural treatments is available.

- Consistently accurate forecasting of average diameter and height growth at the individual stand level is possible only if both early height and density data are available from establishment surveys. Given that for most planning purposes, stratum-level estimates of these variables suffice, it is unlikely and probably unnecessary that such data be collected in routine operational establishment surveys.

- Climatic mortality risk can be estimated as a function of annual evapotranspiration rates and average spring temperatures. Data for these two variables generated by available climate models[1] have been combined with RLP mortality data to map mortality risk zones.

Applications

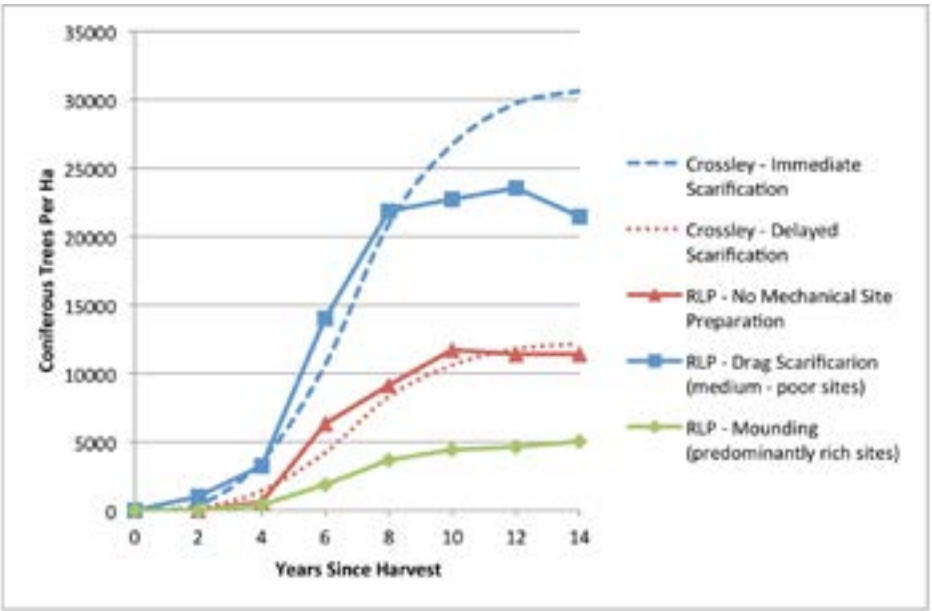
In 2000, Alberta industry and government foresters recognized a shortage of quantitative information that can be used to plan and demonstrate sustained yield management of reforested lodgepole pine stands in the Alberta foothills. While much was already known about fire-origin lodgepole pine in the Alberta foothills, there was relatively little information available to monitor and forecast the development of stands following clear-cutting. The RLP trial provided data which was used by FRIPSY to model the crucial link between reforestation management strategies, regeneration performance, and long-term sustained yield of timber.

Ongoing monitoring of the RLP trial will provide a strong and credible basis for continual improvement of the models and assumptions used in determining the levels of allowable cut that are permitted and sustainable throughout the Alberta foothills forest. Data from ongoing monitoring will be applied to verification and improvement of not only the FRIPSY model, but also other growth and yield models used in forecasting timber yields at maturity.

Next Steps

Re-measurements will continue at two to five year intervals as the stands progress towards maturity. The interval between measurements will be reviewed after each re-measurement. It will be increased from the current two years once rates of mortality, natural regeneration and growth (including responses to the recent thinning treatment) stabilize.

The RLP trial has indicated strong beneficial effects of mechanical site preparation not only on initial crop establishment, but also on longer-term regeneration performance and health. These results have important potential implications for reforestation practice, but require independent verification. Re-measurement and detailed examination of a trial installed by Sundance Forest Industries in 2001–2002[2] to investigate harvesting and site preparation will be undertaken in 2017 and 2018 for this purpose.



Coniferous natural regeneration in pine stands following harvest. Average densities from the Regenerated Lodgepole Pine (RLP) trial are compared to an earlier study by Crossley (1976[3]). RLP results for non-scarified sites closely follow the trend reported by Crossley for cut blocks where scarification was delayed. RLP results following drag scarification are similar to Crossley's trend for immediate scarification except that densities are shown to decline at older ages. The decline in the RLP trial is the expected result of self-thinning mortality at high densities. (Crossley's trend line was based on trees alive at 14 years and does not incorporate trees that died previously.) RLP densities following mounding of predominantly rich competitive sites are relatively low. The Crossley study was limited to satisfactorily restocked cut-blocks, and therefore tended to exclude such sites.

1 Wang, T., Hamann, A., Spittlehouse, D., Carroll, C. 2016. Locally downscaled and spatially customizable climate data for historical and future periods for North America. PLoS ONE 11(6). doi:10.1371/journal.pone.0156720.

2 Landhäusser, S. M. 2009. Impact of slash removal, drag scarification and mounding on lodgepole pine cone distribution and seedling regeneration after cut-to-length harvesting on high elevation sites. Forest Ecology and Management 258: 43–49. doi:10.1016/j.foreco.2009.03.045.

3 Crossley, D.I. 1976. The ingress of regeneration following harvest and scarification of lodgepole pine stands. Forestry Chronicle 52(1): 17-21.

