Ecosystem Based Management Challenges to EBM for Alberta and Saskatchewan Forests

Section F: Tools

fRI Research Healthy Landscapes Program

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Richard L. Bonar

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F. Tools

This section covers the translation of the framework guidance for natural resource management on forest land management areas. The fundamental themes are ecological boundaries, how NRV can be determined and emulated, natural and silvicultural tools to apply disturbances and the role of monitoring, communication and research in assessing the effectiveness of tools to achieve EBM. This section extends what we understand in theory from the systems and frameworks at all scales to guide EBM implementation.

F1. Ecological Boundaries

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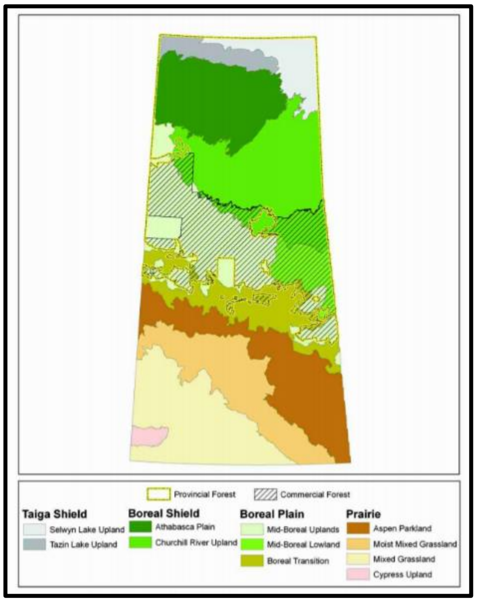
Ecosystem-based management promotes using ecological units as the basis for management. Ecological classification is a system of grouping ecosystems into logical units based on common characteristics that reflect inherent similarities and differences. Most ecological classification systems are hierarchical from broad to specific and from large to small in area. All represent patterns that humans observe and thus are social constructions to represent natural ecological variation (Lee 1993).

Ecological classification systems that support EBM are well-developed in Alberta and Saskatchewan. The *Ecological Framework of Canada* includes fifteen terrestrial and five marine ecozones. An ecozone is a large sub-continental geographical division with distinct representative biotic and abiotic features in the ecological unit. Canadian Ecozones are further subdivided into 53 Ecoprovinces, 194 Ecoregions, and 1,021 Ecodistricts.

Saskatchewan uses the *Ecological Framework* classification system (Figure F1). Eleven Ecoregions are subdivided into more than 150 Landscape Areas (Padbury and Acton 1994) that are comparable to Ecodistricts in the national system. Alberta uses the *Natural Regions and Subregions of Alberta*, (GOA 2006) which closely tracks the *Ecological Framework* (Figure F1). All of these units are available as digital map layers. Ecosite field guides cover Alberta and Saskatchewan at smaller scales (Archibald et al. 1996; Beckingham and Archibald 1996; Beckingham et al. 1996a, 1996b; McLaughlan et al. 2010). Ecosystems and ecological knowledge are represented by robust classification systems that are based on ecosystems:

- Broad ecological classifications (e.g., Canada Ecozones and Ecoprovinces, Alberta Natural Regions, Saskatchewan Natural Regions).
- Watersheds
- Biomes (forest, wetland, grassland, fresh water, tundra, etc.)
- Broad habitat types (Forest: coniferous, mixedwood, deciduous; Wetland: fen, bog, marsh, swamp, shallow water, etc.).
- Digital forest inventory (Alberta Vegetation Inventory, Saskatchewan Forest Inventory).

- Ecological classification (Alberta ecosites manuals), and some mapping (e.g., Hinton Wood Products 2017).
- Terrain, landform, and soils classification and some mapping.
- LiDAR digital inventory and related products (e.g., Alberta Wet Areas Mapping).
- Species distributions.
- Traditional Ecological Knowledge (mostly narrative, some maps).
- Forest fire history and mapping (Canadian Wildland Fire Information System).
- Forest insect history and mapping (Canadian Forest Inventory, provincial data).
- Logging history and mapping (Canadian Forest Inventory, provincial data).



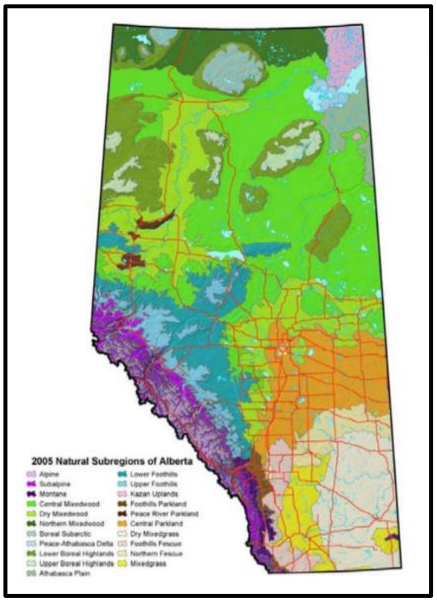


Figure F1. Terrestrial ecozones and ecoregions of Canada in Saskatchewan (left) and Alberta provincial Natural Subregions (right).

Both provinces have forest cover and age classification systems and inventories derived from air photo interpretation. Alberta uses the historic provincial *Phase 3 forest inventory* (Government of Alberta 1985) or the more recent and detailed *Alberta Vegetation Inventory* (Government of Alberta 2005), and Saskatchewan uses the provincial north and south *Digital Land Cover Classification* inventories based on 30-meter pixel satellite mapping (Doyle 2014) and the more detailed *Saskatchewan Forest Vegetation Inventory* (Government of Saskatchewan 2004) for commercial forest areas.

Watershed classification and mapping at multiple scales exists for both provinces. The most recent Alberta watershed mapping system is the *Hydrologic Unit Code (HUC) Watersheds of Alberta* (Government of Alberta 2017a), which is four hierarchically structured drainage basin feature classes created using a modification of the HUC system developed by the United States Geological Survey (Seaber et al. 1987). Saskatchewan uses a watershed classification system based on the Canadian *Standard Drainage Area Classification* (Government of Canada 2003). Hydrography including surface and subsurface water features is included with watershed classification. Ecological classification of water features themselves is becoming more common (McCleary et al. 2012; Wolfe et al. 2018).

Species distribution maps are widely available but vary in quality and have no standardized approach for mapping. Information for species that have attracted human attention (at risk, economic importance, cultural importance, invasive, etc.) tends to be the most comprehensive.

Other potentially useful ecological classification systems include soils (Soil Classification Working Group 1998), wetlands (National Wetlands Working Group 1997; Government of Alberta 2015; Canadian Wetland Inventory Technical Committee 2016), and landforms (e.g., MacMillan and Pettapiece 2000).

In the past few decades satellite remote sensing products were developed to include unique ecological datasets to support EBM (e.g., Pasetto et al. 2018). Some of these classifications and datasets are forest productivity and growth, water stress, carbon and nitrogen fluxes, and hydrological flows.

Challenges

- At larger scales there are no significant challenges related to availability of robust ecological classification systems in Alberta and Saskatchewan. Existing systems more than meet broad management needs.
- Deciding which classifications and appropriate ecological units and scales to use to support EBM is a challenge.
- Although classifications are available at smaller scales, availability of spatial inventories is limited.
- Availability and access to Traditional Ecological Knowledge is limited and uneven. Much TEK rests with elders and those communities who have gathered elder knowledge are not necessarily willing to allow others to use their knowledge.

Recommendations

> *"Some Indigenous groups and individuals are very active in forest management and knowledgeable. They have good understanding about ecological changes and the need for change. These people provide a good base to further EBM within Indigenous circles."* (Anonymous SME).

- Provinces can provide leadership by considering the available classification systems and deciding the ones they feel are most relevant to EBM. This would be valuable guidance to those tasked with implementing EBM.
- Ecological unit designations are now common in many planning initiatives including forest management plans. Emerging consensus is to use ecological areas (e.g., ecodistricts, natural subregions) and their subdivisions as the primary ecological units, with watersheds and species distributions as secondary units. Discussion of these and agreement to use common definitions and frameworks represents a good opportunity.
- The wealth of ecological classifications, especially those at smaller scales, provides opportunities to investigate EBM aspects that were not previously possible.

- Gather Indigenous TEK by supporting community efforts to gather their knowledge, and gain access to it through partnerships.

Ecosystem-based management promotes using ecological units as the basis for management. Ecological classification is a system of grouping ecosystems into logical units based on common characteristics that reflect inherent similarities and differences. Most ecological classification systems are hierarchical from broad to specific and from large to small in area. All represent patterns that humans observe and thus are social constructions to represent natural ecological variation (Lee 1993).

F2 Natural Range of Variation Strategy

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In general, EBM strives to conserve ecological variation in forests to reduce risk and maintain resilience. In simple terms, it calls for keeping every cog and wheel that we observe in forests (Leopold 1949), and trying to maintain complexity consistent with observed variation in nature.

An NRV strategy is a central concept in EBM. Managers use natural pattern knowledge to inform the process of setting targets for future forests. This contributes to effective management of risks to ecological integrity over time. The assumption is that risk is minimized (and resilience is maximized) when patterns are within NRV and variable within NRV over time and space. Risk increases when patterns are outside NRV. The further outside, the greater the risk.

An NRV strategy includes selecting natural pattern indicators, estimating NRV and the historical and current conditions for each indicator, forecasting and setting targets for future conditions with NRV as an important consideration, and monitoring performance for both management activities and outcomes (targets).

There is growing recognition and acceptance that NRV is a useful concept to inform management choices (Keane et al. 2009; Seidl et al. 2016). Using an NRV strategy has been partially incorporated into commercial forest management in Alberta (Government of Alberta 2006) and Saskatchewan (Government of Saskatchewan 2019a), but not as a planning foundation (Andison 2020a). Instead, some natural patterns indicators have been added to the growing list of values and requirements that must be incorporated into plans.

Protected area managers, especially National Parks but also some provincial protected area managers; for example the Ecosystem-based Management Plan for Meadow Lake Provincial Park (Chu and MacKasey 2019) are using NRV to inform plans for future forests.

Challenges

> *"Rules don't really work or there would be no tension. We need place-based solutions based on trust and flexibility. The forest landbase is finite and we have to achieve a balance that respects existing uses. Single issue approaches result in failure at the whole landscape scale. Government rules and regulations enforce divided landscapes."* (Anonymous SME).

> *"In many areas current landscape patterns are well outside NRV or trending that way, therefore there's higher risk for the future."* (Anonymous SME).

> *"How far do we go to increase similarities between fire and harvest? We have to recognize that we can't do some things and accept that. Over time we get ecological convergence (about 25 years) between fire and harvest. That may be good enough."* (Anonymous SME).

> *"Incorporation of the NRV concept into commercial forest management in Alberta and Saskatchewan is well underway, but application has suffered from the tendency to shoehorn NRV considerations into existing management frameworks."* (Anonymous SME).

- Human worldviews tend to focus on short term, individual experiences, and concerns and attentions to specific values. Diverse worldviews can lead to disagreement about what the baseline for comparison should be. For example, an NRV estimate that showed lower amounts of old forest in the past could conflict with the worldview of people who want more old forest.
- Building support for managed change is a significant challenge, particularly when change involves deliberate disturbances and it may take a century or more to recover to pre-disturbance conditions at local scales.
- Controversy around the NRV concept and its application is a continuing challenge to further implementation.
    - The scientific community is still debating the merits of "emulating natural disturbance" and "ecological forestry" in relation to the underlying ethical values and the need to be adaptive and flexible in the face of climate change and other current and future pressures (Klenk et al. 2009; e.g., Batavia and Nelson 2016).
    - Drivers of global change will produce new spatial patterns, altered disturbance regimes, novel trajectories of change, and surprises (Turner 2010; Seidl et al. 2020).
    - Understanding and support in principle for the NRV strategy is uneven with very low awareness among large proportions of society.
    - Estimation of NRV, which often involves historical reconstructions and modelling, is uncertain and dependent on the time period over which NRV is estimated (Seidl et al. 2011; Freeman et al. 2017). This leads to challenges about how to address uncertainty and differences in interpretation (Arsenault et al. 2016).

  - Disagreements over NRV estimates can lead to controversy over which NRV estimates to use. For example, Alberta-Pacific was faced with two estimates for seral stage NRV and chose to use the most conservative estimate to inform FMP targets (Alberta Pacific Forest Industries 2015).
  - While easily understood, the NRV concept can be quite difficult to implement due to scale, data, and analysis limitations (Wong and Iverson 2004). For example, planning for variation in future disturbance event sizes in commercial forests is a challenge when using models to identify potential events.
- Forests that have been pushed out of their natural dynamic equilibrium contain "novel forest ecosystems" (Hobbs et al. 2009) and altered dynamics that could lead to undesirable future tipping points. This controversial concept (Murcia et al. 2014; Morse et al. 2014) diminishes the relevance of historical dynamics and conditions (NRV) for informing future forest management but the underlying principles still apply (D'Amato and Palik 2021). Managing for structural and functional complexity and heterogeneity, and compositional diversity at multiple scales, through an understanding of ecological dynamics, remains relevant to addressing the uncertainties of future global change (Palik et al. 2020).
- Opposition to short-term disturbance effects (ecological, aesthetic, amenity, NIMBY, etc.).
- Incorporating disturbance and variation into the concept of protection.
- Risks associated with disturbance (e.g., liability for prescribed fire).
- The NRV concept has been criticized in principle because NRV includes rare events that human society views as unacceptable (Landres et al. 1999). Examples include naturally low quantities of patterns socially recognized as having high-value, such as old forests, and rare high-impact events such as catastrophe-scale wildfires and floods.
- Dislike of NRV includes resistance to high levels of disturbance (Long 2009) typical of the high-frequency and high-severity natural fire disturbance regimes in many Alberta and Saskatchewan forests.
- Opposition to local disturbance that affects established values that humans see as important and don't want in their local areas of interest, widely known as not in my backyard (NIMBY). NIMBY is a rational reaction that constrains the implementation of an NRV strategy. For example, few would welcome a large fire or logging disturbance in their familiar local forest locations. The intersection of land use and disturbance profoundly affects relationships between disturbance and society (Turner 2010).
- Some view a wide natural range as an excuse for "anything goes" management (Batavia and Nelson 2016).
- People tend to gravitate toward the portion of the NRV spectrum that reflects their interest in a particular value, such as good moose habitat or berry-picking areas, while ignoring or downplaying other aspects of NRV. This tendency to "cherry-pick" NRV is inconsistent with a comprehensive NRV strategy (Andison 2020a).

