FPInnovations

Forest Operations
2017–2018 Collaborative Research Program
April 2017

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Forest Operations
2017-2018 Collaborative Research Program

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2017–2018 Project Summaries

FLAGSHIP INITIATIVES

The Forest Operations division runs a number of flagship initiatives that are clusters of cross-group projects focused on common goals and objectives. These initiatives benefit from enhanced focus on speed of delivery and communications to members. In 2017–2018, the initiatives include:

Nova Scotia Innovation Hub

Steep Slope Initiative

Mid-Term Fibre Supply Initiative

Transportation Initiative

Forest2User 4.0

NOVA SCOTIA INNOVATION HUB

The emerging global bio-economy presents an opportunity for Nova Scotia's renewable bio-resource sector (forest, agricultural, ocean, and municipal solid waste). Nova Scotia is well positioned to lead in providing low-carbon solutions that will also enhance economic prosperity in the province. The creation of an Innovation Hub (iHub) is a first and critical step toward this outcome and will foster strong collaboration among all stakeholders, including FPInnovations. It will determine the primary actions required to establish a compelling value proposition to attract and support an industrial cluster of bio-based processing and manufacturing industries, including a liquid fuel biorefinery.

While year 1 has been successfully completed, the full project roster for 2017–2018 is still in development. The Forest Operations division iHub projects that have started are those under Transportation and Infrastructure. FPInnovations will conduct activities related to two main areas: maximizing payloads on restricted routes; and implementing technology to improve energy efficiency, productivity, and safety.

STEEP SLOPE INITIATIVE

Steep terrain is an important fibre pool in western Canada, and it is the source of more than a quarter of the annual allowable cut in B.C. However, timber harvesting on steep terrain presents several challenges related to safety, cost, investment in equipment, timber supply, regulatory compliance, environmental impact, availability of skilled labour, and planning.

In response to demand from its members, FPInnovations is taking a lead role in building a steep-slope operations research and development plan called the Steep Slope Initiative. This five-year initiative engages forest industry members, equipment manufacturers and distributors, regulators, and other stakeholders in finding solutions to the steep-slope operations challenges.

Objectives:

- Increase the protection of workers on steep slopes and reduce lost-time claims to 50% of the 2014 baseline.
- Increase operating margins by $5/$m^3$ through a combination of lower harvesting costs and higher timber value, strengthening mills, securing local jobs, and stimulating economic development.
- Increase access to up to 2 million m^3 of timber that is currently unavailable while preserving ecosystem integrity.

Evaluation of Steep-Slope Harvesting Technology

The focus of this project will be on winch-assist equipment. Nine brands of equipment are operating or expected to arrive in B.C., and it is anticipated that other new innovative equipment may become available and that additional priority assessments may develop. Innovative cable-harvesting systems, such as grapple cameras and yoaders (loaders adapted to yarding), may also become priorities for assessment.

Implementation of new winch-assist technology involves a learning curve with various challenges in adapting to B.C. conditions. New practices in planning, layout, and operating must be developed. The project will target frequent communication across various platforms to address the priority need for information on this new technology. A technology watch will monitor international and domestic developments of suitable steep-slope harvesting technologies.

Research has been done on machine stability and tilt-table testing. A stability model was developed, and a protocol was established that accurately determines centre of gravity and performs tilt-table measurements (the latter in partnership with John Deere). FPInnovations will continue to collaborate with equipment manufacturers on the development and validation of the stability model through further tilt-table testing and the sponsorship of graduate university students to work in this area.

***Objectives**:*

- Assess newly introduced winch-assist equipment according to performance, availability, environmental compatibility, and safety.
- Develop best operating procedures for winch-assist systems.
- Further develop FPInnovations' stability model for steep-slope harvesting to demonstrate the effects of machine configuration, tethering, slope, and soil conditions on machine stability; Interpret model results to provide guidance to manufacturers for design improvements, to support operator training, and to provide due diligence for steep-slope harvesting operations.
- Study the effects of soil moisture and soil type on the coefficient of friction to enhance the stability model's effectiveness.
- Evaluate other new technologies specific to steep slopes as they become available.

Analysis of Fibre Supply From Steep Slopes in B.C.

In some timber supply areas, the high costs of harvesting on steep terrain have resulted in a portion of the timber harvest land base (THLB) being underutilized. This effectively creates an unsustainable cut level in the portion of the profile that is not on steep terrain. Cost-effective harvesting methods are needed on steep terrain to provide a sustainable cut over the timber profile. Furthermore, additional fibre can be obtained by using currently uneconomical timber in the THLB and marginal wood outside the THLB. This fibre is needed to mitigate mid-term timber supply constraints created by the mountain pine beetle.

Objectives:

- Evaluate the impact of new harvesting technology in improving access to economically available fibre.

Environmental Impact of Ground-Based Steep-Slope Operations

As new ground-based harvesting is applied on steeper slopes, there is concern that ground disturbance, erosion, and slope instability will increase. Planning methods to assess hazards and avoid potential impacts, and methods for minimizing or mitigating impacts are needed. Environmental concerns should be monitored and methodologies for measuring impacts developed.

The working group on environmental impacts established in 16-17 will continue to monitor environmental issues and develop methodologies for measuring site disturbance on steep slopes. The group will also monitor ground-based harvesting activities on steep slopes to quantify and describe the soil disturbance associated with each set of conditions (soils, moisture, slopes, equipment, etc.). Results will be used to provide feedback to contractors to help them achieve site-specific levels of disturbance, and the lessons learned will be compiled in a best management practices document.

Objectives:

- Ensure sustainability by minimizing environmental impacts.
- Develop best management practices documents for steep-slope harvesting to minimize ground disturbance.

Road Construction on Steep Slopes

Road construction on steep slopes is difficult and more expensive than conventional road building because of slope instability and proximity to bedrock, the presence of larger cuts and fills and wetter conditions, and slopes often being in remote locations. Special techniques and technologies are needed to contain road costs while creating sustainable and safe access roads.