Foothills Reforestation Interactive Planning System

Overview

The Foothills Reforestation Interactive Planning System (FRIPSY) project was developed to allow forest planners and silvicultural practitioners to apply the results of the Regenerated Lodgepole Pine (RLP) trial. It is a predictive decision-support tool used in conjunction with other data and models for reforestation and yield planning of stands regenerated following harvesting operations in the Alberta foothills natural sub-regions. To date, the project has focused on forecasting regeneration performance for lodgepole pine, plus incidental aspen occurring in pine stands. Over the next three years the focus will be broadened to include black and white spruce.

FRIPSY is programmed as an Excel spreadsheet application with embedded macros ("XLSM" format) and Virtual Basic (VBA) code. It can be used in batch mode or interactively in single stand mode. Forecasts are generated by the user inputting site and treatment information. A map (or digital GIS dataset) identifying climatic risk zones is provided to users. All other inputs are generally available to, or generated by, users holding timber tenures in the Alberta foothills.

Results

Much has been learned from the RLP trial about the extent to which lodgepole pine regeneration performance can be forecast from site and treatment factors, and the associated limitations. This has resulted in the development of a regeneration model that forecasts performance as defined by the Reforestation Standard of Alberta[1] (RSA) at 12 to 14 years following cut, including responses to site preparation, planting, and tending treatments.

Applications

Alberta reforestation policy recognizes the need to link reforestation strategies to sustained yield management objectives. Since 2004 the Alberta government, in association with the forest industry, has been developing a quantitative link between managed stand yields at rotation and earlier regeneration performance. In 2009 the Alberta Growth and Yield Projection System (GYPSY)[2] was released and approved for linking regeneration

performance to mean annual increment. FRIPSY matters because it provides the crucial additional link between reforestation management strategies and regeneration performance.

Past versions of FRIPSY forecast the stand variables required as input by GYPSY, but prediction of yields at rotation age required that the user run FRIPSY and GYPSY separately. The 2017 version integrates the two models. It includes computer code ported from Excel GYPSY into FRIPSY, effectively "re-creating" the GYPSY outputs. The integrated version allows managers to quantitatively forecast the impact of alternative operational treatments like site preparation, planting and tending on timber yield at rotation. It can be used at the stratum level to support strategic planning decisions made prior to harvesting and reforestation treatments (i.e., silvicultural prescriptions). For plantations, or for natural regeneration where establishment or other early stocking survey data are available, it can also be applied at the stand level following reforestation treatments to forecast whether stands are "on-track" to meet the reforestation standard, or whether remedial management interventions are required.

Next Steps

Testing of FRIPSY is ongoing, and a number of enhancements are planned for the next three years.

A major but necessary enhancement to FRIPSY is the inclusion of non-pine species. The system currently does not provide forecasts for species other than lodgepole pine and aspen. Users have expressed a strong interest in being able to forecast performance of mixed-species stands, particularly mixtures of pine with not only aspen, but planted or naturally regenerated black and white spruce. This will require acquisition and analysis of data from sources besides the RLP trial, such as the Alberta Provincial Growth and Yield Initiative (PGYI) and the FGrOW Empirical Post-harvest (EPH) project.

FRIPSY currently projects regeneration performance at 12 to 14 years after cut, and then relies on GYPSY to project stand conditions to rotation. Ongoing re-measurements of the RLP trial will facilitate extending the FRIPSY regeneration model beyond 14 years.

The current FRIPSY Excel program is already complex and large. As complexity increases, adding new functionality to the existing program becomes more time consuming and prone to error. As size increases, so does the likelihood of file corruption and slow execution time. A different and improved platform will be introduced once the capability has been developed to forecast multiple species.

1 Reforestation standard of Alberta. 2016. Alberta Agriculture and Forestry. Edmonton.

2 Huang, S., Meng, S., & Yang, Y. 2009. A growth and yield projection system (GYPSY) for natural and post-harvest stands in Alberta. Alberta Sustainable Resource Development Technical Report Pub. No. T/216.

Realized Gain Trials

Background

In Alberta, one of the significant challenges with determination of genetic gain in breeding programs, called Controlled Parentage Programs (CPPs), is the lack of realized gain trials (RGT). Genetic gain, in Alberta, is currently calculated on the basis of height gain as measured through controlled progeny trials at experimental test sites. Progeny trials are established on uniform sites, at regular inter-tree spacing, and are controlled for vegetative competition and natural ingress. These types of trials are generally considered adequate for comparing and ranking the families included in the program, however they do not adequately assess performance of genetic stock under normal, operational reforestation conditions. As a result, the link between height gain and volume gain per area of deployment is poorly understood. Realized gain trials are necessary in order to know how much the improved stock increases growth and volume yield.

Overview

Through a grant agreement with FRIAA, six Alberta forestry companies are collaborating with the University of Alberta (through an NSERC Industrial Research Chair), Isabella Point Forestry, and Alberta Agriculture and Forestry to carry out this project.

The RGTs to be established though this project are designed to quantify the volume gain from improved stock instead of wild seed sources. These trials will have substantial value in the monitoring and validation of genetic gain assumptions in current Forest Management Plans, while also providing critical data for the development of growth models that are better able to project yield increases resulting from deployment of improved stock.

All six participating companies have selected field sites from CPP areas within their Forest Management Agreement (FMA) areas to install trial plots during the 2017 planting season. Exact locations were determined during the 2016 planning year based on harvest schedules, site preparation and access. Companies endeavored to select sites within their targeted CPP region across the range of provincial seed zones in which they currently operate. Sites were selected based on uniformity and the ability to ensure all plots within the site are

placed in areas that are ecologically and silviculturally comparable. All plots within an individual site must have the same silviculture treatment regime. Sites will be managed as operational cutblocks with installed plot locations recorded by GPS. The remaining areas in the blocks will be planted to the assigned wild or improved, based on the normal operational practices for each company.