- Whether or not historical variation reflects probable future variation is also debated, especially in relation to potential effects of climate change (Bowman et al. 2020).
- These challenges represent a diversity of perceptions about application of the NRV strategy approach. This is also a challenge and some may be based on beliefs as much as actual evidence (Arsenault et al. 2016).
- Many forest ecosystems have been significantly altered by human activity (Hobbs et al. 2009; Newman 2019) and attempts to return systems to within their historical range of biotic and abiotic characteristics and processes may not be possible (Seastedt et al. 2008) or desirable considering increasing human use pressures (Government of Alberta 2008) and factors such as climate change (e.g., Klenk et al. 2009; Nocentini et al. 2017). The challenge is to recognize that current forest conditions should be the starting point for EBM and a realistic plan for future forests should consider NRV, and other factors, to inform management choices. Increasing variation, informed by NRV knowledge, is an easily understood objective. The challenge is to move in the desired direction.
- Incorporation of the NRV concept into commercial forest management in Alberta and Saskatchewan is well underway, but application has suffered from the tendency to shoehorn NRV considerations into existing management frameworks. Existing management still contains numerous requirements that challenge incorporation of NRV into planning and practice:
    - Missing or inadequate policy describing how NRV is to be used.
    - NRV is not fully being used as a coarse filter planning foundation using ecological units. For example, both provinces require an analysis and target for seral stage (age classes) but they do not require analysis and targets for appropriate ecological units because company tenures have administrative boundaries and companies are not required to work with others outside their tenures to address NRV at relevant ecological scales. Within their tenures, companies are specifically not responsible for the passive landbase within their tenures, which prevents appropriate application of NRV for the entire landbase.
    - NRV is being used for some ecological aspects but not others that may be appropriate. For example, NRV is not being used for watersheds in relation to water quality and quantity and it is not being used for wildlife habitat, including critical habitat for species at risk.
    - Current legal requirements prevent application of NRV for some aspects. For example, current reforestation requirements related to establishment window, stocking, acceptable species, and freedom from competition all act to reduce variation.
    - NRV indicators have been added to the status quo values/VOITs list, not as a planning foundation, so other constraints or targets can have precedence over NRV considerations. This is a challenge because it prevents development and consideration of NRV-guided EBM alternatives to established constraints.
    - In some cases, NRV is being used in inappropriate contexts. Examples:

        - The Alberta process for assessing structure retention in cutblocks (Government of Alberta 2006) counts patches that are islands within cutblocks; this excludes peninsulas and corridors, which are spatial features of natural disturbance events (Andison 2006a). Evaluating residuals at the scale of *disturbance events* as well as internal patches is more appropriate.
        - The Saskatchewan process for defining and measuring disturbance event sizes and remnants (Government of Saskatchewan 2017a) is an advance over the Alberta process but it is overly prescriptive and misses opportunities to address aspects such as remnant survival and between-event variation.
        - Both provinces do not incorporate disturbance within remnant patches, which is a dominant feature of wildfire remnants (Andison ref). Remnant patches left after logging must be undisturbed.
    - Lack of inventory or research needed to estimate NRV.
    - Absence of scenario modelling to estimate future variability and inform target-setting.
    - NRV targets are not set for appropriate ecological units.
    - NRV targets don't incorporate variation.

RECOMMENDATIONS

"EBM remains uniquely "experimental" as a practice, since no jurisdiction has deployed it through the full life-cycle of a forest ecosystem, though it distinctly considers a growing body of scientific investigations examining the contexts, drivers and complex functions of natural systems at ecozone and ecoregional scales. EBM offers a positive degree of relative flexibility in deployment as each different context in ecozone or biogeoclimatic landscape resilience might present as an application backdrop." (Anonymous SME).

"As a broader-looking form of management EBM is perhaps unique in making an explicit start-point connection to natural ecosystems as a guiding foundation that seeks first to assure system resiliency in the interests of multiple-value productivity. A suite of goals, values, measurable objectives, indicators and targets remains a key necessity to monitor for performance and adapt accordingly. NRV provides context."

"In my few very positive interactions with Indigenous communities regarding concepts-of-practice, EBM has been received very positively as a common-ground start-point for dialogue. The visual, observable difference demonstrated on-the-ground with ecosystem-inspired retention harvest blocks of irregular shapes and sizes (relative to traditional clearcut harvests) and the underlying principles of natural disturbance is a matter they readily identify with, rather immediately articulating the ecological benefits of such approaches in their own words. Indirectly, EBM approaches offer an opportunity to build or enhance relationships, trust and mutual learning." (Anonymous SME).

"EBM is the way to go because it embraces change, is well-bounded in science, and resonates well with the public. Follow NRV Mother Nature is relatively easy to explain, people get it and they like it. Variation is key, the more we stay away from cookie cutter approaches and practices the better we are." (Anonymous SME).

"People are struggling with how we aren't currently practicing EBM and what more should we be doing. I would love to see a simple guidebook about how to implement EBM/NRV on an FMP Level." (Anonymous SME).

- Continuing to develop and implement NRV strategies has good prospects to reduce ecological integrity and human wellbeing risks. Two of the biggest risks associated with existing forest management are loss of biodiversity and increasing risks of catastrophic wildfire, both of which may be exacerbated by climate change.
- Understanding NRV for each ecological aspect of interest is the first step in a process to set management targets for future forest conditions. Ultimately the process and decisions must reflect human choices.
- Ecological theory suggests that remaining within NRV and varying within NRV over time in proportions approximating natural patterns reduces ecological integrity risks and should be the first consideration for target-setting.
    - Select ecological pattern indicators including the rationale for why the indicator is chosen, geographic contexts, scales, etc.
    - Estimate NRV for selected indicators through various processes with documented uncertainties and caveats.
    - Assess current conditions for each indicator in relation to NRV.
- Assessing feasibility and considering the possible consequences of managing to remain within NRV comes next, as part of a comprehensive area-based planning process. This is where other NRV indicators, legislation, costs, safety, social acceptability, existing and potential human uses, and a host of other values and considerations come into play. Human values and limitations cannot be set aside from the process.
    - Develop scenarios and forecasts for possible future conditions.
    - Assess scenarios that apply an NRV strategy to achieve, move closer, or remain closer to patterns within NRV.
    - Assess scenarios that apply modifications or alternatives to "full NRV" that address other considerations, including human wellbeing, etc.
    - Use an inclusive, comprehensive and fair process to consider and discuss the scenarios. The outcome of the process is choice of a scenario that best balances ecological integrity, including NRV, and human wellbeing, for the DFA in question.
    - Set targets from the chosen scenario that strive to include variation within NRV over time.
    - Place each target in its NRV context and provide a rationale in relation to NRV. Ideally most targets will be within NRV. If they are not, closer is better than further, and the reasons why the choice was made should be explained.
    - Characterizing targets with an "acceptable range of variation" (Parrish et al. 2003), compared to NRV, may provide useful ways to embrace variation in principle.

  - Where "full NRV" is not feasible or choices have been made to be outside of NRV, recognize the differences and use NRV as an ecological benchmark to support adaptive management.
  - Include a program of adaptive management including research and monitoring to address uncertainties.
- In forests that have major human alterations it is not realistic to return to historical ecological conditions (Millar 2014; Cushman and McGarigal 2019). In these forests managers can plan for future forest landscapes using process-based assessments of ecological system structure and function, where NRV functions as a benchmark or reference framework to assess current system and future system characteristics, drivers and dynamics (McGarigal et al. 2018; Cushman and McGarigal 2019).
- In most situations, managers have opportunities to incorporate at least some consideration of NRV, for at least portions of their Defined Forest Area (Palik and D'Amato 2017). Working from the principle that some is better than none, this represents an opportunity to gain incremental improvements through adoption of NRV where it is not already being used.
- There are opportunities to address concerns about NRV by developing improved plain-language descriptions, definitions, and guidance about how to use NRV in EBM.
  - What NRV is and how increasing variation in line with natural dynamics reduces risk and increases resilience.
  - NRV use guidance that makes it clear where setting targets within NRV are required or advised, and where targets should be informed by NRV but not necessarily within NRV.
  - Targets set outside NRV should still be compared to NRV and the risk implications should be acknowledged and monitored.
- Implementing EBM in the face of uncertainty in many ways is not different than continuing with current forest management. The role of NRV in informing management targets is still important as a risk reduction strategy, but it can't be an inflexible consideration. EBM planning is an opportunity to consider NRV, use it to inform targets, and strive to implement an NRV strategy where other factors can be accommodated. Active adaptive management is the best opportunity to reduce uncertainty (Seastedt et al. 2008; Williams 2011).
- Implementing NRV strategies is a long-term undertaking and the annual and decadal area that would be affected comprises relatively small proportions of the vast forest lands of Alberta and Saskatchewan. Considering that all management is an experiment, this provides time to use adaptive management to learn by doing while largely avoiding risks associated with irreplaceability.
- Recognizing that continued disturbances are necessary to maintain ecological function, NRV strategies offer prospects to use managed disturbances to reduce risk of unmanaged disturbances that would be viewed as catastrophic (MNP LLP 2017; Coop et al. 2020).
- Recent worldwide wildfire behaviour has been characterized as unprecedented, with severe ecological impacts as well as severe impacts on human life and property (Coop et al. 2020). In

rapidly changing, fire-susceptible landscapes such as those in Alberta and Saskatchewan, resilience must extend beyond returning to a similar state to include 'adaptive resilience' and 'transformative resilience', which require substantial and explicit changes to social-ecological systems (McWethy et al. 2019). EBM is well-positioned to contribute.

- Perhaps one of the best opportunities to capitalize on the benefits of using NRV to inform EBM is the communications value of the potential to improve sustained yield commercial forest management and demonstrate to citizens commitments to address real and perceived challenges with the current approach (Palik and D'Amato 2017).
- Using NRV as an EBM foundation offers opportunities to explore differences in interpretation, identify uncertainties, and inform decisions and adaptive management designed to reduce uncertainty. Opportunities include building understanding of NRV through research and communications. Careful consideration and clear statements of how NRV is to be used, or not used, in policy and management would also be helpful.
- EBM is oriented toward ecological integrity and NRV over time horizons that are relevant to humans. This means that NRV should be estimated over historical intervals that represent and are responsible for existing ecological integrity, and not over longer horizons that extend back to previous regimes (e.g., the last glaciation period). Going forward humans may decide to use historical NRV to inform and adopt new targets if climate change affects ecological integrity, especially resilience.
- Develop effective ways to recognize and remedy NIMBY opposition including:
    - Identification of likely NIMBY areas, concerns, and affected people at the strategic planning scale (EBM Plan, FMP, Park management plan, etc.) followed by notifications and dialogue towards acceptable solutions.
    - Resolution by design such as scheduling smaller and less intense disturbance events in NIMBY areas and larger and more intense events where there are no (or fewer) NIMBY concerns. Design could also help to reduce risks and increase resilience by, for example, reducing fuels in landscape configuration ways that reduces the risk of crown fires (D'Amato and Palik 2021).
    - Resolution by interest-based negotiations and adjustments.
    - Fair mitigation or compensation where other measures are not sufficient.

F2.1 Disturbance Patterns

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All forests continuously change at small scales (tree germination, growth, mortality, etc.) and continually change at larger scales (forest fires, biotic agents, weather events, etc.). It makes sense to choose disturbance patterns that:

- dominate and drive change in terms of area affected, frequency, amplitude, and impact.
- associate with locally-important rare, unique, or sensitive ecosystems or species.
- are altered or influenced by human activities.

- affect human wellbeing values.
- have already been selected for management interest and have an inventory and monitoring history.
- reflect the values and interests of participants.

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Disturbance Type

In commercial forests, fire suppression and replacement with logging over time causes gradual conversion from primarily fire-origin to primarily logging-origin on the active landbase. For the passive landbase and in protected forests the conversions would trend toward reduced fire origin and more succession-related origin, depending on fire policies. Insects, disease, and other disturbances could also increase.

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Natural Disturbances

Major natural disturbances are tracked primarily by governments, with the assistance of others, especially the forest sector. They include forest fires, forest biotic disturbances including insects and disease outbreaks, floods, wind and other weather events, landslides, and avalanches. The subset of natural disturbances that are characteristic of different forest areas is the starting point for choosing disturbance indicators. Many natural disturbances occur episodically over short time periods in discrete geographic areas that can be characterized as events (Andison 2006a) The associated patterns have NRV aspects (fire event size, % completely burned, partially burned, and unburned, event and patch shape, etc.).

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Anthropogenic Disturbances

Disturbances due to human activity are generally well-known and they are measured and tracked by multiple organizations. The main interests have historically been to measure human development in various ways for both ecological and non-ecological purposes. Ecological interest has overwhelmingly been oriented toward the negative effects of human disturbances on ecological integrity (Pickell et al. 2013, 2015).

Measuring the combined levels of natural and anthropogenic disturbances and comparing the combined range of variation to NRV of natural disturbance regimes is a cornerstone of including NRV strategies in EBM. A main challenge in doing this is the difficulty in forecasting both planned and unplanned future disturbances and using the information to set future forest targets. FMPs for commercial forests typically use 150–200 year forecasts of proposed logging rates and assume no natural disturbances. Frequent re-planning is used to account for natural disturbances and other developments (e.g., other human uses) and adjust plans and targets. This also incorporates variation caused by changes to human wellbeing such as social imperatives and economic viability of existing and future activities.

In summary, there is an established system of measuring both natural and anthropogenic disturbances. Characterization of NRV for some aspects is well-along but incomplete or not started for others that may be useful.

CHALLENGES

> *"There's so many things we could measure, we can't possibly measure them all, and there's already too many things that have to be measured. We can't afford to add more unless we stop doing some we do now. We have to rationalize in a realistic and reasonable way."* (Anonymous SME).

- Choosing a comprehensive and relevant set of disturbance indicators is a challenge simply because there are so many options (Canadian Council of Forest Ministers 1995).
- The challenges include the costs of monitoring natural disturbances, developing ways to characterize them (Andison 2006a), and measuring or estimating NRV for selected aspects and ecological units of interest.
- Costs of collecting, managing, and access to data on disturbances must be affordable.
- Resources to characterize and use NRV to inform management aspects where NRV has not traditionally been referenced (watershed disturbance, water yield, species population size, etc.).
    - Most effort has been directed at estimating NRV for fires (Andison 1998, 2003a) and floods (e.g., Poff et al. 1997). There is need for NRV estimates for other natural processes including windthrow and insect (especially mountain pine beetle) and disease outbreaks (SME interviews).
    - In some stand types there is no information on within-stand compositional and structural NRV related to gap dynamics. Better understanding of within-stand variation of the oldest seral stage in particular would help managers to plan for old forest variation as well as quantity and configuration, and it could inform silvicultural practices.
    - There would be new costs and technical issues related to characterizing NRV for EBM aspects that currently don't reference NRV.
- One of the ultimate measures of healthy ecosystem is the quality of disturbance activities, not the existence of them (Andison 2020a). This means it is not enough to account for the total area of each disturbance type, and additional within-event indicators will be needed to assess disturbance quality. For example, characterizations of within-event complexity and variation for fires and logging.

RECOMMENDATIONS

> *"A research initiative to assess existing disturbance pattern information, whether or not NRV has been estimated, potential gaps, and potential options for a comprehensive and efficient disturbance pattern portfolio including partnerships, data accessibility, etc."* (Anonymous SME).

- Interactions between fires and floods have been characterized (e.g., Bendix and Cowell 2010), but NRV has not typically been estimated for the interactions at watershed scales. This represents an opportunity to use NRV for interactions between watershed disturbances and hydrogeomorphic disturbances to inform EBM.

- Recompile existing disturbance modelling to generate NRV estimates for additional ecological contexts (watersheds, riparian areas, caribou range, etc.).
- Prepare checklists of disturbance pattern indicators that have NRV and consider whether developing NRV estimates would be beneficial to support EBM.
- A research initiative to assess existing disturbance pattern information, whether or not NRV has been estimated, potential gaps, and potential options for a comprehensive and efficient disturbance pattern portfolio including partnerships, data accessibility, etc.
- Share costs to develop NRV estimates between organizations and stakeholders.

F2.2 Conditions Patterns

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Ecological condition patterns are produced by repeated disturbances and NRV is characterized by comparing conditions over time. Condition patterns are part of the *coarse and fine filter approach* to biodiversity conservation focussed on ecosystems and species respectively (Hunter 2005). Coarse filters maintain a diversity of structures within ecosystems and a diversity of ecosystems across landscapes to meet most of the habitat requirements of most of the native species. Fine filters are additional actions directed toward particular habitats or species that may be threatened or endangered and might 'fall through' coarse filters (Noss 1987; Hunter 1991).

Ecosystems and species can be used in both coarse filter and fine filter approaches. For example, representative and hydroriparian ecosystems and some wide-ranging focal species in a coarse filter approach, and rare ecosystems, rare species and focal species of concern in a fine filter approach (Coast Information Team 2004).

Challenges

"EBM has to be kept at a high level initially and not fall into a trap of bogged down in detail." (Anonymous SME).

- There are many ecological patterns that could be selected for setting targets in future forests. Selecting a relevant and affordable set to use is a challenge.
- When the historic basket of disturbance types and qualities is altered by human activities managers will need to make adjustments to produce future forest landscapes with desired ecological conditions.