FPInnovations is targeting a 5% reduction in the development costs of steep roads, which could result in $5 million in savings in road construction per year. Better control of flyrock during blasting activities improves safety, wood quality, and ballasting productivity (e.g., typical cost of flyrock damage is $35/$m^3$). Stabilizing steep road surfaces can reduce cycle times (estimated savings of $16 500 per year per truck) and maintenance costs, increase user safety through all-weather traction control, and reduce dry-weather dust. Low-cost, self-maintaining stream crossings for low-volume roads on steep slopes will make these roads more economical to build, use, and rehabilitate, and will make the crossings more resistant to intense storms, which are predicted for many areas of B.C. as a response to climate change.

Objectives:

- Document techniques used to reduce cuts and fills during road building on steep slopes.
- Perform field trial(s) of steep-grade road surfaces stabilized with polymers and other products.
- Design ford crossings in collaboration with regulators and industry.

MID-TERM FIBRE SUPPLY INITIATIVE

Restrictions on access to traditional fibre sources will require the forest industry to increase harvest levels in timber supply areas and, given current product values, will result in significant challenges to economic viability. These challenging conditions include:

- Small tree stands.
- Low-volume stands with partial sawlog components.
- Partially harvested stands (e.g., commercial or pre-commercial thinning).
- Salvage after catastrophic events (fire, epidemics, windthrow, etc.).

Timber supply in interior B.C., for example, is becoming increasingly constrained as a result of the impact of the mountain pine beetle. Timber supply is also constrained by habitat management guidelines (e.g., caribou in the boreal forest, adjacency rules, or ungulate winter range). The forest industry needs to develop harvesting systems that are profitable in these marginally economic stands.

A multidisciplinary approach is necessary to bridge new harvesting methods, alternative transportation configurations, new equipment, sorting and processing optimization, examples from other jurisdictions, and integration of processes traditionally thought of as separate. The approach should be a balance between current and new practices.

Commercial Thinning to Mitigate Fibre Shortfalls

Commercial thinning can provide alternative fibre sources because it permits access to stands that have not yet reached maturity, especially in second-growth stands growing close to existing mills. However, commercial thinning has not been used extensively in most parts of Canada because it is more expensive than clear-cutting as a result of the low volume per tree of harvested stems, the lower harvested volume per hectare, and the protection effort toward the residual stand.

Objectives:

- Develop cost-effective commercial thinning techniques that can provide quality logs and sustain healthy residual stands.
- Assess machine productivity and costs in commercial thinning.
- Assess impacts on residual stands.

Harvesting Small-Wood and Low-Volume Stands

In eastern Canada, stands with small piece sizes are relatively common, especially in the boreal forest. The industry needs to develop processing methods that maximize log recovery and produce more or less pulp, with a stronger emphasis on local markets. The decision-making capabilities of machine on-board computers have dramatically increased over the past 10 years. In Scandinavia, these systems are widely used for optimized bucking. However, they are rarely used in Canada. This represents a huge opportunity loss in terms of production efficiency, product quality, value recovery, and costs.

In western Canada, most of the stands killed by the mountain pine beetle that are adjacent to mills have been salvaged, and all that remains are stands close to the mills that have been bypassed because of small piece sizes or stands with very long cycle times (e.g., six or more hours). Sorting at-the-stump trials in 2015 in Mackenzie, B.C., suggested the potential for up to $\$6/m^3$ in savings in processing costs if stems are pre-sorted by a feller-buncher. The application of an adapted sorting process would also contribute to reducing costs of treating stands with a small stem size.

Objectives:

- Demonstrate the potential gains in value recovery when using the optimization features of harvester on-board computers (eastern Canada).
- Compare costs and productivity for a range of sorting scenarios in stands with small piece sizes (western Canada).

Regeneration Strategies

Direct seeding has been used semi-operationally in western Canada by several FPInnovations members for approximately five years now. More research is needed on the conditions necessary for treatment success. Trials have been established across different ecological zones and with different species, and need to be remeasured to determine which cases direct seeding is appropriate for.

In 17-18, FPInnovations will focus on evaluating modified equipment and new species. There is a need for seeding of multiple species (or seedlots) in a mix. There is also interest in seeding Douglas-fir, but the irregular shape of the seed makes precise seeding mechanically challenging. Pelletizing the seed could be one way to

resolve this issue. Some work has been done in developing this concept, but issues around pellet composition and moisture retention must be addressed.

Members in the foothills of the Rocky Mountains in Alberta report having 30% seedling mortality due to winter desiccation. Returning slash to the opening could provide protection to the seedlings by maintaining snow cover or blocking wind. A field trial was established to determine the costs and effect of treatment on seedling survival, and this trial will be remeasured to assess survival.

Members have expressed interest in revisiting the use of machines for planting. Planting attachments have been developed for excavators that can cultivate and/or create a mound on the soil and plant a tree. Mechanical planting may provide a cost-effective regeneration alternative for companies facing large areas that need reforestation, and may be a safe alternative to manual planting for reforestation of hazardous terrain.

Objectives:

- Evaluate direct seeding field trials for germination success.
- Evaluate the mechanics and germination success of seeding with pelletized seed.
- Evaluate the seedling survival rate on a slash takeback trial.
- Evaluate the effectiveness and productivity of mechanical planting machines.

TRANSPORTATION INITIATIVE

Truck transportation is a cornerstone of provincial economies, and improving transportation productivity enhances the competitiveness of Canadian industry. It is well understood that maximizing a truck's payload is the key to improving transportation efficiency.

Transportation ministries across Canada have adopted stringent performance criteria to determine the safety and impact of new vehicle configurations. To enable implementation of the new configurations, FPInnovations must analyze a vehicle's dynamic performance, its road space requirements, and the impact that the new vehicle would have on existing roads and bridges. There are other factors that also influence the overall evaluation of costs and benefits, including:

Safety: Larger trucks mean fewer trucks on the road, reducing interactions with other vehicles and improving overall public safety.