All seedlots to be tested and produced from these CPPs, and their associated seed orchards, are for operational deployment with the intent of enhancing the value of the forest resources in Alberta. In addition, given the increasing constraints on the landbase due to mountain pine beetle and climate change, and particularly energy development, genetic gain improvements may be necessary to sustain the current yields from the forest resources in Alberta through deployment of genetically superior seed.

Methods

The following summarizes the trial design details:

1) Seedlings for each installation include improved and unimproved seedlots grown at the same time, at the same nursery, and of the same stock type.

2) For each cutblock selected, two or three similar areas will be selected a minimum of 80m apart for a total of 20–30 plots for each participating company.

3) Depending on the space available in any given cutblock and current seed inventories, the third plot may be installed with an "elite" seedlot.

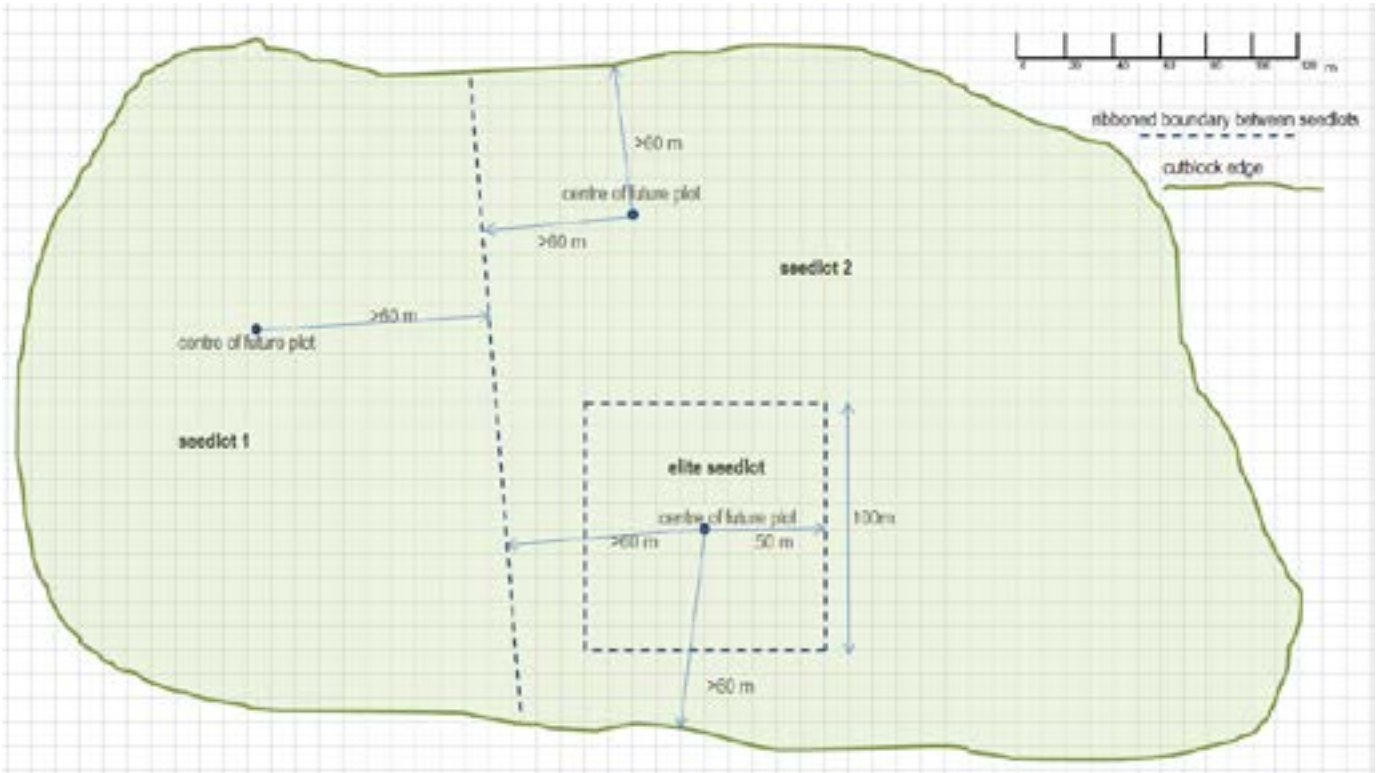
4) Stock will be randomly assigned to the plots within each cutblock. Plots will be planted at the current operational spacing for that species for each company. All plots within each cutblock will be planted on the same day, by the same planting crew and prior to operational planting of the remaining area of the cutblock.

5) Permanent sample plots will be established and an initial measurement completed in a subset of the installations.

6) Stand tending will be carried out according to company operational practices and in the same manner as the remaining block area.

Outside the funded scope of this project, additional measurements of established PSPs will be completed periodically. Additionally, a graduate student (MSc) from the University of Alberta will measure and assess all paired plots and address questions associated with early growth and survival.

Example of plot centre location and seedlot boundary, three seedlots. S. John, Isabella Point Forestry.