Recommendations

"Managing for variation is actually an opportunity because it reduces emphasis on statistical differences which are basically meaningless in dynamic natural systems. Comparisons of before and after points in time totally miss the rich inferences from studying natural variation." (Anonymous SME).

- Ecological assumptions should help to design logging to be a reasonable approximation to wildfire:
    - Resistance – ecosystems and species tendency to resist disorganizing changes caused by novel disturbances (logging, etc.) and novel species (non-native species). Clearing vegetation in a forest ecosystem usually results in a return to forests, not transition to grassland or some other ecosystem type. Most non-native species either fail to become established or do not have major effects on native species and ecosystems.
    - Redundancy — in a highly variable natural system maintaining conditions within NRV should be ecologically sustainable. This allows removal of biological materials (wood, wildlife, etc.) for human use without impairing ecological integrity.
    - Replacement — biological response to different types of disturbance is broadly similar as the processes of succession continue.
    - Resilience — species are adapted to dynamic environments and ecological conditions and are resilient to change.
    - Recovery — differences between disturbance types are most prominent at time of disturbance. Over time ecological conditions tend to converge.

Ecosystems

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Regions and landscapes are typically the largest-scale units used for estimation of NRV (Andison 2020a). Indicators are typically selected at larger scales (e.g., forest type or cover group, forest age class) but can include meso-scale (Hunter 2005) ecosystems such as terrestrial lichen communities and smaller scales such as the amount of downed woody material in stands or stream channels.

Forest type or cover group (major tree species groupings) and seral stage (age class groupings) are the two most commonly-used natural pattern condition indicators at landscape scales and both are required VOITs in the Alberta and Saskatchewan forest management planning standards (Government of Alberta 2006; Government of Saskatchewan 2017a).

Aquatic and other non-forest ecosystems are also part of forest landscapes. Interfaces between aquatic and upland ecosystems include wetlands and riparian ecosystems. Some of these ecosystems are vegetated and thus flammable and subject to fire processes. Others are subject to processes associated with water, especially climatic regimes and floods.

Challenges

- Tree species groups are commonly used because they are discernible in digital forest inventories and inventory information is available. They may not capture relevant within-class ecological differences related to moisture and nutrient regimes, for example.
- Inventory products for different landuse designations use different source information and classifications. This makes comparing information at the largest ecological scales more difficult.

- Availability of inventory information also differs between landuse designations. For example, there may be no detailed forest cover digital inventories for non-commercial forests and protected areas.
- Costs of acquiring new inventory or updating older information are challenges.
- Seral stages are commonly represented by tree age classes but they more properly should represent forest structure and composition. Inventory for these aspects is less well developed.
- Age information is less widely available and must sometimes be estimated. Acquisition of accurate age class information for older ecosystems is expensive.
- Age classes generally assume even-aged forest stands where the previous disturbance killed all or most of the trees. They are less suitable for disturbances that kill portions of trees in stands including mixed fire regimes (Arno et al. 2000) and gap dynamic processes (Cumming et al. 2000; McCarthy 2001).
- Characterization of ecosystems and determination of NRV at finer scales is limited by lack of inventory information.
- Consideration of NRV for aquatic and non-forested ecosystems is not widely done.

Recommendations

- Remote sensing technology is developing rapidly and costs are becoming more affordable. This will be useful to complete inventories and align classification towards a complete forest cover information layer for all forests in Alberta and Saskatchewan.
- Finer-scale ecological classifications are available and inventories are becoming more widespread and less expensive to complete or estimate. This could help to fill gaps from the coarsest levels when needed.
- NRV determined for ecosystems and components can be used to characterize NRV for aspects such as habitat.
- Explore cost-sharing opportunities to acquire inventory information. Also look to share inventory such as the situation in Alberta where forest companies largely paid for AVI inventory and energy companies largely paid for LiDAR inventory.

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Species Habitat

Projections of habitat supply for terrestrial wildlife species have become relatively common in forest management plans (Weldwood of Canada Ltd. 2000; e.g., Sakâw Askiy Management Inc. 2018). The Alberta and Saskatchewan Forest Management Planning Standards contain requirements for wildlife habitat analysis (Government of Alberta 2006, 2018; Government of Saskatchewan 2017a). Habitat analyses are usually concerned with change over time compared to a current baseline (Government of Canada 2011; Government of Alberta 2018).

Aquatic habitat is also highly variable, especially habitat in flowing waters, which have natural flow regimes that change constantly in response to hydrologic, climatic, and other processes (Poff et al. 1997). The ecological consequences of altered flow regimes are well-recognized (Bunn and Arthington

2002), but few have attempted to characterize NRV for aquatic species ecological conditions and habitat.

Challenges

- NRV has not generally been used to characterize species habitat in either terrestrial or aquatic ecosystems.
- Species and habitat biologists have mostly operated outside the drivers of variation in habitat driven by natural ecological dynamics and large-scale human activities.
- Historical separations of management roles and priorities have created silos among species and habitat managers. Historic species and habitat management was concerned mainly with exploited species (fish and game) and species that competed with humans for fish and game such as predators. Over time non-game species and eventually species at risk and biodiversity were added to the mix and recognition of the goal of biodiversity conservation for all species became standard. The original management silos still exist, with different agencies or sub-groups in government responsible for terrestrial species, aquatic species, and species at risk. These silos are powerful deterrents to communication and cooperation among biology disciplines, and between biologists and forest ecologists and managers.
- Habitat is usually addressed as a fine filter stand-alone process and also usually as a species-specific value. This can lead to conflicts between targets set independently for species with differing habitat needs.
- Habitat analyses are not linked or rarely linked to ecosystems NRV.
- Habitat analyses often rely on detailed fine-scale information that are not available in ecological inventories.
- Habitat targets are often short-term in nature.
- Managers are often concerned with unidirectional management, meaning they want more habitat (e.g., species at risk, harvested species), less habitat (e.g., invasive species), or stable habitat that can support stable harvests. The concept of variable habitats over time is generally not incorporated.

Recommendations

- The biggest opportunity is to use ecosystem NRV as a coarse filter biodiversity (habitat) NRV strategy. This will provide linkages between species habitat with NRV and for all ecosystems. It will also provide a common-interest platform to cooperatively manage species habitat.
- Use ecosystems to estimate fine filter habitat NRV for species of management interest. The important species to include in fine filter analyses are those judged to need additional detail not covered by coarse filter habitat.
- Extend the NRV habitat concept to habitats not traditionally viewed as variable (e.g., fish habitat).
- Overcome shortcomings of the critical habitat (Government of Canada 2002) provisions of the Species at Risk Act by incorporating them into EBM (see Section B, SARA).

- A concept paper on the opportunities to develop a comprehensive and integrated habitat management approach through EBM would be a useful basis for discussions.

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Human footprints

EBM is based on characterization of natural patterns and using those to inform management decisions. Characterization of alterations caused by human activity (footprints) is also informative, particularly for footprint patterns that have no natural analogues (e.g., roads and other linear corridors). For these patterns EBM is concerned with minimizing the footprints, mitigating negative ecological impacts, and ensuring restoration to more natural ecosystems after they are no longer needed.

Comparison of natural patterns (e.g., wildfire events) with anthropogenic patterns (e.g., logging events, prescribed fire events) is necessary to plan and implement strategies designed to maintain ecological integrity through an NRV strategy.

Challenges

- Selecting relevant and comprehensive footprints indicators from multiple available options is difficult, and different organizations tend to select different indicators and measure them differently.
- Footprints that are measurable with existing inventories and methods may lack useful details. For example, stream crossings inventories derived from intersecting GIS layers of linear corridors and hydrography are available, but the type of crossing, whether or not it enables fish passage, whether or not it is a sediment source into the aquatic environment, etc., must be determined through ground-based surveys that are more expensive and must be regularly update to detect changes (Foothills Stream Crossing Partnership 2015).
- Updating footprints information is expensive and it can take years for update information to become available.
- Information collection and management is typically divided among organizations and may not be collected in comparable formats.

Recommendations

- Research to identify a baseline set of human footprints indicators as a core starting point for EBM.
- Explore more area-based partnerships to collect footprints inventory and status information such as the Foothills Landscape Management Forum and Foothills Stream Crossing Partnership programs in Alberta and use the information to support area-based EBM planning.
- Explore opportunities to improve the accuracy and timely updating of government infrastructure databases such as the Alberta Digital Integrated Dispositions System.

F2.3 Biological Consequences Patterns

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Disturbances and recovery produce the ecological conditions that govern biological consequences. Each species is adapted to a particular niche produced by natural variation. In very dynamic landscapes such as the forests of Alberta and Saskatchewan species have evolved to cope with changing environments and ecological conditions. Animals move to find and exploit new environments. Plants generally don't move but their seeds and clonal fragments do.

Population sizes and distributions of species change in response to multiple factors including biotic factors, disturbance, ecosystem conditions, and direct and indirect effects of human activities. While these changes are well known there have been relatively few efforts to characterize NRV for them.

There is a strong link between ecosystem conditions (habitat) and species populations. Habitat loss and alteration (Brooks et al. 2002; Fahrig 2003) are the primary causes of population declines and local extirpation or extinction. Most population models do not simultaneously account for changing habitat and most wildlife habitat models assume a static environment, extrapolate poorly in space and time, and lack linkages to population processes (Nielsen et al. 2010). Spatial habitat models (Store and Jokimäki 2003; e.g., Nielsen et al. 2010) have been developed and used to forecast future habitat conditions and populations. The first wildlife habitat analysis in an Alberta FMP was in 1999 (Weldwood of Canada Ltd. 2000). Alberta (Government of Alberta 2018) and Saskatchewan (Government of Saskatchewan 2017a) now require wildlife habitat analysis as part of FMPs.

In addition to biodiversity, other biological consequences relevant to EBM include goods (wood, water, peat, botanical products, etc.) and ecosystem services, which are the benefits people obtain from ecosystems. The Millennium Ecosystem Assessment (2003) grouped ecosystem services into provisioning services such as food and water, regulating services such as flood and disease control, cultural services such as spiritual, recreational, and cultural benefits, and supporting services, such as

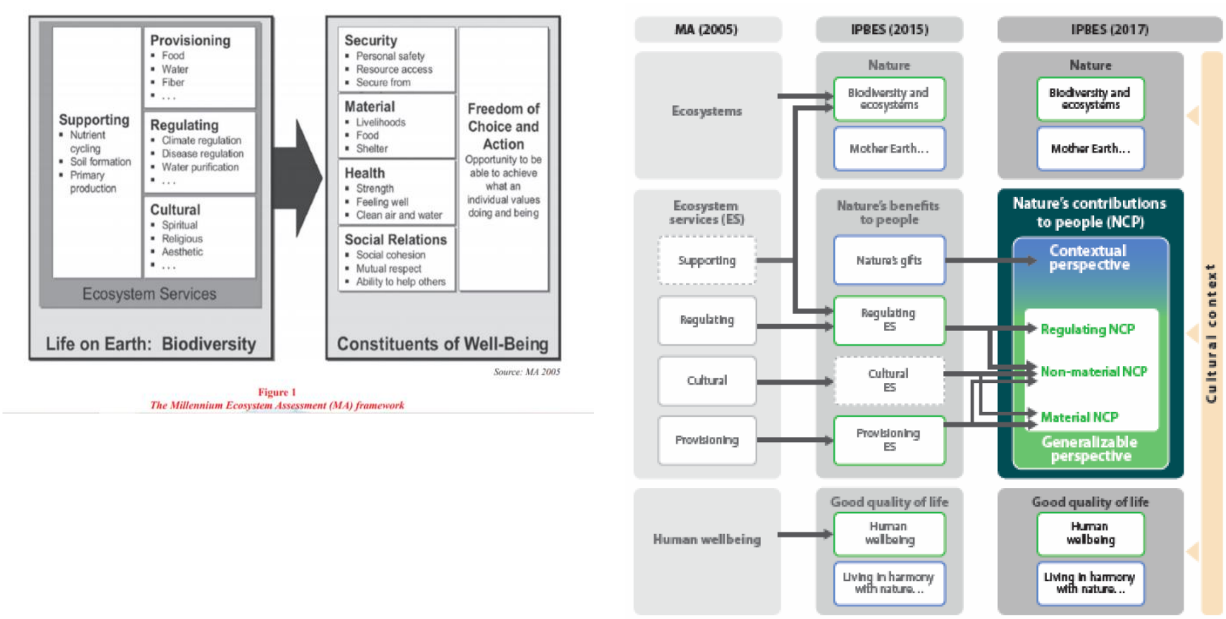

Figure F2. Millennium Ecosystem Assessment representation of ecosystem services (left) and Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) representation of Nature's Contributions to People (Diaz et al. 2018).

nutrient cycling, that maintain the conditions for life on Earth. Supporting services include global ecological cycles that affect climate change (Figure F2, F3; Díaz et al. 2018).

Challenges

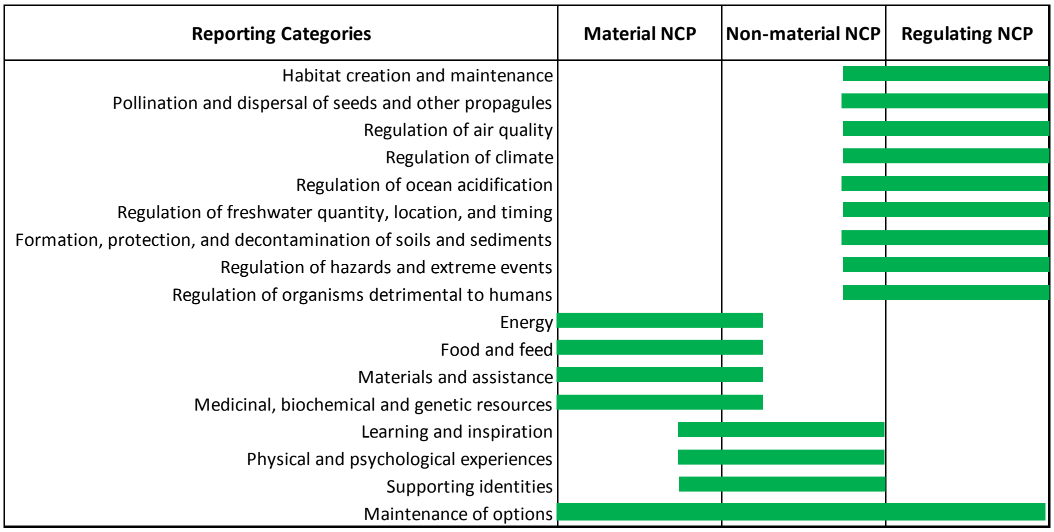

Figure F3. Mapping of 18 NCP categories used in Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) assessments onto three broad groups of Nature's Contributions to People (after Diaz et al. 2018).

- The biggest challenge is to apply a coarse filter approach to link species habitat and population management to NRV by choosing indicators and characterizing NRV for them, and then use NRV to inform setting of habitat and population targets.
- Linking population models to habitat NRV and forecasts is an additional challenge (Radeloff et al. 1999).
- Lack of fine-scale inventory detail inventories at levels needed for species management is a challenge.

Recommendations

- Select indicators that use available information or information that can be estimated through sampling and linked to available information.
- Build species habitat and population models that link to GIS and forest estate models that are used in scenario modelling.
- Advances in remote sensing technology provide opportunities to characterize habitat at finer scales (e.g., Coops et al. 2016; Marchi et al. 2018).

F2.4 Determining NRV

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Implementing an NRV strategy requires NRV estimates for each selected indicator in relevant ecological contexts and scales. Characterization of wildfire-driven disturbance and landscape NRV in terms of age classes and geographic regions has been completed for all Alberta and Saskatchewan forests (Andison 2019a). More detailed examinations that incorporate forest type and spatial statistics have also been completed (Andison 2019b, 2020b) and used to support EBM implementation for FMPs in both provinces.