Energy intensity: Larger trucks may use more fuel per trip, but they also carry a much larger payload, reducing the amount of fuel consumed per unit of payload associated with truck transportation.

Greenhouse gases and emissions: Levels of greenhouse gases and other emissions correspond with the volume of fuel used, so if less fuel is used, overall emissions are reduced.

FPInnovations is engaged in a number of initiatives across Canada to develop and promote the adoption of safe, more efficient heavy vehicles for the forest sector. Examples include:

- 9-axle B-train logging configurations in B.C. and Manitoba.
- 10-axle chip B-train configurations in B.C. and Alberta.
- Heavy-haul corridors in Que. and Nova Scotia.
- Increased capacity for designated routes in Saskatchewan.

With many of these initiatives, there are opportunities to significantly improve the competitiveness of Canadian forest companies and to decrease fuel consumption and greenhouse gas emissions. Work to capture these

benefits will continue to be the foundation of FPInnovations' Transportation and Infrastructure program. A co-operative effort between industry, government, and FPInnovations is required to achieve new gains in transportation efficiency for the Canadian forest sector.

FOREST2USER 4.0 INITIATIVE

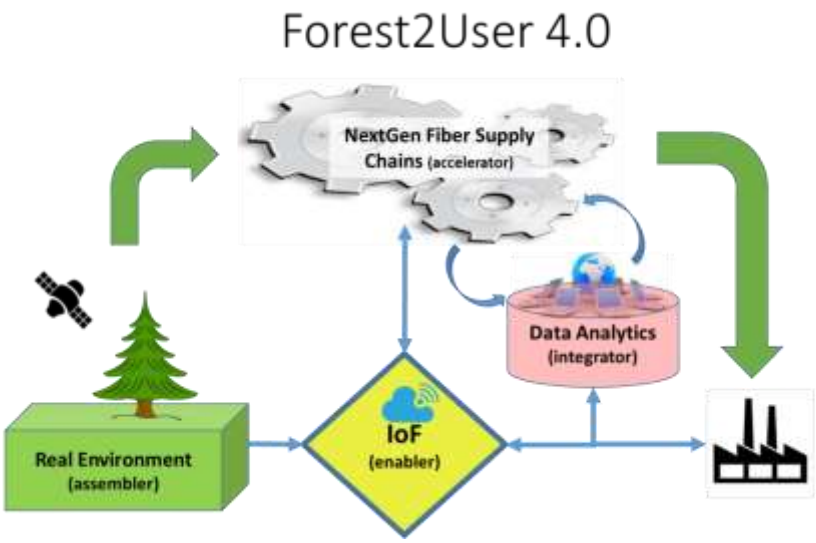
Supply chains have evolved significantly in recent decades and are on the edge of more changes driven by the digital revolution. Currently, Canada's resource sector is challenged to be part of this revolution, and the biggest gaps are the lack of adequate communication networks reaching remote locations and the limited technology levels of forest contractors.. To close these gaps, it is necessary to continue developing technologies that will enable the generation and access to real-time process input/output data relevant to supply chain management and adapted to Canadian conditions. Several enabling technologies must be developed, implemented in the Canadian context, and coordinated, including elements such as the Internet of Things (IoT), real-time communication systems, and remote sensing, among others.

The Forest2User 4.0 initiative aims at bringing the upstream part of the forest value chain to fully leverage the agility and power of Industry 4.0. One of the key goals of the initiative is to assist contractors of the forest sector value chain to be more reactive and resilient by adopting connected technologies.

Four themes have been defined for the Forest2User 4.0 initiative that will help establish the foundations of a new "connected" value chain for the forest sector. These themes are:

1. Real Environment: This theme is dedicated to developing technologies necessary to feed the value chain with foundational data on which monitoring, analysis, and decisions can be taken along the supply chain (*assembler* function).
2. Internet of Forests (IoF): Analogous to the IoT, this theme is the critical link in many remote and large areas of Canadian forests. The initiative activities involved represent the key *enablers* in the exchange of real-time data between forest sector contractors and mills.
3. NextGen Fibre Supply Chain: Under this theme, new production systems will be developed, tested, and implemented. This theme is seen as the *accelerator* of the value chain, using data of the Real Environment to adapt actions based on user needs.
4. Data Analytics: This theme serves as an *integrator* of the complete upstream process to implement "smart harvesting" and artificial intelligence to the management of the Canadian forest sector value chain.

The illustration below shows how the four components fit together along the value chain.



Theme 1: Real Environment

Theme objective:

- Develop foundational data on which monitoring, analysis, and decisions can be taken along the supply chain.

The theme has three focus areas:

- Forest resource assessment
- Operating environment
- Monitoring outcomes

1. Forest resource assessment

Developed by the Canadian Wood Fibre Centre, the concept of enhanced forest inventory using light detection and ranging (Lidar) information is the focus of improved forestry supply information. While inventory products based on enhanced forest inventory are still being developed, additional or alternative sources of information can be collected from current processes to improve knowledge about the forest resource.

Development of a Geostatistical Method for Computing Forest Biomass Volume
Biomass supply analyses currently forecast the distribution of total wood volume in each period of the planning horizon. There is a need to refine these strategic analyses to predict the volume available by the desired fibre quality attribute.

Objectives:

- Use enhanced forest inventory, terrain classification, and new provincial light detection and ranging acquisition to accurately calculate and locate volume to generate large-scale, value-based inventory.

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2. Operating environment

Data collected from machines can represent foundational data on which to establish connections with biophysical data (stand, terrain, weather, etc.). It can be acquired from production monitoring systems (on-board data loggers, on-board computers) or from external sensors.

Automated Production Data Collection in Harvesting Systems

Real-time capture of harvesting production data can provide decision-support data for wood flow and inventory management. Cut-to-length machines generate data-rich production files that need to be captured and processed into useful information and then reported to the contractor, manager, and their customers in a timely, semi-automated process. Some of the work involves testing and implementing existing original equipment manufacturer mobile device-based transfer solutions to ensure timeliness and usefulness of the data.