Empirical Post-Harvest Stand Assessment Project

Until relatively recently, the focus of growth and yield practitioners has been on developing good estimates of volume in mature, natural stands. As more of the landscape is harvested, it is increasingly important to understand how managed stands grow and respond to treatment and there is a recognized shortage of measurement data available for post-harvest regenerating stands, particularly for stands older than performance survey age. The Empirical Post-Harvest Stand Assessment Project (EPH) is both assembling available measurement data and making new measurements on stands where previous measurement data are available. These data will be analysed in conjunction with silviculture records to develop scientifically defensible relationships between treatments and stand conditions at different ages.

This project was initiated in 2016 and is being supported through FRIAA Open Funds. It builds on a project that began in 2008 and created a database that included permanent sample plot data from managed stands, establishment and performance survey data, and silviculture records for the surveyed opening. An important component of the project was re-measurement in 2009 of 58 older openings that had performance-style survey data collected in the 1980s and 1990s.

The project is still in its initial stages and has focused on obtaining more managed stand measurement data, including establishment and performance survey data, and other trial data including the WESBOGY Long-term Study. Fifty five of the openings measured in 2009 are being re-measured and additional stands with performance surveys 5–10 years ago will also be selected for re-measurement. These will be chosen to fill gaps in strata and silviculture treatment information.

The most important outcomes of the project will be improved understanding of the relationships between silviculture treatments, early stand composition and conditions in more mature stands. The data and analysis will be shared with growth model developers to build growth functions for managed stands and to aid in model calibration and validation. The results of the analysis will also help silviculturists to better evaluate potential long-term growth trajectories of different silviculture strategies and adjust future activities accordingly.

Tree Species Adaptation Risk Management Project

Wide spread forest tree species, such as white spruce and lodgepole pine, comprise a series of populations that are genetically adapted to the local environment. These local environments include climate and seasonal weather conditions, insects, diseases, and circadian rhythms arising from variation in day length. When choosing seed and vegetative materials for reforestation, foresters attempt to preserve this local adaptation so the populations remain in equilibrium with their environment. In addition, foresters ensure that planted forests retain sufficient genetic diversity to continually evolve in response to changes in their environment.

Climate records show that both local and broad scale weather patterns are changing at an unprecedented rate. In contrast, due to their perennial nature, long generation intervals and slow evolution, forest trees are unlikely to be able to keep pace with the current rate of environmental change. This alteration in the balance between the trees and their environment will lead to forests that are vulnerable to drought, insects and diseases, resulting in a decline in forest productivity, and consequently a decline of the forest industry in Alberta. On the other hand, while climate change may have a negative effect in some forest regions, a positive impact may be felt in others. For example, an increase in summer heat may lead to loss of productivity in the drought-prone boreal forest region while increasing productivity in the foothills and mountainous areas where precipitation is currently high but the growing season is short and cold.

Recognizing that the negative and positive impacts of climate change can be addressed through the genetics of tree populations and tree breeding programs, the Climate Change and Emissions Management Corporation (CCEMC, now Emissions Reduction Alberta) funded the Tree Species Adaptation Risk Management (TSARM) project from 2012 to 2015. The $3-million project was implemented by forest companies, the Alberta Government, and the University of Alberta, and was administered and managed through Tree Improvement Alberta (TIA).

The project had the following major activities:

- Extensive analyses of all available white spruce and lodgepole pine data from provenance and progeny trials linked to tree breeding programs in Alberta. These analyses have provided a measure of the transferability of genetically improved seed among breeding regions.
- Climate envelope modeling of all Alberta breeding regions for coniferous and deciduous tree species was completed to predict the extent and direction of climate change in each breeding region for all biologically meaningful climatic variables.
- A vulnerability and climate change risk analysis was completed for all 24 Alberta breeding programs using a set of common criteria including factors such as the climatic source of parent trees in the program breeding population, genetic diversity in the seed the breeding program is deploying, seed production from the program seed orchards, test site locations and ranges, and other criteria that can affect the breeding program and program owners' ability to meet their reforestation obligations in a changing climate.
- Development and comparison of various vegetative propagation techniques for aspen designed to reduce the cost per plant when clonal deployment is being considered for aspen reforestation. Unlike other poplars, aspen is difficult and expensive to propagate clonally, and therefore more challenging as a deployment option compared to seedlings. This is a potential barrier to using selected and genetically improved clones as part of a climate change adaptation strategy. Replacing post-glacial clones with selected or bred clones is a climate change adaptation strategy for a species that lacks significant natural regeneration through seed, which is how genetic recombination, evolution, and adaptation take place.
- Identify, select, and develop new genetic field test sites in parts of the province that have much drier, warmer, or cooler climates than the existing provenance and progeny trials. These sites are critical for providing space for a series of new provenance trials designed to identify climatically tolerant populations and clones from across Canada, for our commercially important species.

Results from the first two activities have been published in two journal articles, and separate reports were written for the owners of breeding programs to assist with management and planning of their tree improvement programs in light of climate change and the adaptation challenges it poses to our forests.

Stand Dynamics after Mountain Pine Beetle Attack

Overview

Members of FGrOW were among the first people in the province to realize the importance of understanding how forests will respond to attack by mountain pine beetle (MPB). A push to begin quantifying development in stands attacked by MPB was inspired by a 2007 field tour organized by the FGYA in parts of British Columbia that were heavily impacted by MPB.

Working with the fRI Research Mountain Pine Beetle Ecology Program, the first step was to protect a network of 240 existing pine permanent sample plots from harvesting and other human interventions. This was seen as an ideal opportunity to capitalize on existing information about pre-attack conditions and to continue monitoring these plots in the event of attack by MPB.