NRV has also been characterized for wildfire disturbance (Andison 2003b, 2013; Andison and McCleary 2014). An analysis tool called NEPTUNE (Forestry Corp. 2006) aggregates mapped features into disturbance events that can be used to assess landscape conditions (Figure F4).

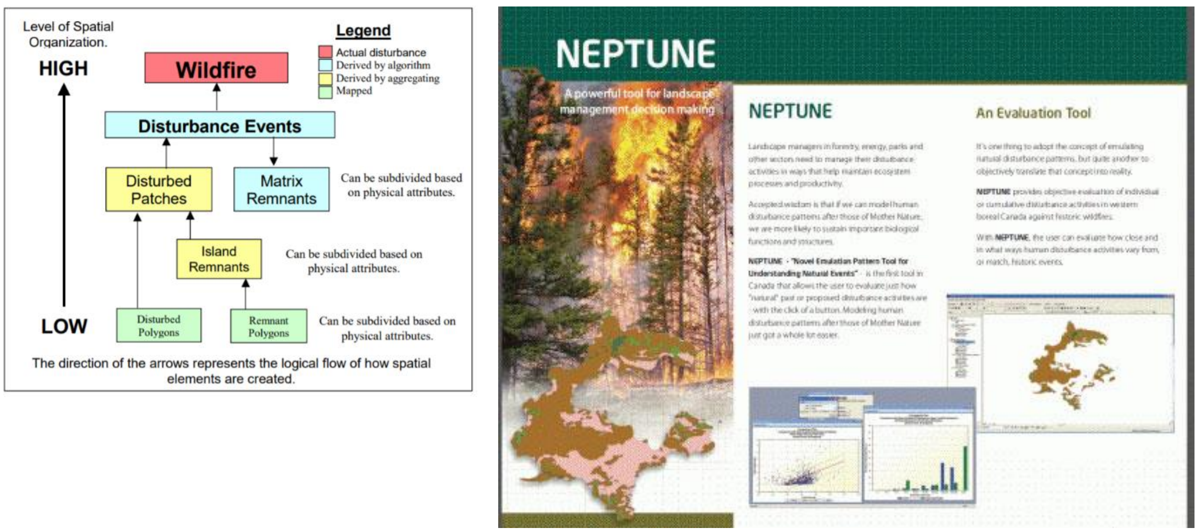

Figure F4. Spatial language for wildfire events (left, Andison 2013) and NEPTUNE evaluation tool.

CHALLENGES

- NRV characterizations have been extensively developed in Alberta and Saskatchewan over the past two decades primarily in relation to natural fire regimes. More work is needed to gain additional value from completed NRV characterizations. These include NRV estimates for landscape scale patch size and shape, watersheds, and species distributions.
- NRV information is not being used in management planning to the extent of available characterization estimate coverage.
- There are many other ecological aspects for which NRV could be useful to inform management and NRV estimates would be possible.
- Agreement to develop and use NRV estimates is a challenge, especially if development and application challenges other legal and customary practices such as critical habitat for species at risk. There is little value in developing NRV estimates if managers and regulators are not willing to use them.

Recommendations

> *"Initiate a project to identify NRV characterization needs and opportunities with priorities based on the most promising areas for EBM implementation."* (Anonymous SME).

> *"Administrative scale interferes with ecological scale. A manager that wants to have a big disturbance event runs into trouble if that would cover whole traplines."* (Anonymous SME).

- Additional information is possible for little cost by recompiling existing NRV characterizations for different ecological contexts. This could include watersheds of varying sizes and species distributions (e.g., caribou ranges).
- Initiate a project to identify NRV characterization needs and opportunities with priorities based on the most promising areas for EBM implementation.
- Scope research agendas to develop estimates and explore research coalitions and funding to develop new NRV estimates.
- Develop a framework that describes relevant ecological units and scales for characterization of NRV, with options and rationales. This would provide useful information for managers who must select units and scales for EBM plans and increase efficiency and comparability between areas. The framework could eventually be adopted as guidance for EBM planning.
- Ideally all areas should have a description of the natural disturbance regimes (and NRV if possible). This information should inform decisions about future disturbance regimes. These include
    - Whether or not to attempt to manage the natural regime in any form (e.g., supress fires and other large-scale natural disturbances, introduce human activities, etc.).
    - Where fires are suppressed, what planned disturbances (e.g., prescribed fire, logging, mechanical and chemical vegetation management, etc.) will be applied to approximate natural regimes. This includes accounting for natural disturbances that occur plus planning for deliberate human-initiated disturbance.
    - Areas where fires are supressed and there is no planned alternative disturbance (e.g., passive landbase, some protected areas).

ecological units and hierarchical scales that may be useful for EBM implementation.

Ecological Analysis Units
Natural Subregion
Landscape
Sub-landscape
Event
Patch
Site
Element
Largest watersheds
Landscape (Major) watersheds
Sub-landscape (Local) watersheds
Watershed, waterbody type
Stream segment, waterbody
Stream reach
Element
Species Designatable Units
Species sub-population Units
Local species population units
Group
Family unit
Individual

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Analysis Units

Analysis units for NRV characterization should be the same units used to set EBM targets or monitor ecological conditions (Section F2.2). These should be a combination of ecological units and administrative units. The largest ecological units should be subdivided into smaller linked units that can be used to compare NRV to current conditions and future variation targets (Table F1). Administrative units are primarily useful to assess performance against targets that EBM managers are accountable for accountable for or that organizations are interested in.

CHALLENGES

- Deciding appropriate ecological units and scales to use to support EBM is a challenge.
- Ecological units usually cross administrative boundaries, making it more difficult to use common units and align plans and targets.

RECOMMENDATIONS

> *"Landscape ecosystems transcend geo-administrative bounds at regional scales. Cooperation is needed to overcome this problem."* (Anonymous SME).

> *"Ecosystem resiliency, sustainability, species conservation, healthy watersheds, soil-productivity conservation, and general human dependency on natural systems are arguably all common interests or goals on all landscapes regardless of land-use policy designation. These points in commonality could serve to represent a dialogue start-point for future agreement that ecosystem-based approaches be adopted nation-wide and that management plans seek harmonization between parties on either side of geo-administrative boundaries."* (Anonymous SME).

- Provincial leadership to initiate a system of analysis units that managers could use to frame their portions of units and identify others to work with to characterize ecological units.
- A research project to identify unit alternatives and assess pros and cons of different unit sizes and combinations.

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INVENTORIES

After NRV is characterized it must be compared to historic and current conditions derived from inventories. Ideally future conditions for an NRV indicator can also be forecasted so managers can explore alternatives for future conditions as an aid to setting targets.

CHALLENGES

> *"Adversaries are using information as a weapon, and the public doesn't know what information to trust."* (Anonymous SME).

> *"Data is expensive and often proprietary. Companies that pay for data don't want others to have access to something that could be used against them."* (Anonymous SME).

- Digital ecological inventories needed to support long-term EBM planning are mixed in availability and quality.

- Inventories are incomplete and uneven across geographic and administrative scales
- Inventories at finer scales (e.g., within-stand forest structure) are generally not available.
- Inventories are expensive and funding is not available to cover all areas.
- The best inventories tend to be for commercial forests with area-based tenures, because tenure-holders are required to create and update inventories. Digital inventory information and coverage is less complete for protected areas and non-commercial forests.
- Responsibilities for procuring information are divided among organizations.
- Inventory comparability across land categories and ownership is variable. Data standardization or comparability still needs work.
- Information is valuable and owners may not make it available or may charge for access.
- Historical information is generally only available for recent decades and these are usually insufficient to span appropriate time periods.
- Estimating older historical information is expensive and not well suited to large areas.
- Models must be used to estimate NRV where historical reconstructions are not feasible.

Recommendations

> *"Information technology is developing so fast it's hard to keep up. There are all sorts of new things that should help with EBM and keep costs down at the same time."* (Anonymous SME).

- There are good opportunities to use developing remote sensing products to augment or substitute for more traditional inventories based on aerial photograph interpretation.
- Where local NRV estimates are not available extrapolations from other areas can be used to get started while local research is commissioned to fill data gaps.
- Rough estimates may be possible through analysis of inventory information combined with expert opinion.

F2.5 Incorporating Variation

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Natural variation manifests in both space and time. At any point in time landscapes and other ecological scales have different proportions, locations, and configurations of ecological conditions that reflect historic variation in disturbances. NRV has probabilistic limits that can be measured and integrated into NRV metrics and targets (Andison 2020a).

Like many human endeavors and governance models, federal, Alberta, and Saskatchewan forest management legislation, policies, and other regulatory requirements have tended to be simplified, specific, and usually rigid rules. By definition, rules reduce variation and conflict with the EBM objective to maintain variation.

Rules are ubiquitous, and widely unpopular, especially when imposed by governments. Rules and the rule of law represent societal norms and are designed to control human behaviour for various purposes.

These include reconciling economic and non-economic values, preventing unacceptable actions, encouraging desirable actions, safety, human rights, etc. Rules often follow the S.M.A.R.T. criteria: specific, measurable, attainable, realistic, and time-related (Doran 1981).

Over the last two decades EBM considerations have entered Alberta and Saskatchewan government forest management planning standards and FMPs. Forecasted VOITs typically display variation over the long-term planning horizon, and companies now routinely show the forecasted variation over time in graphs that also display the upper and lower NRV limits. The government approval is typically to follow the plan, which has incorporated the variation described in the forecast. By default, this introduces some level of variation.

Some examples now exist of targets being set in terms of frequencies and quartiles (West Fraser Mills Ltd. 2014). The draft CBFA forestry requirements for natural range of variation (NRV) analysis and target setting (Canadian Boreal Forest Agreement 2015) proposed that targets should be set within the middle two NRV quartiles, which is the same as the interquartile range in the FSC Boreal Standard (Forest Stewardship Council 2018). These targets are arbitrary and reduce variation by 50% compared to NRV.

Incorporating variation into some NRV distributions is more challenging. For example, natural variation in disturbance event sizes is being used to inform design of logging events in commercial forests and is required as part of the SFMPS (Government of Saskatchewan 2017b). Very small (<2 ha) logging events may be uneconomic and very large (>10,000 ha) logging events may be socially unacceptable and are difficult or impossible to accomplish in relatively short time periods. Achieving a distribution of logging event sizes also takes many decades to accomplish. This challenge may be addressed by keeping a catalogue of all disturbance events and using future forest design to meet variation objectives.

CHALLENGES

> *"Variation can be achieved through quantitative targets such as patch size but also through just more qualitative concepts such as direction to increase variation. The forest sector has gotten better with qualitative, and in some cases that may be enough."* (Anonymous SME).

> *"The energy sector has deep suspicion of adding more rules to the pile because they have seen little evidence of old rules going away when new ones come in. They tend to oppose new rules on principle."* (Anonymous SME).

- Existing rules are often problematic for EBM, because they mostly don't support the desire to manage for variation. Rules also tend to focus on activities rather than outcomes.
- Many management activities are deliberately intended to reduce natural variation, especially for large natural disturbances (e.g., fire suppression, flood prevention), but also for human disturbances (e.g., cutblock size, proportion of area logged, succession truncation, etc.).
- Some human activities unintentionally increase variation in ways that have shown to have negative ecological effects. For example, fragmentation due to linear corridors (Pickell et al. 2015) is associated with threats to biodiversity (Benítez-López et al. 2010).
- Management often does not consider variation as a desirable objective.

- Management systems often feature non-variable targets and frequently act to reduce variation. Minimum standards required by governments may truncate NRV or set targets that are outside NRV. Governments frequently express targets in terms that meet policy objectives, and these may not reflect ecological variations as much as they could. Minimum standards are an example of a target that could reduce variation, especially if the minimum standard target is not within NRV or represents conditions within NRV that occur over relatively small proportions of time horizons.
- Government requirements tend to be expressed as fixed numbers because compliance is easier to measure. For example, it's much easier to specify and audit a maximum width for a road right-of-way than to specify and audit a variable-width right-of-way that minimizes disturbance while meeting construction, environmental protection, and safety needs.
- Where variation is allowed or required the comparison is often against current conditions rather than the NRV context (e.g., water yield change of up to ±15% from current). This limits options when allowable variation does not encompass NRV and when an indicator current condition is at the low or high end of NRV (or outside NRV). Worse, it could lead to unintended ecological consequences. If an indicator current condition is scarce (low end of NRV) allowing an up or down change from current condition could increase conservation risk.
- Incorporating variation into targets and rules is difficult.
    - NRV is a distribution with minimum and maximum levels. These simple statistics along with mean and median are often used to establish targets.
    - Andison (2020a) listed averages, thresholds, ranges, range groups, and frequency distributions as possible ways to include variation in targets. All of these have strengths and weaknesses. The challenge is to develop a portfolio of targets that increases variation that is consistent with NRV where that is decided.
    - Moving away from activities toward targets for outcomes is a challenge. Rules and processes based on "Tell me what you want the outcome to be, not how I should do it" are not easy to implement.

OPPORTUNITIES

> *"Variation isn't just an ecological imperative; it applies to humans too. We have variation in uses, needs, opinions, power, and so on. EBM has to recognize and accommodate that."* (Anonymous SME).

> *"Some companies (e.g., Al-Pac and Mistik) deliberately deploy their contractors according to the equipment and inclinations each has. If they want more retention, they assign a contractor who tends to leave more, and vice versa."* (Anonymous SME).

- Alberta and Saskatchewan have both provided opportunities for forest companies to propose alternatives to minimum government standards in their forest management planning standards (Government of Alberta 2006; Government of Saskatchewan 2017a) and their operating rules (Government of Alberta 2016; Government of Saskatchewan 2020). These opportunities are not used as often as they could be used (SME interviews), and some industry proposals have been rejected. Finding ways to increase usage of the alternatives system and obtaining government approval is a challenge.

Recommendations

- Most government rules have provisions that allow alternatives to following the rules if they are justified and the proposed variance is approved by a designated government official. These provide opportunities to propose and implement new EBM improvements.
- Develop policies recognizing the value of variation and promoting variation through EBM.
- Measure current and recent historic variation, compare to NRV, and use the knowledge to inform future targets to align variation closer to NRV.
- Governments have recognized the need for operational flexibility (e.g., the Alberta harvest plan amendment system; Government of Alberta 2006) and have been willing in principle to approve plans that incorporate targets with variation over time. In these cases, approvals typically say "follow the approved target". More use of plan-based variation will help to address performance verification requirements.
- NRV truncation may be appropriate if the truncation includes rare conditions that have unacceptable impacts on other ecological values such as species at risk, and human wellbeing aspects such as fire threat. The value of an NRV strategy is that it provides an ecological baseline for comparison and an aspirational target. The NRV concept is also useful in determining how much change is appropriate and is thus useful for avoiding or mitigating risks associated with too little or too much change. Decisions that differ from NRV do not necessarily compromise ecological integrity and they are necessary to support many aspects of human wellbeing.
- Regular plan revision is one way to address uncertainty and incorporate variation. It is impossible to predict the future for many aspects, so accounting for unplanned and unforeseen events that occur between plan revisions and incorporating the new information in the new plan recognizes unplanned variation and includes it in historic variation monitoring and future variation planning.

F3 Disturbance tools

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Disturbance tools vary considerably depending on the landuse designation of forest units. Commercial forests primarily use logging. Prescribed fire (broadcast burning for reforestation) was formerly more common but has declined to very low or nil levels, mainly due to public opposition to smoke and liability concerns. Herbicides are used in specific situations to control vegetative competition. National Parks use prescribed fire almost exclusively, with logging to minimize community fire threat. Prescribed fire and harvesting are occasionally used for other forest units, but at low levels. The dominant disturbance type for these areas is unplanned wildfire, and amounts vary over time depending on location and fire suppression efforts. Mechanical disturbance related to surface infrastructure is widespread. Control efforts are often directed at major insect (e.g., mountain pine beetle) and disease outbreaks. Ecological restoration is applied to reforest after logging or wildfire (if needed) and reclaim human footprints (wellsites, roads, stream crossings, etc.). All other natural disturbance types are more or less unmanaged, meaning that nothing is done to alter the natural regime.