Objectives:

- Develop and test production data collection systems that use sensors/captors for full-tree equipment connected with on-board data loggers, such as FPInnovations' FPDat system.
- Develop and test production data collection for cut-to-length equipment

Mobile Ground LiDAR for Machine Vision

Point cloud data generated by terrestrial laser scanners provide detailed and accurate 3-D data and have the potential to reconstruct terrain, stand, and tree structure. Reconstruction algorithms for trees developed by the Canadian Wood Fibre Centre have shown some potential for implementation in an operational setting, but the feasibility of using this type of system in real time on a moving machine to help make decisions is still to be proven and implemented.

Objectives:

- Determine the acquisition feasibility and data quality from mobile light detection and ranging (LiDAR) sensors.
- Determine whether available algorithms could be used directly for terrain and stand feature extraction on the data collected to facilitate operator decisions

The outcome of this activity will help generate a road map for the implementation of more advanced systems to support operator decisions, facilitate more advanced terrain navigation, and automate repetitive or non-strategic tasks.

Advanced Roadbed Engineering Modelling

There is a lack of understanding about the impact of heavy vehicles on frozen roadbeds. Road managers need to design roadbed structures using models that account for the behaviour of frozen pavement under load. Canadian regulators do not have an adequate engineering pavement analysis procedure to evaluate the bearing capacity of frozen pavement. In 2016, FPInnovations leveraged its membership in the NSERC i3C Chair on pavement (at Université Laval) to commission advanced pavement modelling and testing in state-of-the-art, large-scale laboratory facilities. Pavement responses to vehicle loading were monitored on frozen pavement structures and used to validate and calibrate empirical models.

Objectives:

- Provide Canadian transportation ministries, in general, with improved, science-based roadbed modelling tools.

3. Monitoring outcomes

Post-harvest surveys are normally done to ensure that biomass resources have been used to their full potential and that conditions are suitable for the establishment of a desirable forest stand. With the developing field of remote sensing, images are now providing detailed and accurate information that should lead to full area census much more efficiently than with traditional ground-based methods.

Harvest Residue Assessments With UAS

Given the ease of deployment and comparably low-cost acquisition of very high resolution data in small or inaccessible areas, images based on unmanned aerial systems (UAS) could potentially be an alternative solution to conventional waste and biomass surveys. This technology has raised a lot of interest with FPInnovations' stakeholders, who hope to reduce the intensity of cruising for logging residue assessments while maintaining or even improving the quality of information generated.

Objectives:

- Validate image segmentation techniques combined with quantitative GIS tools on UAS-based image mosaics to provide spatially explicit, piece-size details of dispersed residue on the ground.

Forest Establishment and Free-To-Grow Status Assessment With UAS

Currently, regeneration assessment from remote sensing imagery is done through human interpretation. This process is tedious, subjective, and prone to errors. The development of automated processes could save a lot of money while providing information on areas that would be difficult to cover.

Objectives:

- Explore the potential of unmanned aerial systems (UAS) products to replace ground establishment and free-to-grow surveys.
- Develop and calibrate image analysis models in various stand and acquisition conditions.
- Test algorithms' robustness for softwood regeneration.
- Develop algorithms or models to automate image analysis of regeneration assessments for mixed-wood and free-to-grow stands.

Monitoring Treatment Results and Stand Vigour With UAS

Miniaturized sensors based on unmanned aerial systems (UAS), such as light detection and ranging (LiDAR), infra-red, and multi-spectral, offer the flexibility needed for monitoring treatment results over time. Thermal regime, normalized difference vegetation index, or other indices from multi-spectral images could also help assess stand vigour after a silvicultural treatment.

Objectives:

- Provide a complete stand inventory, including canopy and subcanopy elements, to help assess current and successional potential in managed stands.
- Determine whether high-resolution, multi-temporal LiDAR acquisition could be an effective method to assess stand growth and site quality.
- Assess stand vigour and effectiveness of silvicultural interventions with spectral indices.

Theme 2: Internet of Forests

Theme objective:

- Develop and implement communication systems in resource operations that enable the implementation of the Industry 4.0 standard.

The overall approach is to find, test, and/or develop communication systems to determine whether they meet the requirements for vehicle-to-vehicle and machine-to-machine (M2M) technology and data flow of remote forest operations. Furthermore, the terminal part of a forest-wide communication network is the fleet of equipment operating in the forest. These machines must be able to act as nodes for the efficient transmission of data among them, or from them to the office/network and vice versa.

For all the systems, FPInnovations will test different performance criteria, including operational range, bandwidth, robustness, and affordability.

Objectives:

- Test communication systems related to extending cell networks, meshing, or clustering communication systems to determine applicability, as well as technical and cost effectiveness in rural areas.
- Continue work with the electrical and computer engineering department of the University of British Columbia on two initiatives:
    - Development of dedicated short-range communications technology for the resource sectors and investigation of the feasibility of such systems to support autonomous vehicle operation in confined rural applications.
    - Investigation and development of the potential for ad hoc communication networks that can manage and optimize the use of the communication networks that will be available to the resource sector.
- Further develop the M2M technology in the FPDat system to develop additional applications that allow data exchange between machines, data transfer to the office, and data transfer from the office to specific machines in the field (e.g., for configurations).

Theme 3: NextGen Fibre Supply Chain

Theme objective:

- Develop and implement next-generation equipment, hardware, software, and models to allow forest contractors to run to an Industry 4.0 standard by being automated, connected, and accessed in real time.

Development of Advanced Automated Vehicles for Rural Road Networks and Forest Operations

The Society of Automotive Engineers (SAE) has categorized driving automation technology into six levels, from 0 (no automation) to 5 (full automation). Technologies at SAE level 1 (driver assistance) and level 2 (partial automation) are on the market now, or soon will be, and must be tested for their applicability to rural and resource roads. There are also opportunities to take advantage of the remote and controlled environment of forest operations by developing niche vehicles at levels 4 (high automation) and 5 (full automation), which can be implemented without the restrictions that apply to highway transportation.