Results

These plots were assessed from 2008 through 2016, with 63 attacked plots still being actively monitored. Analysis of the data gathered has so far focused on rates of infection and mortality caused by MPB. It has shown a wide range of infection and mortality, with some stands appearing to be resilient to MPB. The potential significance for salvage and rehabilitation planning makes it important to understand the factors causing this variability.

The results also suggest that predictions for stand susceptibility based on work in British Columbia are not accurate in Alberta. This has prompted both further analyses using Government of Alberta overwintering success and spread data, and an assessment of plots that were MPB-infected by 2010 but have not been monitored since. Results of these undertakings will be available by mid-2017.

Next Steps

A complementary project began in 2015, with support from the FRIAA Mountain Pine Beetle Rehabilitation Fund. It looks to fill the gaps in knowledge of how stands with high levels of MPB-caused mortality are developing. 119 plots were established throughout the range of natural sub-regions with pine stands that have been attacked by MPB; 32 existing government and industry PSPs were also re-measured.

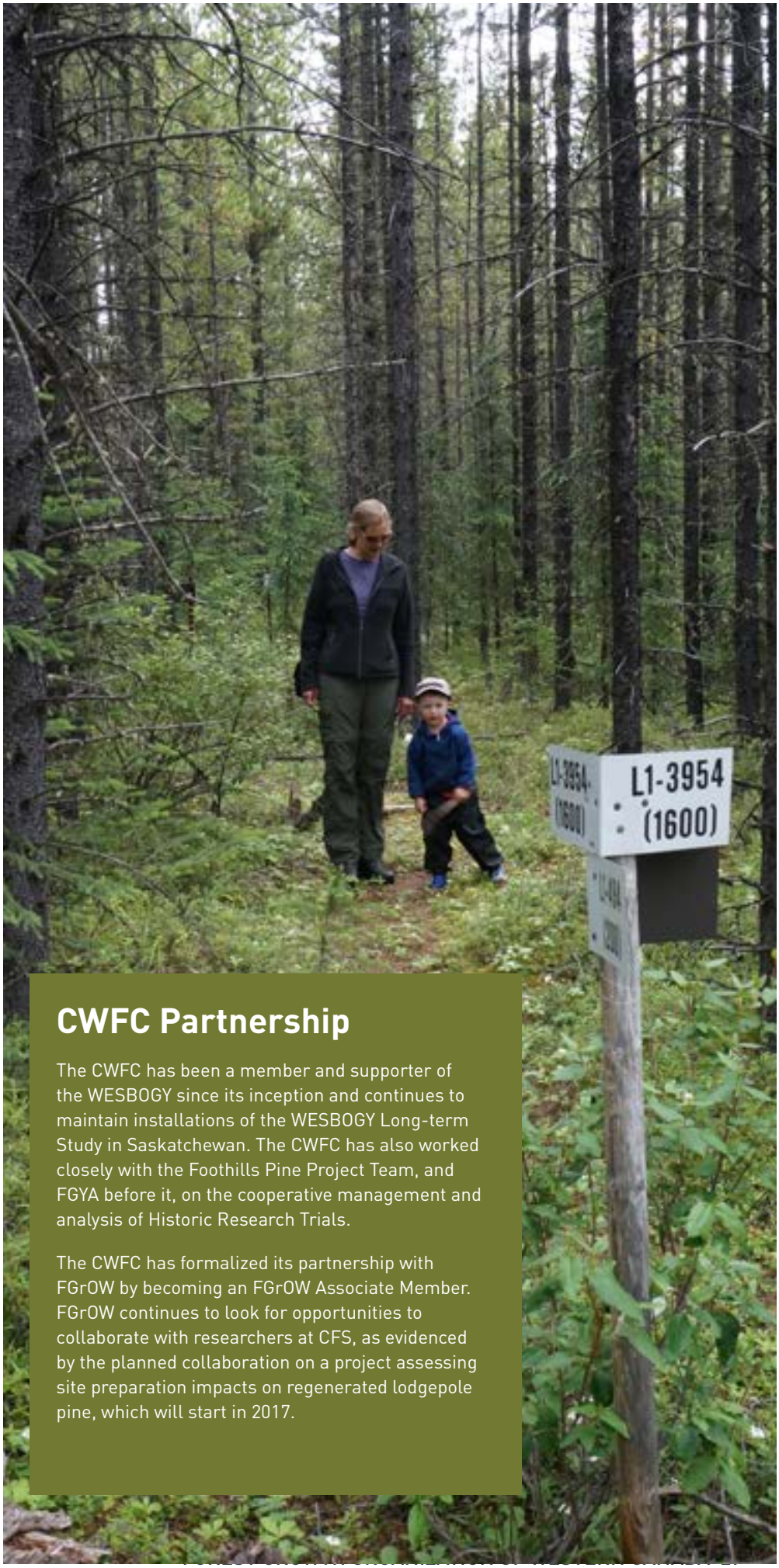
Data from both projects will contribute to models and yield curves that predict response to MPB attack and will be useful in aiding forest managers in making decisions about where to salvage or apply rehabilitation treatments. The data will be used to make statistically sound conclusions regarding the effects of MPB on stand dynamics, the likely regeneration outcomes in pine dominated stands killed by MPB, and projected growth trajectories of these stands, as well as for developing yield curves to support allowable cut calculations.