F3.1 WILDFIRE

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Forest fire is the dominant natural disturbance in Alberta and Saskatchewan forests (Rowe and Scotter 1973; Wotton et al. 2010). Historical fires were so frequent that long-term-fire-cycle estimates were 45–130 years for continental forests and 30–250 years for cordilleran areas (Andison 2019a). Reduction or cessation of Indigenous burning (Lewis 1978; Murphy 1985; Lake and Christianson 2019), industrial-era changes in land use and fire exclusion policies (Murphy 1985) have significantly modified fire regimes and forest landscapes across much of North America (Pyne 2007; Ryan et al. 2013).

Government fire policies developed primarily to protect human life and property from the impacts of uncontrolled wildfires, and because fires were considered to be detrimental to natural values and a waste of usable timber (Murphy 1985; Tymstra et al. 2020). Today the Alberta, Saskatchewan, and federal governments maintain large fire suppression organizations and capabilities and successfully supress the majority of wildfires that ignite and are designated for suppression (Cumming 2005; Tymstra et al. 2020). Some fires overcome suppression efforts and some of these high severity fires can grow to very large size and consequences (MNP LLP 2016, 2017).

Canadian wildfire management is based on either zonation or no zonation, and full response or risk-based appropriate response, and some wildfire management agencies are transitioning from a zone response approach to a wildfire appropriate response approach (Tymstra et al. 2020). In Alberta all wildfire ignitions are evaluated using a risk management framework with five priorities to determine appropriate response (Government of Alberta 2001; Figure F5). Alberta applies a full suppression policy to all forested lands and attempts to initial attack all wildfires before they reach two ha in size. In Saskatchewan there is a full response zone for communities and for the primary timber management areas in the commercial forest zone and a modified response zone in northern forests, separated by the Churchill River (*Saskatchewan's 2009 State of the Environment Report and State of Saskatchewan's Provincial Forests* 2009). All Saskatchewan wildfire ignitions are evaluated against provincial policies to determine appropriate response, regardless of which zone they occur in. Saskatchewan has large areas of non-commercial forest in the Canadian Shield with low numbers of people and allows many wildfires to burn naturally to conserve the ecological values of wildfires. See Figure F5.

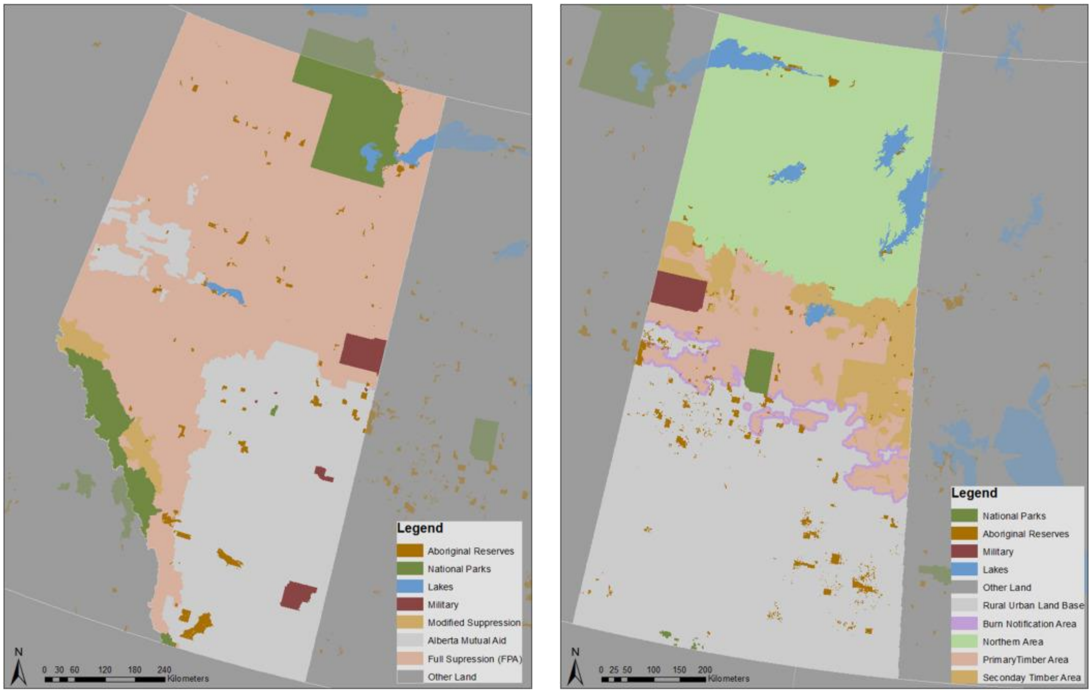


Figure F5. Wildfire management zone maps for Alberta and Saskatchewan (from Tymstra et al. 2020).

Challenges

> *"We often speak highly of the value in emulating some functional and structural aspects of natural disturbance (wildfire). To a community or person who has lost property, loved ones and memories of home to a wildfire, the articulation of such strategies by forest practitioners must be abhorrent, offensive, illogical and deeply flawed. Trust in forest management professions and science would logically suffer if we are not careful and rather specific here."* (Anonymous SME).

> "*Insurance companies faced with huge payouts related to forest fires appear to be mainly concerned about charging clients enough to pay for current and future claims, not in reducing fire risks so claims go down."* (Anonymous SME).

> *"Fire policies are an issue. For example, slash abatement including pile and burn slash is expensive and may be ecologically damaging. It would be better to spread it out for ecological value. When big fires get going it is in conditions that are so extreme that anything burns and nothing stops it. Hazard abatement is seen as "doing something" but probably has little benefit. Fear of fire is a powerful challenge, but ignoring it or doing things that look good but aren't effective isn't helping."* (Anonymous SME).

> “*The Alberta provincial fire agency culture is ‘fire is bad we need to put it out’. The focus is on equipment and emergency management. There are no fire ecologists working in fire management, no expertise to manage ecosystems. The agency has tools but doesn’t have the bigger picture in mind. The agency needs direction and culture change to get there, and would need to build capacity. Having collective discussions would be a good start.*” (Anonymous SME).

> “*Wildfire suppression contributes to a wildfire problem but paradoxically it is wildfire use that will help to solve this problem (double fire paradox). A major barrier in Canada to address the double fire paradox is the inadequate funding to support the vision of an innovative and integrated approach to wildfire management*” (Tymstra et al. 2020).

> *“Fire has been omnipresent in the multi-millennial story of forested landscape ecology and human history. Societal and professional attitudes about wildfire have moved from the 1960's Smokey-the-Bear "fires are bad, prevent them always" perspective, to a short period of alternative perspectives communicated by the forest management science-sector in the 1990's where “fire is a good agent of renewal, biodiversity trigger and ecosystem health”. We now face a likely return to probable widespread perspectives that fires are but a negative, destructive force. Public statements by a former US president, point to "forest management" as an alleged causal agent of blame for the fire destruction of communities. Similarly, “deadwood” was vilified and needed to be corrected by raking forests. It will be hard to overcome this kind of framing.”* (Anonymous SME).

> “*The Alberta provincial fire agency culture is ‘fire is bad we need to put it out’. The focus is on equipment and emergency management. There are no fire ecologists working in fire management, no expertise to manage ecosystems. The agency has tools but doesn’t have the bigger picture in mind, needs direction and culture change to get there, and would need to build capacity. Having collective discussions would be a good start.*” (Anonymous SME).

- Societal orientation with respect to wildfire is overwhelmingly oriented to wildfire prevention and control, to protect human values (Dods 2004). Conversations to explore how EBM could protect human values while doing a better job of managing fire to help maintain ecological integrity are in relatively early stages.
- Public acceptance, aversion to risk, and inadequate funding are greater challenges to modifications to wildfire management policies than remaining ecological unknowns (Ryan et al. 2013).
- Most provincial fire management agencies are structured to respond to fires, not to govern them (Sutherland 2020).
- Government wildfire agencies and their partners are facing increasing demands as human presence in forests increases and wildfire occurrences increase (Tymstra et al. 2020). In extreme fire hazard conditions if there are multiple ignitions initial attack capacity is overwhelmed.

- The costs of wildfire operations and the impacts of unsuppressed wildfires are increasing. The 2016 Horse River Wildfire in northern Alberta was the costliest insured natural disaster in Canadian history at $3.84 billion (MNP LLP 2017).
- Climate change projections suggest that there will be more wildfires in the future (Flannigan et al. 2005; de Groot et al. 2013).
- Decades of wildfire suppression have altered forest fuel loads and continuity in ways that increase wildfire risks (Arno and Brown 1991; Keane et al. 2002; Keane 2008) and the challenge of managing wildfires.
- More than 4400 terrestrial and freshwater species from a wide range of taxa and habitats face threats associated with modified fire regimes including exclusion of fire in ecosystems that need it, and increases in fire frequency or intensity (Kelly et al. 2020)
- In commercial forests wildfire reduction is necessary to protect timber supplies that support AAC. Simply put, less wildfire means more timber to log (Coogan et al. 2020). This approach has largely been successful but it has had unintended consequences. These include more wildfire risk on the passive landbase and reduction of fire as an active ecological process in commercial forests. The challenge is to maintain timber supplies while using fire in the passive landbase and as a complement to other management tools on the active landbase.
- Suppression of stand-maintaining wildfires promotes fuel buildup and continuity and creates a higher risk of wildfire, which is a wildfire paradox (Arno and Brown 1991).
- "*Wildfire suppression contributes to a wildfire problem but paradoxically it is wildfire use that will help to solve this problem (double fire paradox). A major challenge in Canada to address the double fire paradox is the inadequate funding to support the vision of an innovative and integrated approach to wildfire management"* (Tymstra et al. 2020).
- Managers are constantly faced with deciding which wildfires to fight and which to let burn with conditions (Martell 2001).
- As more human economic development occurs in wildland areas, more numerous and diverse values on the landscape will be placed at risk of wildfire (MNP LLP 2017).
- Considering the human wellbeing values at risk (Johnston and Flannigan 2018)
- New ways need to be found to maintain fire as an active process to support ecological integrity (Moritz et al. 2014; Tymstra et al. 2020).
- Funding for wildfire research to support science-informed wildfire management has been a major challenge.
- There are significant challenges related to increased use of prescribed fire and harvesting is not allowed or limited in protected areas, non-commercial forests, and the passive landbase.

"*Insurance companies faced with huge payouts related to forest fires appear to be mainly concerned about charging clients enough to pay for current and future claims, not in reducing fire risks so claims go down."* (Anonymous SME).

Recommendations

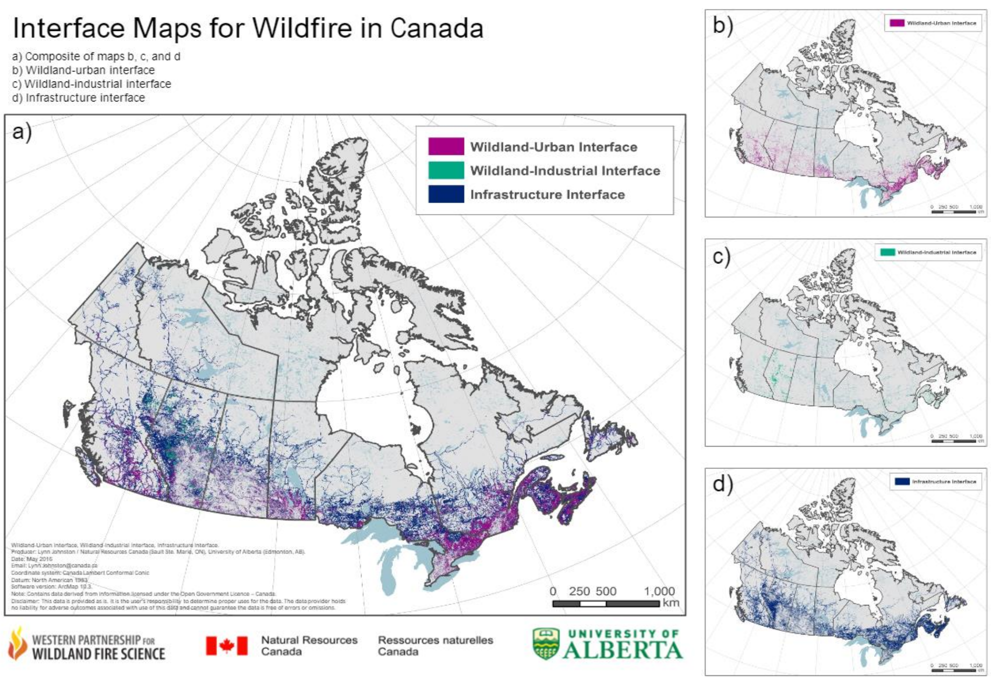
> *"How are we managing fire? Does fire suppression create conditions for more catastrophic fires? Is climate change going to make fires worse? We have to find ways to live with fire and use it more as a tool. The opportunity is huge, the path will be exceedingly difficult."* (Anonymous SME).

> *"Response policies for wildfire may be an opportunity, with modified response rather than full suppression in some cases."* (Anonymous SME).

- Preparing for, preventing, and mitigating wildfire damage requires long-term commitment by all parties (MNP LLP 2017). As a management approach that aims to be comprehensive and involve all interested parties, EBM, is a good process for this initiative.
- The ecological consequences of alterations to fire regimes are becoming better understood and are a primary reason for implementing EBM. Maintaining fire as an active process on human-dominated landscapes while managing risks of uncontrolled wildfires is a significant EBM opportunity.
- Developing an adaptive resilience approach that reduces fuels to adapt some ecosystems to more frequent fire and protects communities, manages more wild and prescribed fires with a range of severities; and prepares human structures to better withstand inevitable wildfire (Schoennagel et al. 2017)
- Return fire to fire-adapted landscapes to prevent and mitigate larger more uncontrollable fires and promote ecological health (Sutherland 2020).
- Restructure the way fire reintegration is done, by whom, and on whose terms through partnerships. In northern Saskatchewan, for example, Indigenous peoples have very strong desires to influence policy and eventually deliver programs (Zahara 2020).
- Fire suppression policies have been largely successful in reducing wildfires, but not completely. Escaped wildfires do provide ecological benefits, sometimes with little impact on human interests. Opportunities to provide similar benefits may be possible through modification of fire response actions in carefully selected situations that can be considered in advance through regional wildfire response planning.
- There are opportunities to manage fuel loads and continuity using tools such as harvesting and prescribed burning. This has the dual benefits of reducing wildfire risk and increasing disturbance to more closely approximate natural disturbance regimes and ecological conditions variability in forests.
- *"The wildfire management toolbox must include wildfire use to manage wildfires at the landscape scale because it is not feasible to effectively use prescribed burns and/or fuel management treatments alone to restore expansive wildfire-dependent ecosystems*" (Tymstra et al. 2020).

- Tymstra et al. (2020) envision a wildfire management paradigm shift triangle to coexist with wildland fire (Figure F7). If implemented, this approach could also serve to increase the ecological role of wildfire in EBM.
- Alberta requires a landscape fire threat analysis as part of the forest management planning process for commercial forests, but the analyses aren't used to make substantive active management decisions. Fire threat is an indicator with NRV. There is opportunity to determine fire threat NRV and characterize current and future forest conditions in terms of NRV. This may help to identify opportunities to reduce wildfire threat.
- There are substantial areas in the north of both provinces with relatively low levels of human presence (Figure F6; Johnston 2016). There may be additional opportunities to maintain wildfire as a more active ecological process in those areas, especially in partnership with Indigenous peoples.
- Expand efforts within the Alberta Departments of Agriculture and Forestry and Environment and Parks to link wildfire management with planning under the Land-use Framework, Forest Management Agreements, and other relevant planning initiatives (MNP LLP 2016). This opportunity also applies to the equivalent agencies in Saskatchewan. Better cooperation of wildland fire managers with the ministries responsible for land and resource management creates opportunities to integrate wildfire as an ecological process at the front end of land use (and EBM) planning (Tymstra et al. 2020). Look at similar opportunities in Saskatchewan.