Objectives:

- Evaluate and monitor technology related to vehicle automation, driver assistance, and remote control of off-road machines.

- Continue development of a fully automated yard truck and other vehicles specific to the forest sector.
- Identify opportunities for adapting new technologies to forest harvesting and for assembling a team of partners and collaborators.

Development of a Resource Road Traffic Simulation Model

Having a robust traffic model that tracks individual vehicles provides opportunities to study many "what if" scenarios on resource roads. The focus of the project is to collect data at a case study location to replicate real-world traffic through calibration, and then consider how changes to parameters, such as traffic flow, traffic scheduling, or adding pullout locations, can change metrics that are important to safety. This decision-making tool will be valuable for transportation managers to improve safety on high-volume, multi-sector resource roads.

Objectives:

- Continue development of a microsimulation traffic model specific to resource roads by extending the functionality of Aimsun, a popular highway traffic simulation software.

Cloud-Based Feedstock Management Systems

This project will investigate cloud-based systems for tracking biomass feedstock properties and explore new technologies to monitor and reduce biomass moisture content.

Objectives:

- Conduct a trial with Pineland Forest Nursery in Manitoba on wood chip piles for combined heat and power (CHP) applications. Pile hotspot temperatures, moisture, and emissions will be monitored using Sentroller devices and infra-red smartphone camera. Biomass quality will be modelled using weather monitoring data.
- Conduct a trial in partnership with Skogforsk (Sweden) to assess the effectiveness of the Drinor mechanical dewatering press.
- Evaluate new technologies, such as X-ray and radar, to monitor moisture of comminuted biomass and improve real-time decision-making in industrial CHP applications.

Theme 4: Data Analytics

Theme objective:

- Develop and adapt analytics, algorithms, and methods that enable creating predictive models for forecasting and optimizing production systems.

Few decision-support tools exist that can be used in a practical and cost-effective way. This theme proposes to bring the implementation of these technologies closer to reality by leveraging available data streams into integrated solutions.

Geospatial Link Between Enhanced Forest Inventory and Production Data Streams

Production files from cut-to-length harvesting machines provide detailed stem information, including diameter changes over the length of the stems (taper), and are, in effect, extraordinary “cruising” systems. This project focuses on connecting forest inventory information and production data obtained from machine on-board computers to help calibrate the inventory information and enable some predictive ability through correlation of cruise versus actual data. Forest inventory information will be validated using geospatial referencing, and predictive functions will be generated and linked with other FPInnovations modeling and decision-support tools.

This work represents one of the early steps of connecting some of these complex and separate data streams to provide a richer information set than the individual data flows can.

Objectives:

- Validate forest inventory information based on geospatial referencing data from the harvesting machines.
- Develop prediction algorithms that can be linked with other FPInnovations tools.

Decision-Support Models for Forest Supply Chains

Existing planning tools for harvesting and allocation of biomass to manufacturing plants do not explicitly account for the capacities of downstream facilities. This can result in plans that are either not feasible or unrealistic. This project continues ongoing testing and prototyping, as well as developing new approaches for several existing and new FPInnovations technologies.

Objectives:

- Investigate the opportunity to move from an Access database in the FPInnovations cost model (FPInterface) to an SQL database to be able to process larger datasets.
- Adapt and validate a tool developed by a university partner (FORAC Research Consortium) that uses a mathematical solution to explore the flexibility of optimal scenarios and test the trade-offs of obtaining less precise solutions but doing so more quickly.
- Develop a way to link FPInnovations decision-support models to currently implemented management systems (e.g., web service, API for MaxTour, and other tools).
- Develop a methodology for evaluating supply chain scenarios for producing new bioproducts integrated in current forest supply chains.
- Prototype the ForestPlan tool as a strategic planning decision-support tool and explore its integration with GIS-based software for spatial representation of the forest inventory (FPInterface) and test its capabilities for scenario analysis.

OTHER RESEARCH AND DEVELOPMENT PROJECTS

FIBRE SUPPLY

Prevention of Hemlock Sinkers

This project focuses on reducing losses from sinking hemlock bundles in log booms. The density of live hemlock will be monitored during the seasonal cycles for an entire year. FPInnovations will determine the rate of hemlock log water uptake under ambient air conditions and in water conditions. FPInnovations will also investigate the effect of stump/log height on flotation and assess methods for improving flotation.

Objectives:

- Develop techniques to prevent losses from hemlock sinkage.
- Complete and integrate four years of earlier hemlock sinker research.

Effective Compliance With Caribou Habitat Guidelines

From a wildlife perspective, new guidelines for caribou habitat management that have been introduced in many provinces, including Quebec, Ontario, Alberta, and B.C., are restricting harvesting activity in the boreal forest. Operations are constrained into short time spans and minimal disturbance, including limited forest road deployment on the landscape. This project will focus on how logging strategies can comply with these new regulations in the most effective manner.

Objectives:

- Evaluate how logging strategies comply with the new caribou habitat management regulations.

Weather-Proofing Harvest Operations

Climate change and the associated increase in the frequency of extreme weather events are affecting harvesting and hauling operations. One major effect of climate change is the reduced duration and higher temperatures of the winter season and associated freeze periods. These effects are significantly impacting forest harvest operations, which have traditionally relied on the winter season to harvest on soft and sensitive sites,

The industry is already experiencing challenges of reduced access for winter logging, more soft-ground operations, and more frequent summer fire closures from extended droughts. Increased salvage logging can also be expected as operators deal with disturbances caused by more fires, insect outbreaks, and windthrow. Increased winter precipitation will bring higher risks of erosion, landslides, and flooding to forest operations. This project aims to develop strategies and approaches to help forest operations cope with these changes.

Objectives:

- Study the use of light detection and ranging-generated wet-area maps imbedded in machine navigation systems.
- Complete field trials to test strategies and working methods that would allow skidding on soft ground without causing unacceptable soil disturbance (e.g., lower ground pressure machines or trail consolidation).