Historic Research Trials

Beginning in the late 1930s and ending in the 1980s, the Canadian Forest Service (CFS) established a number of fertilizer and spacing trials in lodgepole pine stands throughout Alberta. After visiting them in August 2001, representatives of the FGYA, the CFS, and the Government of Alberta concluded that these trials were invaluable resources for forecasting, monitoring and demonstrating the effects of nutrition and density management. Since 2002, the FGYA (now the Foothills Pine Project Team of FGrOW), Alberta Agriculture and Forestry (AF) and the Canadian Wood Fibre Centre (CWFC) of the CFS have had a signed agreement for joint management of the trials to ensure their ongoing protection, measurement and interpretation.

FGrOW and AF are responsible for trial measurements and support the CWFC on data analysis. The CWFC uses the data in their wood properties research, which focuses on understanding and modeling the relationships between tree growth and various wood fibre properties, and the influence of site and silviculture treatments. Their models of these relationships could link with other forest management planning tools and have been integrated with MGM.

Results from these trials can only be of increasing importance as landbase pressures rise and forest managers look for ways to improve productivity on the land still available for harvest. Continued measurement of the trials will provide an invaluable resource for supporting growth model development and creating accurate projections of treatment response for use in yield curve development. Data from these trials has already been used in the development of the Tree And Stand Simulator growth model in BC. These improved models will allow forest managers to make informed decisions about the potential return on investment for enhanced forest management activities.



CWFC Partnership

The CWFC has been a member and supporter of the WESBOGY since its inception and continues to maintain installations of the WESBOGY Long-term Study in Saskatchewan. The CWFC has also worked closely with the Foothills Pine Project Team, and FGYA before it, on the cooperative management and analysis of Historic Research Trials.

The CWFC has formalized its partnership with FGrOW by becoming an FGrOW Associate Member. FGrOW continues to look for opportunities to collaborate with researchers at CFS, as evidenced by the planned collaboration on a project assessing site preparation impacts on regenerated lodgepole pine, which will start in 2017.

Provincial Growth and Yield Initiative

The forest industry and the Government of Alberta have invested millions of dollars in permanent sample plots (PSPs). Historically, the chief use of these plots has been to develop yield curves for timber supply analysis and allowable cut calculations. This has been done company by company, with an analysis-intensive process. More recently, PSPs have been used to develop growth models, opening the door for a new way of developing yield curves and streamlining companies' PSP programs.

The development of growth models and their increase in importance in yield curve development, along with the recognition of the importance of a better understanding of managed stand dynamics gave rise to the Provincial Growth and Yield Initiative. PGYI is a cooperative data collection and management program that supports development, validation, and calibration of growth models.

The Provincial Growth and Yield Initiative is the first undertaking of its kind in Alberta, and possibly in Canada. By joining forces and pooling their permanent PSP data, the province's forestry industry is reducing the workload on individual forestry companies while increasing the amount of data available to those developing growth and yield models.

Working with Alberta Agriculture and Forestry, FGrOW has developed standards for collecting PSP data and has assigned each of the participating organizations the number of plots it must maintain based on the company's annual allowable cut. Companies must also have specific types of plots based on the natural subregions and forest cover types on their contributing land base.

Participating companies load their required PSP data into a central database that all contributors and model developers have access to. If they wish to do so, companies can contribute additional PSP data that are only available to model developers.

The PGYI database is already proving to be an excellent resource. It has been used to support FGrOW projects at UofA and will be used in 2017 for GYPSY development, as well as for two other FGrOW projects. As participating companies have made a long-term commitment to establishing and re-measuring PSPs for PGYI, the database will represent the range of stand ages and conditions in Alberta forests. This database will continue to be a resource for growth model development and for answering new questions about forest growth and treatment response.

Mixedwood Treatment Response

Over sixty percent of the contributing landbase from the Province's FMAs is composed of aspen and white spruce stands with varying proportions of the two species. Understanding the interactions between the two species has important implications for forest management, including forest health, meeting biodiversity targets and reforestation obligations, and calculating or increasing annual allowable cuts. However, mixedwood interactions are complicated and, although experienced silviculturists have a good understanding of the desired future forests that they are creating, these relationships are difficult to quantify or accurately reflect in growth models.

The Mixedwood Project Team is focused on improving predictive tools and the understanding of treatment response in mixedwoods. As part of their work, the Team has established two long-term trials aimed at obtaining information about aspen-spruce interactions following treatment.

Dynamic Aspen Density Experiment

In clearcut stands, there is value in regenerating aspen in combination with spruce, with aspen serving as protective cover and providing an additional source of merchantable timber. Although the value of aspen is recognized, we still need to understand the impacts of aspen on the growth of the understory spruce, so that we can best manage for both species. DADE was initiated in 2008 and is investigating the response of white spruce to varying aspen densities. Installations were established in fourteen 17- and 22-year old stands with aspen densities over 10,000 stems per hectare and planted white spruce densities of at least 1,000 stems per hectare. In each installation, aspen densities were then modified to one of the following 5 treatment densities: unthinned (control), 0 stems/ha, 1,000 stems/ha, 2,500 stems/ha or 5,000 stems/ha. To date, two measurements have been completed on the majority of the installations.