Figure F6. Interface maps for wildfire in Canada, from Johnston 2016.



- The creation of a collaborative research network described in the *Blueprint for wildland fire science in Canada: 2019–2029* (Sankey 2018) is a positive step that can be expanded to meet research and decision support needs.

Figure F7. Wildfire management paradigm shift triangle (Tymstra et al. 2020).

F3.2 Prescribed Fire

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Indigenous fire stewardship was used for thousands of years to promote desired landscapes, habitats, and species, and to increase the abundance of favored resources to sustain knowledge systems, ceremonial objectives, and subsistence practices, economies, and livelihoods (Lake and Christianson 2019).

Managers use prescribed burning to partially restore natural fire regimes and garner ecological and human wellbeing benefits. Major reasons for prescribed burning include:

- Fire hazard reduction by removing or reducing flammable fuels near communities and other human interests that are vulnerable to uncontrolled wildfires.
- Fuel reduction at strategic landscape positions to block potential for uncontrolled wildfire expansion.
- Control of non-native vegetation.
- Insect and disease control.
- Production of habitat conditions that benefit important species used by humans (berries, mushrooms, game species, species at risk, etc.).
- Creation of a more balanced distribution of forest ecosystem compositions and conditions.
- Silviculture aimed at reforesting logged areas.
- Maintenance of fire as an active ecological process.
- Restoration of native ecosystems, communities, and species.

Despite the many benefits available from prescribed burning (Weber and Taylor 1992), its use has not been extensive enough to replace historic fire regimes (Woodley 1995; Andison et al. 2021). The Alberta

> *"I think that we also have to do a bit more controlled burning to catch up with what Mother Nature would have done if we hadn't suppressed fires for a long, long time."* (E. Zruski in Pearson 2019)

Buck for Wildlife program started in 1973 used prescribed burning for wildlife habitat enhancement. In 1988 Buck for Wildlife completed six prescribed burns that enhanced 3761 acres of moose, elk and deer habitat (Government of Alberta 1989). Prescribed burning for wildlife habitat continues under the oversight of the Alberta Conservation Association (Rasmussen and Stavne 2016).

Parks Canada has the most active prescribed fire program of all government agencies in Alberta and Saskatchewan, yet continues to fall behind the historical fire cycle (Edward Zruski quoted in Pearson 2019) .

CHALLENGES

> *"It took 60+ years of fire suppression to get today's landscapes, it will take a long time to restore. Fire will never return to a fully natural role, but we can do more than we're doing now."* (Anonymous SME).

> *"Some of the most pressing and challenging issues that pose significant barriers to prescribed fire application include: our broad land management framework… gaps in legislation and policy and even definitions… legal liability for fire escapes… protection of human health and current smoke management guidelines… current high fuel loads… and capacity limitations as it relates to training and skills to execute sound, ecologically appropriate prescribed burns."* (Blackwell 2021).

> *"There will be impacts of smoke for longer duration if we let more fires burn and do more prescribed burning."* (Anonymous SME).

- Societal aversion to risk often trumps known, long-term ecological benefits (Ryan et al. 2013).
- Human interests at risk of fire damage have increased in forest landscapes, which increases human wellbeing risks related to both natural and prescribed fire.
- Smoke-caused air quality impacts and compliance to air quality regulations can be an impediment to the use of prescribed fire, especially near population centers (Navarro et al. 2018).
- Liability risk related to fire escapes is a large challenge that is widely recognized but not quantified and accepted or shared among possible participants (Yoder et al. 2004).
- Fire managers are overwhelmingly oriented toward fire suppression and most fire resources go to that objective. Knowledge, experience, and capacity to implement more prescribed fire is limiting (Blackwell 2021).
- Public acceptance and human health concerns related to smoke (Aguilera et al. 2021) and aversion to risk, liability, inadequate funding related to fire planning and operations, and narrow burn windows are often greater challenges to the use of fire than remaining ecological unknowns (Ryan et al. 2013).
- Leadership and commitment of individual decision-makers and fire managers is needed to promote and implement prescribed fires (Schultz et al. 2019).
- There are comparatively few knowledgeable and experienced personnel needed to plan and implement prescribed fires.

- Prescribed burns are expensive and funding, which usually comes from governments, is limited. Costs can range from $10 to $1,000 per hectare, depending on the size and conditions of the burn. The average cost is $80 per hectare (Rasmussen and Stavne 2016).
- Narrow burn windows restrict ignition opportunities (Quinn-Davidson and Varner 2012).
- Regulations governing prescribed fire are complex and challenging to comply with.
- Environmental laws limit prescribed fire opportunities, especially those related to smoke emissions and effects on air quality, water quality, and biodiversity (fish, species at risk laws, etc.).
- Societal support for prescribed fires is low.
- Climate change concerns have increased public aversion to fire in general, because fires release large amounts of carbon into the atmosphere.

RECOMMENDATIONS

> *"Prescribed burning is a good tool but ignition windows are few and far between, which limits opportunities. We definitely can widen the windows by taking on a little more considered risk."* (Anonymous SME).

> *"Work with Indigenous communities to identify challenges and opportunities for returning to cultural burning."* (Anonymous SME).

- Government leadership in acknowledging and promoting the use of prescribed fire to treat fuels and restore fire-adapted landscapes.
- Smoke from wildland fire is inevitable, particularly in fire prone ecosystems where full wildfire suppression is unsustainable. This has led to increased interest in using fire to improve ecological health and reduce risks of catastrophic wildfires (Schweizer et al. 2017).
- There are opportunities to build value propositions for the use of prescribed fire and to develop predictive tools and practices to minimize smoke exposure and effects.
- Differentiating the risks of applying prescribed fire from those of catastrophic wildfire can help to build support for prescribed fires.
- The liability from escaped fires is minimal (< 1%) and other underlying factors may be leading to concerns of risk of liability when applying prescribed fire (Weir et al. 2019). Innovative proposals and practices to address liability challenges present opportunities to remove liability as a challenge to prescribed fire implementation.
- Investigate insurance opportunities to reduce risks and liability that currently discourage more use of prescribed burning (MNP LLP 2016).
- Promote increased use of prescribed fire and strategic management of wildfires in fire-dependent ecosystems through integration of science, policy, and management.
- Increase societal acceptance through education and public involvement in EBM.

- Use collaborative forums and other initiatives to facilitate communication, problem-solving, resource sharing, and acceptance among partners.
- For commercial forests, explore opportunities for government agencies to work with industry to use prescribed fire as a site preparation tool and to add fire to logging disturbance events.
- Explore opportunities to use prescribed fire as a disturbance tool in the passive landbase of commercial forests.
- Restore multi-scale structural variation and complexity through burns at different times of the year, under different weather and fuel-moisture conditions, and the use of heterogeneous ignition patterns (Schultz et al. 2019).
- Assess current levels of knowledge, expertise, experience, and resources to identify opportunities to build capacity for prescribed burning.

F3.3 Mechanical Tools

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Mechanical tools are defined here as mechanized killing of trees and other vegetation as a disturbance agent where the treatment does not promote or produce an economically valuable product such as timber or biomass. Examples include mechanical soil disturbance, cutting shrubs or trees, crushing vegetation, etc. Mechanical tools might be used to reduce fire threats near communities or facilities (e.g., FireSmart), remove undesirable vegetation (e.g., weeds, tree ingress in grasslands), improve habitat (e.g., shrub cutting to promote browse), and restore ecological communities (e.g., aspen cutting to initiate stand renewal).

Challenges

- Using mechanical tools can be expensive, partly because there is usually no economic product produced. For this reason, they are not extensively used.

Recommendations

- Mechanical tools could be used to increase disturbance where commercial timber logging is not economically viable or environmentally feasible (e.g., the passive landbase).
- Mechanical tools could be used more extensively if new economic uses become viable (e.g., biomass logging for biofuels).

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Logging

Large-scale logging occurs in commercial forest areas on the approximately half of the landscape that produces merchantable forest stands and is available for logging. Logging is confined to mature and old stands where individual trees have grown large enough to have commercial value.

Small-scale logging occurs throughout the forests of Alberta and Saskatchewan. Logging to clear forests for human infrastructure and to cut firewood are probably the largest non-commercial uses. EBM challenges and opportunities related to logging are described in Section F4

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Stand Management

Commercial forestry includes disturbance tools that are applied to protect trees and promote tree growth. Tools include mechanical and chemical treatments to remove or control competing vegetation, thinning to reduce crop tree density, and commercial thinning to remove products and improve growth and quality of retained trees.

Challenges

> *"In slow-growing forests there are few economic options for stand management to get more timber. Usually you'd be better off putting your money into banks."* (Anonymous SME).

- Most stand management tools are applied to meet legal requirements and not as economic investments.
- Stand management is situation-dependent and may act to reduce variability (e.g., removal of deciduous shrubs and trees) or increase it (e.g., commercial thinning to increase terrestrial lichen communities).

Recommendations

> *"Dump the rules that act against the grain of natural ecological processes. They are too costly and reduce variation. Work with Mother Nature, not against her."* (Anonymous SME).

- Increase variation by looking for alternatives to expensive stand management tools, and also look for opportunities to reinvest cost savings into activities that can replace any associated AAC losses. The opportunity is to increase variation and maintain AAC without additional costs at minimum, and to reduce overall costs as a best case.

F3.4 Fire Salvage

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Many species and ecological communities have adapted to exploit burned forests, especially in the first few years after fires. Natural fire regimes in Alberta and Saskatchewan provide many opportunities for fire-adapted species. Wildfires have been significantly reduced in commercial forests through fire suppression activities (Andison et al. 2021). For this reason, governments are keen to conserve ecological values associated with burned forest on commercial forest landscapes (Nappi et al. 2004; Guedo 2007). This is consistent with EBM as it pertains to retaining natural processes.

When unplanned wildfires occur in commercial forests companies usually try to log fire-killed timber to capture the economic value of trees that otherwise would have supported AAC, and to reduce further fire risks. Only merchantable timber that is relatively lightly scorched can be used by many mills, because there is risk of charcoal mixed in with wood chips and contaminating pulp made from wood chips. Economic value is lost fairly quickly as fire-killed timber dries and checks, and wood-boring beetle larvae penetrate tree boles.

To balance the desire to salvage timber with the ecological values of fire-killed forests provincial governments have policies that mandate fire salvage and ensure a portion of fire-killed area is not salvaged (Box F1; Government of Alberta 2007; Government of Saskatchewan 2017a).

Box F1. Provincial Fire Salvage Policies

Alberta: *For fires that affect >1000 hectares of Productive Landbase, 10-25% of the merchantable burned trees within the fire boundary will be retained. For fires greater than 10,000 hectares, the 25% target is mandatory.* (Government of Alberta 2007).

Saskatchewan: *Proportion of a natural disturbance event retained un-salvaged - The licensee shall ensure that ≥ 20% of the area within a salvaged disturbance event be retained intact.* (Government of Saskatchewan 2017a).

Challenges

- Fire salvage requirements are oriented to, and accounted for, individual fire events. This acts to reduce variation and may constrain opportunities to balance salvage with retention at larger scales.
- Salvage requirements are oriented toward relatively small events. Large events usually trigger a more considered review and approach to salvage.
- The Alberta fire salvage policy is quite prescriptive and differs according to fire size. Prescription is oriented toward retention of green patches and merchantable timber. This may reduce opportunities to maximize variation and economic opportunities for individual fire events.
- Salvage challenges also arise from other disturbances including both stand-replacing and stand-maintaining events. These includes forest insects and disease, wind, flooding, drought, red belt desiccation, etc.
- Salvage activities can undermine many of the ecosystem benefits of major disturbances by removing biomass and critical habitat and by altering the disturbance legacy of a site, thereby changing long-term biotic and abiotic conditions (Lindenmayer et al. 2004).

Recommendations

"The question is how much to salvage versus leave at larger scales over time, not for individual occurrences. If biomass burning becomes viable that would change the equations." (Anonymous SME).

- Use knowledge obtained from studies of natural forest fire events to design salvage events that approximate natural variation, retain intact a proportion of representative burned ecosystems, and provide for economic salvage of fire-killed timber.
- Adjust salvage policies and activities to reflect occurrences and amounts of potentially salvageable timber using a plan-as-you-go flexible approach.
- Monitor salvage events and track them as part of disturbance event catalogs.

F4 Silvicultural Tools

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Commercial forest management has evolved from early development of sustained yield policies and industry tenure systems in Alberta and Saskatchewan, but the basic model is still to maximize timber production on the active landbase portion of tenures while complying with constraints introduced for other values. Companies are not responsible for the passive landbase, the actions of other users, and the management of non-timber values. A complex mix of manuals, planning requirements and specific regulations is used to maximize timber and protect other values. Planning standards and requirements are incorporated in plans which bind licensees when approved (Vertinsky and Luckert 2010).

Regulations require companies to rapidly reforest cutblocks with commercially valuable tree species and meet establishment and performance targets. Most of the cost goes into reforestation to meet regeneration standards and maintain or increase AAC (Lieffers et al. 2020). After those requirements have been met additional interventions are discretionary and few companies invest in them. Comparatively low productivity and distance to markets necessitate a low-investment forest management approach, which minimizes costs over the lifetime of a forest stand to maintain economic viability of the forest sector.

Challenges

> *"SFM is more specific to sustained yield and the technical aspects of maximizing timber harvest. EBM is broader, it's more than just the forestry piece."* (Anonymous SME).

- The silvicultural strategies used in Alberta and Saskatchewan are mainly focussed on maximizing timber production in ways similar to agricultural crop production (Smith 1962) which Seymour and Hunter (1999) called production silviculture. Silvicultural systems are overwhelmingly clearcuts and even-aged management. Regeneration standards promote uniform tree distribution to fill most or all of the available growing space with maturing trees (Lieffers et al. 2020). Silvicultural strategies are generally not designed to create stand compositions and structures representative of natural forests, although they do so for many stand types.
- The challenge is to shift towards increased variation characteristic of natural forests in ways that maintain economic wood supply for the forest sector.

Recommendations

> *"There are ways to implement EBM without giving up on SFM, but they have to look at everything from pluses to minuses, with no untouchable sacred cows."* (Anonymous SME).

- EBM offers a process opportunity to step back from the current approach of bolting on EBM aspects (e.g., structure retention) to the production silviculture baseline and plan future commercial forests that better conserve both ecological integrity and human wellbeing including timber production. This will likely lead to a mix of strategies that increase variation and maintain economic wood supply.

- Manage logging disturbances to better approximate natural disturbance events and within-disturbance severity in terms of the proportions of trees that survive disturbance.
- Develop regeneration standards and methods that increase variability and work with nature to reduce costs and improve ecological integrity.
- Initial focus should be on "win-win" solutions at stand and landscape levels that cost little and have substantial ecological benefits (Burton et al. 2006).

F4.1 Even-aged Management

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Even-aged management refers to managing forests as a mosaic of different-aged forest stands (patches) where most of the trees in each stand are approximately the same age and originated over a comparatively short time interval after a stand-replacing disturbance such as a clearcut. This was thought to be consistent with the view that natural forests in Alberta and Saskatchewan are primarily mosaics of even-aged patches that originated from wildfires that killed all of the trees from the previous stand. Research has shown that natural forests are more complex mosaics of even-aged and uneven-aged patches (Weir et al. 2000; Odion et al. 2014).