Innovative Zero-Waste Practices

This project focuses on B.C. forest companies that need assistance in developing techniques to utilize fibre from residue and marginal stands. Using this fibre is a desirable alternative to burning debris piles or disposing

of residues at landfills. The alternative to not harvesting the profile of small wood in the timber harvest land base may be a reduced regional annual allowable cut. The project could provide an increase of 2 million cubic metres of economically available fibre and up to $5/m^3 of reduced wood costs.

Objectives:

- Conduct a sensitivity analysis on the modification of merchantable specifications (e.g., top diameter).
- Identify sources for residue suitable for pulp applications and provide samples for detailed lab assessments.
- Develop strategies to reduce the cost of delivered fibre derived from secondary harvest and marginal stands.

Contractor Capacity Building

To help industry in increasing the operational efficiency and financial success of its wood fibre producers, a business skills workshop and a contractor diagnostic package were successfully developed in 2014–2015. Since then, a large number of workshops were given across the country and several diagnostics were conducted. Several member companies have expressed interest in these services, and a number of fee-for-service opportunities have also been identified through various provincial funding envelopes. There is a need to consolidate these offerings in a service package aimed at increasing overall contractor sustainability.

Objectives:

- Continue providing the workshop and diagnostic services to members and other clients, and continue updating and improving the content.
- Increase delivery capacity by mentoring key FPInnovations regional staff in the delivery and maintenance of these two service packages.

Sustainability Assessments of Forest Operations

To fully benefit from sustainability certifications, increased accessibility to green markets, carbon credit revenue, and a positive public image, forestry companies are keen to understand how sustainable their operations are and how to maintain and increase their sustainability levels. There is particular interest in the impact of additional biomass recovery on the sustainability performance indicators. Similarly, to support sustainability policies, provincial and federal levels of government are interested in sustainability impact assessments of forest operations. This project will focus on the sustainability aspects of forest biomass harvesting. These assessments will identify biomass heat and power applications in remote and indigenous communities, comparisons between Canadian and international biomass supply chains, and innovative harvesting and biomass recovery supply chains.

Objectives:

- Investigate the integration of climate change mitigation objectives within the framework of forest biomass sustainability.
- Implement sustainability indicators developed at the global and national levels.

Further Development of FPInnovations' Telematics Tools

In 2011, FPInnovations introduced the FPDat data logger, the FPCom data communication system, and the FPTrak data-hosting web portal. Since then, the technology has proven popular among industry and contractors across Canada, with over 800 data loggers installed in various machines and contexts. Several testimonials have been received about the positive benefits of the on-board GPS navigation system, the

tracking of machine utilization, and downtime, providing excellent base data for continuous improvement strategies and the ease of access of the information through the website and automated functions.

To enhance the performance of the FPDat/FPCom/FPTrak platform and better respond to user needs, new features are required, such as additional reporting capabilities, new key performance indicators to monitor, map features, and others. While FPDat is efficient for collecting spatial and time-based information, there are challenges to collecting production-based information (i.e., cubic metres, tonnes). However, very good volume information is collected by cut-to-length harvester/processor heads and is stored in files that follow the StanForD format. FPInnovations has started collaborating with major equipment manufacturers to develop data transfer pathways so that the production data files from the cut-to-length heads can be sent automatically to the FPTrak website and be combined with other data streams to generate various productivity key performance indicators.

Objectives:

- Ensure improved reliability and performance for end users, responding to requests for additional features.
- Develop automated data transfer pathways for the production data collected by harvester/processor cut-to-length heads to FPTrak.

TRANSPORT & ENERGY

Energy Intensity Reduction

Given the instability in fuel prices, the Forest Products Association of Canada's "30 by 30" Climate Change Challenge, and the Vision 2020 goal to minimize the industry's carbon footprint, forest companies must reduce their consumption of diesel fuel during logging operations and during the delivery of fibre to mills.

Forest companies require a program of targeted fuel studies to identify operating techniques and technology that can reduce fuel consumption, reduce greenhouse gas (GHG) emissions, and increase overall productivity. The goal is to reduce the overall energy intensity, or litres of fuel burned, needed for the delivery of raw products to mills. Contractors and operators also want to confirm that the technologies being proposed do in fact offer fuel savings, and they want to know which operating techniques can achieve improvements in efficiency.

Objectives:

- Identify techniques and technology that can reduce the energy used per unit of production; Transfer the knowledge gained in energy intensity reduction activities through workshops, electronic multimedia tools, and implementation activities.
- Develop tools that can help industry account for and use to report on their GHG reduction efforts and carbon footprint,

Improvement of Transport and Driver Safety

The forest sector as a whole strives to provide a safe working environment for its workers and the general public who access resource roads for recreational or other purposes.

The level of hazards associated with forestry transportation is extremely high to drivers, forest workers, and the general public. As well, a top priority of many FPInnovations members is recruiting and retaining log truck drivers. Keeping drivers healthy and injury-free is an important strategy for retaining a viable truck driver pool.

Making the job easier and less stressful by simplifying or eliminating some of the driver tasks can also help retain older drivers and attract newer ones.

Objectives:

- Identify the technologies, practices, and systems that improve forest transport safety, reduce driver injury and improve driver health, and simplify the job of drivers.
- Identify innovative safety technology that can be readily adopted in forest operations to help the operations mitigate unique safety challenges often associated with work in remote locations, adverse weather conditions, limited access, and phase congestion.

Energy Intensity Benchmarking

Off-road equipment operators and their managers have expressed a strong desire for sound machine-operating practices that reduce fuel consumption and increase productivity. There is a need to quantify the energy intensity and carbon footprint of various tasks and working conditions for commonly used harvesting machines in Canada. Quantifying this energy intensity is the first step in the development of an accurate carbon footprint model for Canadian forest harvesting operations.