Strip Cut Understory Protection Project

In stands with a mature aspen overstory and a sub-merchantable spruce understory, clearcut harvesting results in destruction of understory trees. One method for taking advantage of existing merchantable timber while still protecting younger, viable spruce seedlings in the understory is stripcut understory protection harvesting. With this method, aspen are removed in parallel strips; machinery then "reaches" on either side of these machine corridors to remove the deciduous overstory, protecting existing understory spruce in the reach areas. The purpose of the SCUP Project is to collect data on the growth of the understory white spruce trees after deciduous overstory removal, and on aspen regeneration and growth in the resulting machine corridors. Beginning in 2005, 92 PSPs were established in openings that were harvested using strip cut understory protection techniques. By 2019, 10-year re-measurements will have been completed on all the plots.

Applications

Early results from both trials have been used to evaluate the performance of existing growth models, GYPSY and MGM. However, in both cases most of these stands are less than 10 years after treatment and relationships are still developing dynamically. Measurement of both trials will continue on a 5-year basis until treatment response has stabilized; in the interim, data will continue to be used for evaluation of, and improvements to, both GYPSY and MGM.

Although still in the early stages of measurement, these two projects are of high importance to many forestry companies working in Alberta. The most important outcomes of the project will be the ability to do more effective crop planning and to create defensible yield curves for strip cut understory protection.

Venue for Discussing Management Challenges

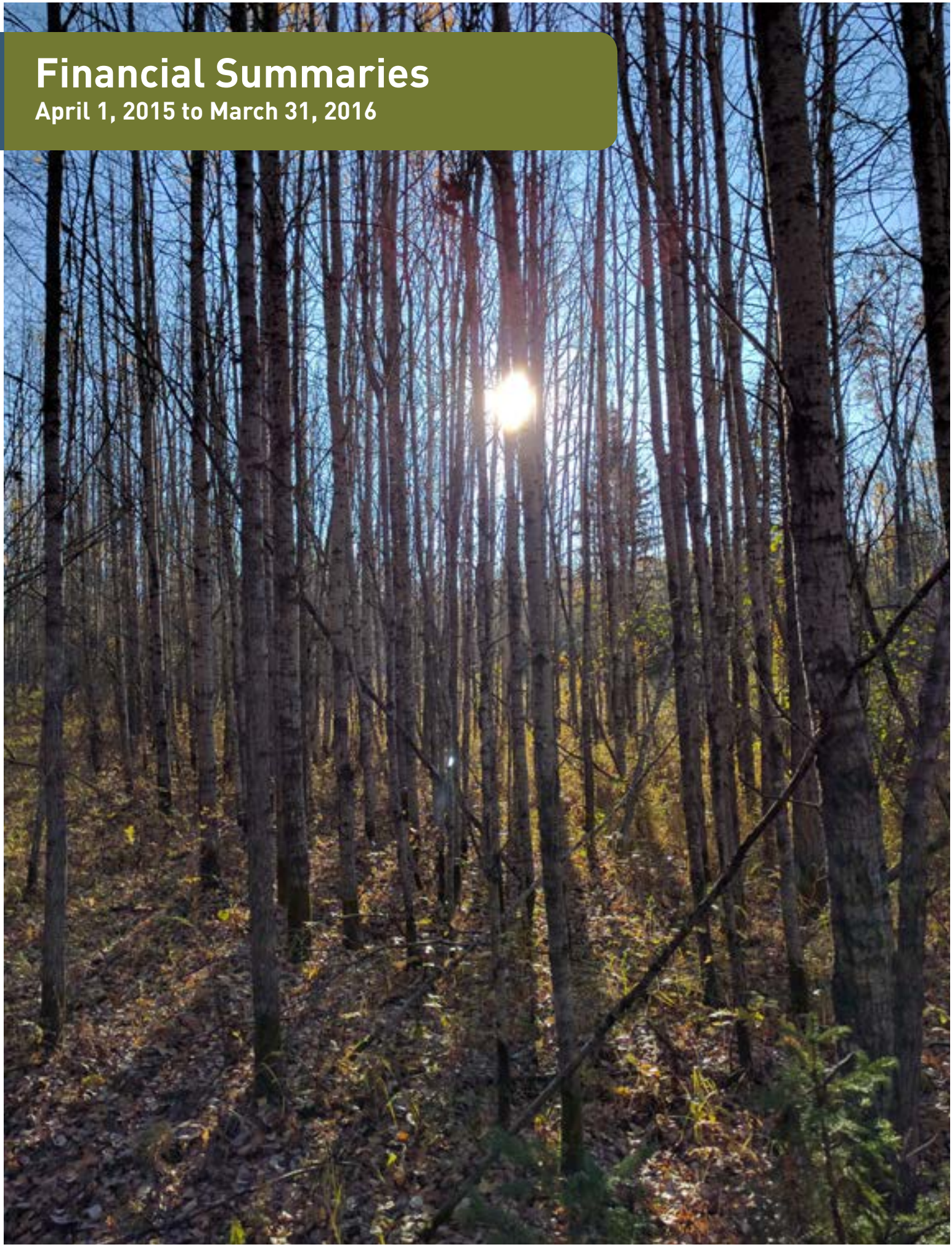
In addition to pursuing research and providing knowledge transfer opportunities, FGrOW provides a venue for members to discuss forest management issues of concern through the Policy and Practice Project Team.