Even-aged management is usually pursued to minimize costs and maximize forest growth of desirable species and AAC. In theory, the goal of even-aged management is a normalized forest, with equal amounts of each forest age class on the active landbase, but no old forest past rotation age. Optimizing the efficiency of commodity production, mostly of wood for timber, pulp, and fuel, is consistent with an agricultural production approach (Kuuluvainen et al. 2012).

Challenges

> *"The existing silviculture process is too focussed on timber; it's not maintaining all of the ecological processes and values. It's also too focussed on even-aged management."* (Anonymous SME).

- At the forest-level, even-aged management does not maintain the natural variety of mixed-age stand types and structural compositions naturally found in the forests of Alberta and Saskatchewan (Bergeron et al. 1999). Increasing the diversity of stand types consistent with NRV is a challenge.
- Uniform even-aged management treatments and schedules is a form of "farming" that is inconsistent with the natural variability of EBM (Newman 2019).
- The practice of clearcutting is becoming increasingly unacceptable to society (Bliss 2000).

Recommendations

> *"We need to look at mixed fire regimes and do more of those to represent the full range of natural patterns."* (Anonymous SME).

> *"There's great opportunities to use uneven-aged silviculture to protect other values and still get timber. Caribou and riparian are two promising examples to explore."* (Anonymous SME).

- Most natural stands originated from stand-replacing wildfires, which clearcuts approximate when compared to patches where the fire killed all the trees. Even-aged management with dispersed and clump structure retention is a fair approximation of burned patches. Some form of uneven-aged management is a fair approximation of partially burned remnants.
- There are opportunities to use uneven-aged forest management regimes and other silvicultural practices to increase diversity through creation of stands with different age class and structural compositions (e.g., Bergeron et al. 1999; Perera et al. 2008).
- A mixed mosaic of even-aged stands of different ages and uneven-aged stands of different ages is consistent with natural forest diversity and may improve biodiversity outcomes more than either approach alone (Pukkala 2016; Schall et al. 2018).
- Uneven-aged management in some stand types can be equal to or better than even-aged management from a cost and timber production perspective (Puettmann et al. 2015).
- Selective logging of individual trees or clumps to maintain continuous forest conditions may increase public acceptability of logging in sensitive areas (Gustafsson et al. 2020). The scenic beauty of logged areas affects perceptions of the social acceptability of forest management (Ribe 2005).
- Future successful use of uneven-aged management will recognize the disturbances and dynamics of suitable ecosystems and use these to guide management (O'Hara 2002).

F4.2 Structure Retention

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Biological legacies are "*the living organisms that survive a catastrophe* [disturbance]*; organic debris, particularly the large organically-derived structures; and biotically derived patterns in soils and understories"* (Franklin 1990). The ecological importance of biological legacies in continuity, recovery, and development of ecosystems following disturbance has been well-documented (e.g., Franklin 1990; Franklin et al. 2002). Originally developed to mitigate the impacts of clear-cutting (Lindenmayer and Franklin 2002), structure retention at the time of logging retains some of the original stand in tree patches, clumps, and individual live and dead single trees to maintain continuity of structural and compositional diversity (Gustafsson et al. 2012; Lindenmayer et al. 2012). Research that covers Alberta and Saskatchewan described the structures remaining after forest fires (Andison 2003b, 2006b, 2019a).

Stand structure retention policies and practices, initially led by forest (e.g., Alberta Pacific Forest Industries (Al-Pac) 1993; Weyerhaeuser Canada 1997) are now required in Alberta and Saskatchewan (Government of Alberta 1994, 2016; Government of Saskatchewan 2017a). There is considerable variation in structure retention that reflects forest type (deciduous, mixedwood, coniferous), individual company practices, and the ability of companies to maintain economic wood supply to their mills. A

2015 GOA proposal to increase the minimum proportion of *merchantable* tree retention in cutblocks to 10% was revised to 3–5% due to concerns from some companies about wood supply.

Studies on the ecological effects of structure retention have generally been positive (e.g., Gustafsson et al. 2012; Storch et al. 2020). In Alberta the Ecosystem Management Emulating Natural Disturbance (EMEND) research project, established in 1998, aims to track the ecological effects of structure retention in mixedwoods over the long term.

Coarse woody debris (CWD) is an important aspect of structure retention and reduction of dead wood has created major biodiversity challenges in Europe (e.g., Humphrey et al. 2005; Lassauce et al. 2011). Conservation of existing dead wood at time of logging and planning for future generation of CWD are the main EBM aspects. Most retention trees will eventually fall and become CWD.

CHALLENGES

> *"Variable retention is… variable, and not always for good reasons. More would get left if wood supply was assured and those who oppose retention as "high-grading" or "waste" could be convinced to make changes."* (Anonymous SME).

> *"It's a combination of individual attitudes, some in both industry and government are just not interested. It comes down to individuals and whether or not they are open and progressive. Some individuals are very aggressive over cutting costs and short-term issues."* (Anonymous SME).

- Many natural disturbances leave patches with partial tree survival, and varying proportions of individual tree survival (Andison 2013). This occurs for both stand-replacing and mixed-severity wildfires. Multi-aged stands with complex structures and compositions also develop when gap dynamic processes occur in older stands (Cumming et al. 2000). Uneven-aged silviculture, which could approximate these complex stands, is uncommon in Alberta and Saskatchewan forest management.
- Structure retention has been shown to have ecological benefits (Franklin et al. 2019) but there is still much to learn about quantities, composition, and locations. There are still many questions related to how to achieve optimum ecological benefits balanced against retaining commercially valuable-merchantable trees, which decreases wood supply. The challenge is to achieve a science-informed balance that has broad social acceptance and ends the ongoing controversy over how much is enough.
- A significant challenge to structure retention is to avoid or mitigate loss of economic wood supply and associated effects, in some areas, on forest development viability.
    - Retention of merchantable trees represents a loss of AAC which is a constraint against economic wood supply needs of some forest companies that have limited flexibility or options to replace losses.

    - Retention may reduce annual growth of merchantable timber if retention occupies growing space and shades or competes with new potential future crop trees.
    - Low levels of spatially dispersed retention generally result in high rates of post-logging mortality which are unlikely to be offset by increases in residual tree growth (Thorpe and Thomas 2007; Bose et al. 2014).
    - Retention may increase logging and reforestation costs by hindering use of mechanical equipment.
    - Retention could make it more difficult for companies to meet reforestation requirements.
- New requirements brought in to implement EBM elements or aspects tend to be prescriptive and have been restricted to a few aspects of NRV.
    - Alberta requirements for structure retention in cutblocks are prescriptive and capture only a small portion of the remnant complexity associated with wildfire events.
    - The requirement to include minimum amounts (currently 3–5%) of merchantable volume "*representative of the harvested stand*" in cutblocks is not based on NRV analysis (Andison 2012) and is not consistent with "*The objective is to retain sufficient structure with minimum impact on timber supplies*." (Government of Alberta 2006). Analysis at the event scale and targets based on all remnants would be better.
- Additional analysis of fire event data would be helpful to determine what proportions of remnants in wildfires were merchantable and representative of pre-fire ecosystems, but there is no particular ecological reason to do so.
- There are good arguments that non-merchantable and non-representative retention could have more ecological value than merchantable trees. For example, most woodpecker species prefer non-merchantable trees or portions of trees for nesting and foraging (Bonar 2000; Jackson and Jackson 2004).
- Tree retention may constitute a higher safety risk for workers during logging and subsequent operations (Sougavinski and Doyon 2002), and for the public. Managing retention in ways that ensure human safety is a challenge.
    - In Saskatchewan dead trees and snags are to be left standing during forest operations where not prohibited by The Occupational Health and Safety Regulations, 1996. (Government of Saskatchewan 2017a).
    - Alberta does not have a similar requirement to leave dead trees and snags standing. The Alberta Occupational Health and Safety Code says "*A worker cutting timber must… fall or remove snags and trees that create a danger to workers as the cutting progresses*".
    - Companies have implemented structure retention that meets safety requirements but there are ongoing challenges to ensure good safety outcomes.
- Structure and CWD conservation are challenged by requirements to abate fire hazards. These include reduction of CWD accumulations and heights, slash-free zones, and piling and burning of logging debris (Government of Alberta 2016; Government of Saskatchewan 2019b).

- Structure retention is viewed by some as wasteful, especially when retention dies or falls over (windthrow) soon after it is left in logging disturbances (e.g., Moore et al. 2003; Coates et al. 2018). This is another aspect of the major challenges in determining “how much is enough” and “what does society view as acceptable”.

RECOMMENDATIONS

> *“Manage retention at the scale of disturbance events. Change the reforestation rules to allow more variation. Look at NRV in multiple ways, and set targets that best increase variation within the limitations of silviculture. Stop the trend of replacing old rules with new ones that are just as prescriptive and probably won’t get the hoped-for results.”* (Anonymous SME).

- There are positive stories to explore in relation to structure retention in logging events. Increased retention is expected to support multiple ecological processes (e.g., succession, productivity, and water, element and energy cycling, wildlife habitat) that are desirable EBM aspects (Beese et al. 2019). As a highly visible EBM practice it is also a good opportunity to have discussions about EBM, demonstrate commitments to EBM, and increase societal support for EBM. Structure retention reduces the visual impacts of logging and is more acceptable to society (O’Hara 2002).
- Retention should be considered at multiple appropriate scales. The disturbance event scale (Andison 2003a, 2006a, 2012) is a good starting point, with retention in cutblocks a secondary scale to be compared to natural structure in disturbed patches. This is more ecologically appropriate and can be used to compare merchantable tree retention at the event scale.
- Consider moving away from the focus on retention of merchantable trees and structure that is representative of the pre-disturbance stands. The emphasis does not appear to be based on analysis of living structure remaining after natural disturbances. In the short term, mature healthy trees have lower ecological value that unhealthy and dead trees.
- Increase retention and reduce wood supply impacts by exploring mitigation or replacement options:
    - Retention of “leave forever” non-commercial or less valuable species (e.g., birch, tamarack, balsam fir) and trees (dead, low timber value, visible decay indicators, wildlife use, etc.). In most cases these trees are the least valuable for commercial use and the most valuable for ecological roles (e.g., Cooke and Hannon 2012; Gutzat and Dormann 2018).
    - Retention of “log later” young and healthy trees (e.g., understorey protection), including those that may currently be merchantable that will likely still be potential crop trees at the next rotation, and more valuable due to larger size than new tree cohorts. The increased volume and economic value of the logs from retained trees cut during the second rotation may offset initial losses due to merchantable tree retention (Weyerhaeuser Canada 1997).

  - Design logging events to include accessible patches of merchantable timber which could be cut in a future event (e.g., mid-rotation), with accompanying reduced impacts on overall AAC. This process could also be reversed (e.g., first event is small isolated patches and main event comes later). This would require access. Reforestation of energy wellsites in advance of logging could be good opportunities for this.
  - Other strategies to replace wood supply decreases related to retention of merchantable trees/volume that will not be available for future logging.
  - These could include the "accounting rules" for how to treat merchantable tree retention, which are somewhat inflexible. For example, retention of merchantable trees is a surrogate for retention that is representative of the existing forest stands. Assessing retention at the scale of disturbance events (aggregated cutblocks) is more ecologically relevant than at the scale of cutblocks (disturbed patches) and would be a better way to demonstrate that merchantable trees have been retained, including those outside cutblocks.
  - Variable retention logging experience in BC suggests that it is possible to balance production of wood with biodiversity conservation (Beese et al. 2019).
- Work with provincial Occupational Health and Safety agencies to develop practices that support safe retention of structure, especially dead trees and unstable living trees, while ensuring worker and public safety.
- Work with provincial authorities to find ways to increase retention of stand structure including CWD that meet the intent of fire hazard risk minimization within acceptable risk management frameworks.
- Develop communications initiatives to highlight structure retention as a highly-visible and widespread indicator of EBM and use the opportunity to foster more general conversations about EBM.
- Continue monitoring and adaptive management to improve structure retention practices over time.

F4.3 Stand Composition

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Forest tree species composition (forest stratum or type) changes within NRV over time in response to disturbance types and frequencies, ecological succession, and the biological reproduction strategies and requirements of tree species. The fire-dominated disturbance regime in Alberta and Saskatchewan forests produces heterogeneity in stand age and structure from stands dominated by a single tree species to stands with multiples species and transitions between species over time. Alberta regulations related to tree species composition require maintenance of existing timber strata (forest species compositions, especially between coniferous and deciduous species) proportions over time, unless changes are approved in higher-level plans such as an FMP (Government of Alberta 2006). Forest stands are commonly divided into coniferous and deciduous categories for reforestation. In recent years provincial governments have added a mixedwood category, but practices still tend to "unmix the mixedwoods" (e.g., Hobson and Bayne 2000; Lieffers et al. 2008) and reduce heterogeneity. Strata rules were made to maximize timber productivity (Hawkins and Balliet 2008) and to protect AAC allocations made to companies that have overlapping logging rights to deciduous and coniferous tree species on DFAs (Cumming and Armstrong 2001; Government of Alberta 2006).

CHALLENGES

> *"Reforestation rules discriminate against non-commercial tree species. They also unmix the mixedwoods, which is very expensive and doesn't work."* (Anonymous SME).

> *"In nature stand composition changes all the time. The idea that we should use current composition as a fixed point for recreation of future forests is wrong."* (Anonymous SME).

- Forest strata rules conflict with EBM because they reduce variation.
- Ecological processes that change tree species composition are reasonably well understood at the stand level (Andison and Kimmins 1999; Comeau et al. 2005); knowledge at landscape scales is mostly limited to inferences and extrapolations of knowledge at the stand level (Chen et al. 2009; Bergeron et al. 2014).
- Alberta (Government of Alberta 2017b) states that cover type (strata) targets should ensure cover types remain within NRV throughout the planning horizon. However, nobody has attempted to estimate landscape-level NRV for stand types.
- It is very challenging to maintain the natural complexity of stand dynamics in a forest management context (Bergeron et al. 2014).
- The most cost-effective way to achieve sufficient free-to-grow spruce in mixedwoods is herbicide treatment of half of a cutblock (McRae et al. 2001). This results in cutblocks that are two spatially separate areas, one with aspen dominance and one with pure white spruce, an *un-mixed mixedwood* (Lieffers et al. 2008).
- Strata rules and regeneration standards are aimed primarily at timber production (Lieffers et al. 2008), which favoured coniferous species until more economic uses for deciduous species developed in the 1990s (Burton et al. 2003). Incorporating ecological considerations to produce stands that are representative of natural regimes may reduce timber production or change tree species mixes available to mills.
- Regulations that require conversion of mixedwoods to coniferous and elimination of deciduous species in reforestation are sometimes very expensive and not always successful (Lieffers et al. 2008).
- Long-term application of stand conversion practices has altered landscape-scale stand compositions (Venier et al. 2014).
- To minimize reforestation costs, relatively pure coniferous or deciduous stands are targeted for logging more frequently than mixedwood stands, relative to their respective abundance (Cumming and Armstrong 2001; Lieffers et al. 2008). Over time this tends to alter both the relative proportions of stand species compositions and their age class compositions.

- Tree species that have no or lower commercial value are either actively discriminated against or left out of timber management considerations and actions.

RECOMMENDATIONS

> *"Use an ecological approach to manage mixedwoods while maintaining cuts of both softwood and hardwood. It costs less and is more defensible. People have figured out how to do it, but there are huge trust issues in the way. Start with a value proposition and negotiations at senior levels."* (Anonymous SME).

> *"Regeneration surveys should accept all trees, regardless of species, age, and merchantability. They all have ecological value. Make adjustments to timber yield curves to account for proportions that don't have commercial value."* (Anonymous SME).