Objectives:

- Develop a fuel utilization profile for various work phases in forest operations.
- Create a model for fuel consumption for a given harvesting system in given conditions,
- Develop database tools that members can refer to for benchmarking their operations.

Implementation and Tech Transfer of FPInnovations' Support Tools

This project aims to help FPInnovations members implement FPInnovations' technologies that are related to transportation and energy, such as the FPDat data logger and the FPInnovations fuel management system. The project will also develop online tools to help members with their transport operations. In 2017, FPInnovations will finalize an online Canadian weights and dimensions guide.

Objectives:

- Assist FPInnovations members implement technologies related to transportation and energy.
- Develop online tools to assist members in their transport operations.

Investigate the Potential of Electric Yard Vehicles

Electric engines and off-road machines have made great progress in the past decade, and several electric or hybrid off-road machines are now available. However, not many of the types of machines used in forest or mill operations are available as electric or hybrid models. FPInnovations will look into the potential of electric or hybrid machines, identifying possible return on investment, greenhouse gas reduction opportunities, and barriers to entry, as well as technologies that can help introduce these machines in operations, such as battery swapping and solar- or wind-powered chargers.

Objectives:

- Evaluate the potential of implementing electric or hybrid yard machines, with particular attention to return on investment, durability, maintenance and energy, and greenhouse gas reduction potential.

Contamination Removal From Chip Trucks

Parasitic weight reduces log truck efficiency and, when entering the pulp mill process, it can damage refining plates and conduits, with an annual cost of more $1.4 million. Truck wash stations are expensive and problematic in winter. A simpler approach would be to remove the parasitic weight using heavy grids, also known as cattle guards.

Previous efforts in using cattle guards have been largely ineffective. A new approach would be to design a more effective cattle guard-like structure that would dislodge more dirt from the truck. This would entail spacing the bars at random intervals and at varying heights, and doing so for a greater length of travel.

Objectives:

- Design and test a cattle guard-like contamination removal system for chip trucks.

Development of Advanced Vehicles for Rural Road Networks

With the current rapid development of advanced vehicles for North American highways, there are questions related to the applicability of these new and developing vehicle technologies to rural roads, such as whether these vehicles can run on rudimentary infrastructure.

There is a gradient of technologies that needs to be investigated. These technologies are classified by the Society of Automotive Engineers into six levels of driving automation, from 0 (no automation) to 5 (full automation). There are technologies at levels 1 (driver assistance) or 2 (partial automation) that are on the market now, or soon will be, which need to be tested for their applicability to rural roads. There is also a need to investigate the application of more advanced levels of automation. For example, levels 3 (conditional automation), 4 (high automation), and 5 (full automation) can be implemented without the restrictions that apply to highway transportation.

Objectives:

- Initiate the integration of autonomous transport systems in a controlled and segregated area, such as a product transfer yard.
- Test driver assistance systems that can enable different levels of driving automation.

Safe and Efficient Trucking

Transportation accounts for up to 50% of the costs in the forest sector in B.C. These costs are greater than $1 billion per year, just to deliver fibre to the mills; this translates to more than 240 million litres of fuel and 640 000 tonnes of CO_2 emissions annually.

New, larger, and more productive (yet safe) configurations need to be researched, developed, and adopted. Higher-payload, safe, and efficient vehicles are key to a sustainable forest sector in B.C.

Objectives:

- Provide industry with a road map document to facilitate future route approval for 9-axle log truck configurations.
- Develop a vehicle concept for a new 9-axle steep-terrain configuration and conduct initial vehicle evaluation.
- Collaborate with industry and trailer manufacturers to obtain initial approval for proposed 10-axle chip van.
- Continue to explore opportunities to partner with manufacturers to develop a two-container hauler configuration.

- Support industry with approval of additional routes for 9-axle flatbed configuration.
- Summarize research on the impact of wide-base tires on pavement, with a goal of updating the methodologies that the Ministry of Transportation and Infrastructure uses to evaluate the road impacts of configurations equipped with such tires.
- Conduct an evaluation of an ergonomic truck seat under development in B.C.

Greenhouse Gas Reduction

The B.C. Ministry of Forests, Lands and Natural Resource Operations and the Ministry of Environment have legislated to reduce greenhouse gas (GHG) emissions by 33% by the year 2020 compared to emissions levels in 2007. There is a need to explore GHG reduction opportunities that could systematically be used and categorized with respect to GHG reduction impact, likelihood of success, and a path toward implementation. Previous research in equipment operation and fuel consumption fully supports that operator technique and practice have a large impact on fuel consumption and, hence, GHG emissions. As has been observed in studies in support of FPInnovations' SmartDriver training for truck drivers, fuel savings of up to 10% are possible.

As such, FPInnovations will continue field tests quantifying the impact of energy-intensity reduction strategies and will use this information in specific SmartOperator modules that address the audience needs in other sectors.

Objectives:

- Test technologies and operating practices to document and validate GHG reduction impact.
- Deliver SmartOperator workshops that will encourage and entice industry to adopt GHG reduction practices.
- Engage other off-road sectors (construction, mining, agriculture, and oil and gas) to gauge their receptivity and acceptance of the SmartOperator approach.
- Create an online version of the workshop.
- Deliver SmartOperator workshops to the forest sector first, and use the feedback received to tailor the content to other sectors.
- Implement a pilot project of a complete energy intensity management system in an operation.

RESOURCE ROADS

Adapting Roads to Climate Change

There are many planning, construction, and maintenance challenges associated with resource roads and climate change impacts. Climate change and the associated increase in the frequency of extreme weather events are affecting the safety and performance of resource road infrastructure.

One effect of climate change that has significantly impacted forest operations is a shortened winter season. As a result, the skidding period on frozen ground is shorter, freeze–thaw periods are more frequent, and the time during which winter roads can be used, as well as changes in the start and end of the frozen season, are also affected.

Expected loss and damage to infrastructure can be mitigated through sound engineering design, construction, and preventative maintenance. There is a need for predictive tools and knowledge exchange on how to prevent failures and perhaps change resource road designs by performing risk assessments. Increased winter precipitation will bring higher risks of erosion, landslides, and flooding to forest operations. This project will help resource road managers cope with these changes.