These discussions can do more than make members feel happy to know that they are not alone. Outcomes have included:

- A subcommittee of members working to develop recommendations for policy changes and presenting them to the Government of Alberta
- Hosting a workshop for members to learn about and provide feedback on new government guidelines for growth and yield programs
- Identifying new areas of research or tool development

Financial Summaries

April 1, 2015 to March 31, 2016



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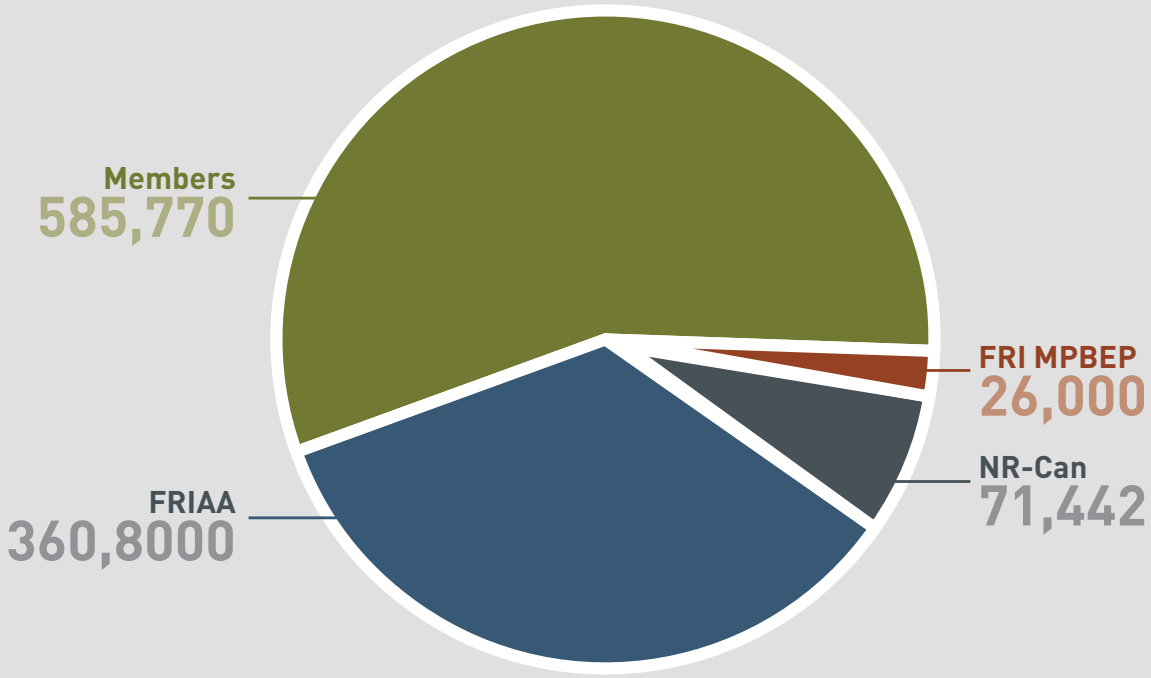
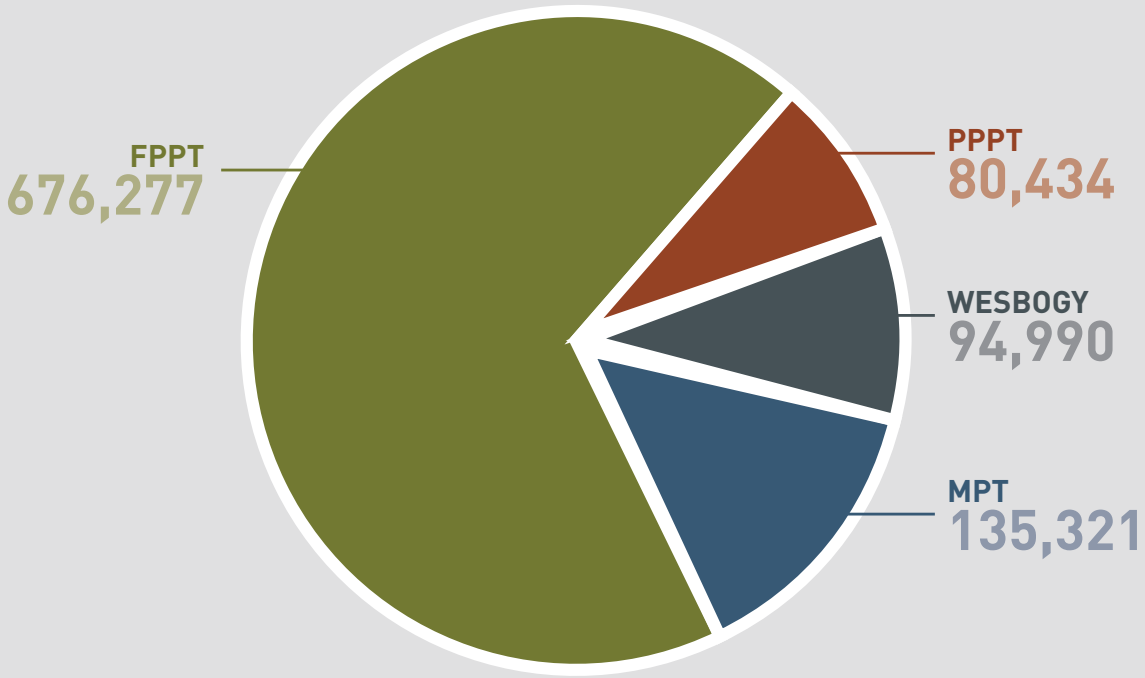


Project Team Expenditures



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