Objectives:

- Evaluate and implement a recognized protocol and the performance of innovative designs to enhance the ability of resource road infrastructure to respond to climate change impacts.
- Identify resource construction and maintenance practices that provide the opportunity for resource roads to be resistant to storm damage.
- Plan and construct winter roads to meet operational and environmental needs.

Enhancement of the Environmental Performance of Resource Roads

One of the road design and construction challenges is the ability of drainage infrastructure to maintain natural landscape and wetland hydrology. Inadequate bearing capacity of the road base and substandard water crossing structures are frequent challenges for resource road managers.

Objectives:

- Develop resource road infrastructure that maintains landscape and wetland hydrology.
- Determine adequate bearing capacities required for roads and infrastructure to withstand the impacts of climate fluctuations associated with climate change.
- Develop innovative road construction practices that can mitigate the environmental impact of roads (erosion and sediment control measures), including maintaining the hydrologic function of wetlands and reducing the gravel and material needs to create high-performing roads.

Development of Training Aids for Road Construction Operators and Field Staff

FPInnovations members have expressed a need for resources that can aid machine operators and field staff in implementing road construction techniques. New staff and contractors are entering the industry without the knowledge of historical practices or experience to aid in determining the best operating techniques for an operation.

The success of FPInnovations' training tools, such as the Grader Operator Course and the Business Skills Workshop, highlights both the industry's need for tools such as these, and the ability for FPInnovations to develop and deliver key information to the sector.

Objectives:

- Develop training aids for equipment operators and field staff that present key techniques in road construction and maintenance.
- Provide industry with resources to help contractors and industry staff meet design and road performance requirements.
- Identify techniques, equipment, and opportunities for road construction and maintenance research studies and evaluation.

REMOTE SENSING

Handheld Tools for Stand Assessment

Ground pre-harvest inventories still involve the use of a prism, measuring tape (for fixed diameter plots), and caliper to determine tree diameter at breast height and basal area. Smartphone and tablet apps are now available for determining stand characteristics more quickly, but their level of precision needs to be validated.

Objectives:

- Evaluate the precision of available smartphone and tablet apps that measure tree diameter at breast height and basal area, and their suitability for inclusion in operational workflows.

Remote Sensing Technology for Low-Cost Yard Monitoring

While sensing technologies are used extensively for controlling processes in sawmills and pulp mills, wood yards are still lacking automated monitoring and controls that could optimize production and improve safety. Remote sensing technologies could help in monitoring accurate inventory status, volume, and wood flow in wood yards.

The current methodology of measuring logs entering a wood yard simply by weight-to-volume conversion is imprecise and single-stem measurement is a tedious and expensive alternative. A better method of estimating the volume of a log pile in the yard, and the log diameter and volume distribution in the pile, would significantly reduce inventory management costs, improve planning capabilities, and contribute to increased overall mill operation profitability.

Objectives:

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- Develop and test volume assessment algorithms from a lidar point clouds or massive image overlap
- Implement a geographic scaling mechanism for photo acquisition in conjunction with image processing tools (e.g., contrast thresholding, edge detection, classification).
- Identify the best potential approach for full-length stem piles.

Remote Sensing Challenge

Current inventory methods tend to present accuracy and timing challenges for operational planning, but this is unsuitable for timber inventory (block or stand and landscape levels). By contrast, timber inventory at the block level (i.e., timber cruising) is conducted based on more intense field sampling and typically does not include remotely sensed information. Remotely sensed timber inventory information for operational or tactical purposes provides an opportunity to transform current practices and later adapt and extend them elsewhere in Canada.

FPInnovations partnered with Foresight Cleantech Accelerator Centre to launch a challenge focusing on remote sensing solutions for conducting forest inventories. Technology providers were challenged to reduce costs by up to 75%, reduce carbon emissions associated with traditional surveying, and provide more precise data than is currently possible, thereby enabling more efficient operational and environmental planning before harvesting.

Objectives:

- Working with the challenge winner, provide detailed information on the distribution of wood volume in a timber block by species, quality, and dimension.

MODELING AND DECISION SUPPORT

Implementation of a Forest Value-Predicting Model

FPInnovations has developed a new model for predicting the value of forest stands. Called NCCruise, this model combines standard cruising with a forestry company's own sort descriptions to generate improved predictions of the volume distribution in a stand by species and grade. This model assists in evaluating the economic operability of stands under current and future projected market conditions, enhancing a forestry

company's decision-making process with respect to harvest planning, optimization of product combinations, and future investment planning.

The model has been prototyped and validated on several case studies, and the next step in its development is to explore its commercial potential.

Objectives:

- Accelerate the uptake of the NCCruise technology by FPInnovations member companies.
- Identify a supplier partner that would be interested and capable of commercializing the technology.

Wood Yard Optimization and Analysis

While forest operations and manufacturing have seen much improvement from the application of optimization and automation technologies, wood yard operations are lagging behind. There is uncertainty and risk associated with poor log yard management, which can result in inefficiencies and losses in log value and volume, and, consequently, in profit.

Objectives:

- Develop methods for management of wood yard inventory storage and mill infeed decisions for the optimal log diet supplied to the mill.
- Investigate methods for log inventory management from truck unloading, storage, and reclaiming to the mill.
- Develop or adapt tools to optimize mill yard performance, including pile location management, inventories, and flows.
- Identify the best practices in yards (e.g., operations, layout, and machine complement and utilization), analyze and evaluate the missed opportunities (i.e., the cost of not applying best practices), and develop benchmarking guidelines for Canadian wood yards.
- Develop a comprehensive toolbox of methods for wood yard analysis, focusing on different components within the yard, including machine utilization, improved yard organization and layout, optimal fleet complement (i.e., capacity, type, and number of machines), cycle time of trucks in yard, and yard surfacing and infrastructure (pavement, roads).

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