- Consider managing for a more natural distribution of stand compositions and allowing changes over time that may have ecological benefits and produce equivalent or better timber yields for less cost (Comeau et al. 2005; Lieffers et al. 2008; Bergeron et al. 2014).
- Assess advantages of managing to maintain mixedwoods and mixed-species stands at both the stand and landscape scales, including maintaining biodiversity, improving tree growth and forest productivity, reducing the risk of wildfire and insect and pathogen outbreaks, and improving resilience to climate change (Bergeron et al. 2014).
- Research that investigates the processes underlying the complexity of natural patterns and the silvicultural options required to reproduce them (Bergeron et al. 2014).
- Research that develops ecological succession and transition pathways and applies them to landscape simulator and forest estate models would be useful to characterize NRV and predict future forest conditions in response to management alternatives.
- Review policies and tenure allocations that require non-variable maintenance of both coniferous and deciduous AAC to look for alternative ways to meet commercial needs while improving EBM outcomes.

F4.4 STAND STRUCTURE

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Stand structure is the arrangement and interrelationships of live and dead trees (Brassard and Chen 2006). Structural diversity can be measured using a range of variables, including tree size, density, canopy complexity, dead wood, etc. Natural structural diversity is highly diverse and variable over time and reflects the initial disturbance, the stage of succession, subsequent disturbances, and other factors.

CHALLENGES

> "EBM harvest is being practiced now in the big deciduous FMAs (Al-Pac and Mercer [DMI]). The coniferous FMAs are not there yet because they are not leaving enough stand structure and CWD due to wood supply issues. Biological legacies are very important. We need to learn from Sweden where there is little dead wood in forests and they have related biodiversity issues." (Anonymous SME).

- Logging, reforestation, and stand management tends to reduce natural stand structural variation in many ways (McRae et al. 2001; Rosenvald and Lõhmus 2008).
    - Dead wood provides critical habitat for thousands of species in forests (Sandström et al. 2019), structures stream channels (Naiman 2002), stores carbon (Janisch and Harmon 2002) and contributes to many other aspects of ecological integrity. Young forests have high amounts of dead wood after natural disturbances and old forests have high amounts due to trees dying as part of natural forest dynamics (Harmon et al. 1986). Dead wood resources (standing and down) tend to be reduced or destroyed (soft logs) at time of logging or as part of site preparation (Fridman and Walheim 2000; McRae et al. 2001). Dead wood may be utilized, removed for safety or equipment efficiency, fragmented and crushed, etc. Reduction of old forests on the active landbase over the long term also reduces dead wood. Increases of old forest in the passive landbase may offset reductions in the active landbase.
    - Initial tree density from natural regeneration or planting after logging is typically a much narrower portion of NRV. For example, in Yellowstone National Park 11 years post-fire lodgepole pine sapling density ranged from 0–535,000 stems/ha and about 25% of burned area had sapling density >10,000 stems/ha (Turner et al. 2004).
    - Old forests have high amounts of structural diversity for multiple indicators (Brassard and Chen 2006). Management practices tend to reduce old forest on the active landbase and increase it on the passive landbase.
- A challenge is to better understand structural diversity and adjust forest management targets and practices to maintain and improve variation in managed stands as part of a whole landscape approach.

Opportunities

> *"Structure retention will go a long way toward increasing stand structure variation. When trees are removed for human uses the managed forest won't be the same as a fire regime forest, but it will be closer and that's good."* (Anonymous SME).

- Structural diversity conservation has usually been addressed at the practice scale and not as a whole landscape approach. Practices such as retention of remnants in logging events both within and between cutblocks will increase diversity over time at whole landscape scales. Coarse filter EBM aspects such as seral stage targets will also contribute to structural diversity conservation. Whether or not current management effectively conserves structural diversity over whole landscapes is unknown because nobody has taken a whole landscape approach.
- An initial research opportunity is to better characterize natural structural diversity for Alberta and Saskatchewan forest ecosystems over successional gradients and compare NRV to current practices in managed stands and natural stands to quantify similarities and differences.
- A related opportunity would be to review existing policies and practices to see if improvements could be made to increase variation. Include current approaches related to structural diversity in

Alberta (Government of Alberta 2006, 2016), Saskatchewan (Government of Saskatchewan 2017b, 2020), and similar jurisdictions (Snetsinger 2010; Grenon et al. 2011).

- Combine the characterization of current practices over whole landscapes with policy and proactive reviews to add value to structural diversity planning and implementation as part of EBM.
- Companies and government agencies responsible for preparing FMPs could voluntarily incorporate structural diversity analyses and targets into the next revisions of their FMPs.
- The key decision for structural diversity over the life of regenerated stands is the structure and composition of biological legacies from the previous stand to provide continuity.

F4.5 Truncated Succession

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Truncated succession refers to altering natural processes and patterns of ecological *succession* following natural disturbances (Swanson et al. 2011). Timber-focused management usually tries to truncate succession at the beginning and end of the natural cycle. Forest managers are required to rapidly re-establish trees on logged areas, whereas after natural disturbances tree re-establishment may sometimes take decades (Pinno et al. 2013). When even-aged stands reach their assigned economic maturity rotation length (tree growth starts to slow) they are normally scheduled for logging.

By design, maximum sustained yield steadily reduces the amount and extent of old forests on the active landbase (Ballin and Vyse 2020), until eventually the only old forest is in the passive landbase. As regenerated stands mature, they are scheduled for logging before they can develop old forest characteristics. Deliberately leaving some stands to get older would reduce AAC.

Similarly, reforestation requirements and other silvicultural treatments are designed to maximize AAC and they reduce natural variation.

Challenges

> "If we continue on current paths most of the future old forest will end up in the passive landbase and protected areas. That's a problem." (Anonymous SME).

> "Ensuring reforestation after harvest is essential but unrealistic performance requirements force companies to apply expensive treatments when ecological alternatives would be better." (Anonymous SME).

- Truncating succession maximizes sustainable AACs but simplifies forest structure and composition patterns and is not consistent with EBM for some ecosystem types.
- Logged areas must be promptly reforested to required stocking levels. This shortens the NRV of the time before tree species are established. No company has undertaken an NRV analysis of natural stand establishment because they are legally required to truncate natural succession.
- Truncating stand establishment variation could reduce or remove from commercial forests some early-seral ecosystems such as grass, forb, and shrub communities. This is a possible gap in EBM but it would require investigation to see if it is significant.

- Truncating succession when stands reach their rotation age eventually removes older stands from the active portion of forest landscapes, which reduces variation (McRae et al. 2001).
- Protecting in place older-than-rotation forest stands is not an effective long term solution in dynamic forest landscapes where there is risk of loss to natural disturbance and age-related stand break-up.

Recommendations

> "Reforestation costs could be reduced and outcomes improved if we allow a little more time for natural regeneration in many situations, and accept changes in tree species (strata). Manage the mix at large scales in FMPs, not at the stand scale." (Anonymous SME).

> "The obvious opportunity to get a better distribution of future old forest is to manage for more in the active landbase and replace the AAC loss with wood from the passive landbase." (Anonymous SME).

- Explore opportunities to maintain representation and variation of older-than-rotation stands in the active landbase by using combinations of treatments.
  - Temporarily protecting some older stands and leaving some mature stands to grow older. Rotate these stands through logging schedules over time to reduce impacts on timber supply.
  - Apply treatments to younger stands to promote development of old forest structures and compositions at younger ages.
  - Manage complex older stands using uneven-aged silviculture to maintain them over long periods.
  - Retention of understory, veterans, and other living trees in various configurations at time of logging.
- Explore opportunities to maintain representation and variation of early-seral communities on some sites by delaying reforestation or using other treatments to develop early-seral successional communities. This would require stand-establishment variance approval. Although this would reduce timber supply it could also reduce reforestation costs on some sites, and the savings could potentially be used to replace or increase timber supply on other sites.
- Explore opportunities to increase variation that work to minimize loss of wood volume that supports existing mills. These might include:
  - Increase access to timber in the passive landbase and other areas not currently scheduled (e.g., private land, non-tenured forest areas) for logging as replacement for AAC reductions in the active landbase associated with increasing variation.
  - Intensive treatments to increase AAC on some portions of the active landbase (e.g., tree improvement, competition control, fertilization, etc.).
  - EBM-inspired mechanical logging in protected areas, possibly combined with prescribed fire, intended to both increase disturbance in protected areas where prescribed fire is

insufficient to maintain disturbance at planned rates, and to partially support wood supply.

F4.6 Reforestation

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Reforestation is the practice of establishing a new age cohort of trees after a disturbance event. After natural disturbances reforestation follows multiple pathways that reflect diversity in environmental conditions and complex biological processes. Reforestation after logging has traditionally followed a very strong timber production emphasis, although there appears to be a slow trend developing to also incorporate other resource values (Farnden 2010). To this end, provincial governments use reforestation standards (Government of Saskatchewan 2012a; Government of Alberta 2018) which specify tree species preferences (usually commercially valuable species) and minimum establishment densities. Objectives to maximize crop tree production led to additional requirements for tree size, health, vigour and freedom from competition by other vegetation (free-to-grow). Government requirements in Alberta and Saskatchewan are broadly similar, with industry responsible for implementing reforestation and reporting progress to the government.

There are many reforestation requirements that are intended to ensure logged areas are promptly and successfully reforested with commercially valuable tree species and that stands are growing at rates that maximize and match timber growth and yield projections used to determine AAC. Reforestation requirements are aimed at timber production with little connection to other values (Lieffers et al. 2008). Requirements include regeneration delay, stocking (tree spacing and occupancy), acceptable tree species and tree characteristics, growth performance (minimum tree heights), and absence of competing vegetation. Provincial governments have detailed requirements for reforestation standards and surveys that must be followed by forest companies.

Companies are expected to develop silvicultural strategies that specify how reforestation will proceed for each major stand type. Generally, the strategies aim to promptly establish the same species that existed on the site at time of logging and to maximize growth until the next cut. This straight path differs markedly from the complex processes and multiple interactions that create the natural mosaic of stands and patterns on the landscape (Box F2; Government of Alberta 1971, 1992).

Box F2. Reforestation Requirements Increase Over Time – An Alberta Example

Reforestation requirements following logging were first introduced in 1954. By 1971 the Alberta Regeneration Standard was 6 pages long (Government of Alberta 1971), and by 1992 it was 72 pages (Government of Alberta 1992). The 2018 Reforestation Standard of Alberta is 376 pages long. Alberta also has separate reforestation documents for industrial site reclamation, including the Alberta Regeneration Standards for the Mineable Oil

Challenges

- The trend over time with respect to reforestation has been to add on rather than reinvent. The basic system is still an agricultural crop model that is inappropriate for some ecosystems and acts to reduce natural variation.
- In some cases, reforestation requirements do not appear to be producing forests that are similar in composition and structure to those found naturally (Lieffers et al. 2008).

> *"Alberta reforestation requirements work well in deciduous, which are mostly leave for natural regeneration. For conifers requirements are too aggressive and outside EBM/NRV. We could successfully do more leave for natural in more areas if we didn't have to meet such short windows for establishment and performance. This should be an option. In mixedwoods policies are bizarre and not ecological. The system is designed to accommodate quota holders and is heavily influenced by politics. There has to be a better way."* (Anonymous SME).

> *"We need to stop managing trees like they are agricultural crops. Move away from the whole idea of forestry as tree-farming."* (Anonymous SME).

> *"People are entrenched in silos about reforestation, especially about some specific practices such as site preparation and herbicides. The power people won't change unless we model the results."* (Anonymous SME).

- Acceptable tree species and acceptable trees (age, health, growth form, etc.) are limited to those species with commercial value and depend on the stratum declaration (e.g., aspen not acceptable in conifer stratum in Alberta). The effects of these policies are to reduce within-stand species diversity and to reduce non-commercial species composition.
- Reforestation requirements are expensive to implement on some ecosites and are not always successful.
- To meet requirements companies may control competing vegetation using herbicides, which has long been a widely unpopular practice with the public, Indigenous people, and others (Buse et al. 1995; Kayahara and Armstrong 2015).
- Simple forests are easier to categorize as "regenerated" than complex forests (Lieffers et al. 1996). Administrative needs and processes do not currently accommodate the range of natural variability from simple to complex forests.
- Stand level silvicultural strategies that could be consistent with EBM (Lieffers et al. 1996; Bergeron et al. 2002; Comeau et al. 2005) are not widely used because regeneration standards, especially free-to-grow and strata requirements, limit the options available for a given cutblock (Lieffers et al. 2008).
- Broad application of free-to-grow standards is a challenge to ecosystem-based management of boreal mixedwoods (Lieffers et al. 2008).

- The current rigid management system and the large and complex policy documents that accompany it discourage experts and scientists from trying to influence forest management policy (Lieffers et al. 2020).

Recommendations

> *"Ecological reforestation plans and practices matched to effects on wood supply in FMPs should be encouraged and approved after government review. This will spur innovation while still ensuring reforestation and providing a solid basis for performance assessment."* (Anonymous SME).

> *"Caribou range plans bring the energy sector to the table, and there are some glimmers of hope on changing long-time practices. For example, reforesting pipeline rights-of-ways, and even reforesting to a certain height on powerlines. Opinions on these are divided but moving in the right direction."* (Anonymous SME).

> *"We need to be thinking about stocking standards, there are some win-wins. We spend a ton of money on brush control and herbicide which the public hates. We could reduce herbicides if we could use ecological practices."* (Anonymous SME).

> *"The new caribou is climate change; some want to shut off the energy sector. Reforest and restore helps with climate change. The COSIA faster forests initiative is an example, and there are others. EBM could be a framework to integrate all uses."* (Anonymous SME).

> *"Low hanging fruit includes reclamation of all footprint within cut blocks as part of reforestation activities, and possibly footprint adjacent to blocks."* (Anonymous SME).

> *"We are getting hit with more drought and higher fuel loads. There are so many things, where do you start, because changing one thing has cascading impacts on other values. On the right sites, maybe we plant lower numbers so trees don't get water stressed, or lower the stocking standard to prolong berry-producing shrubs for bears, or not control deciduous shrubs to provide moose browse, or promote lichens for caribou. All of these have natural analogues."* (Anonymous SME).

- Silvicultural strategies and practices that could better meet both ecological and timber objectives and targets are available and could be deployed by building them into FMPs and supporting implementation practices (Lieffers et al. 1996, 2008; Bergeron et al. 2002; Comeau et al. 2005).
- This would require government approval for innovation and variance from legislated requirements.
- Risks related to incomplete knowledge and a lack of data to support alternative silviculture decision-making are smaller than the risk of maintaining the status quo, adhering to past assumptions, and relying on the false certainty implied with current systems (Lieffers et al. 2020).

- Forest-level objectives and targets should direct silvicultural strategies and practices in a top-down planning process. The current practice is constrained by legal requirements at the back end, which drives up costs and reduces variation. Provincial governments and forest companies could begin a process to review the entire reforestation system to look for opportunities to better meet management objectives including EBM through revised regeneration standards that implement strategic EBM directions.
- Stocking surveys could benefit from statistical approaches and availability of remote sensing tools to ensure adequate reforestation and growth at lower cost and less red tape than current systems. This includes mixed-landscape surveys that include tree retention and all species including non-commercial species, gaps, and both natural and managed species composition changes.
- In “difficult” reforestation situations, link regeneration results to growth and yield and AAC and reallocate cost savings to maintain wood supply. This could be a voluntary variance application with approval supported by concurrent investment to maintain economic viability.
- Expensive silvicultural treatments that are deployed to meet establishment and performance requirements could be avoided by allowing and supporting natural ecological processes to occur (e.g., white spruce establishment under deciduous canopy in some mixedwoods). Cost savings could be redirected to more cost-effective practices to recover any loss of timber growth potential.
- The current standards force intensive management on a large part of the landscape—thereby limiting opportunities for stands to follow more natural successional pathways or stands that focus on values other than timber. Some lands should be managed extensively using systems of management that produce the composition and structures found in forests under natural development and disturbances (Lieffers et al. 2008).

F4.7 Stand Establishment

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Foresters use several disturbance tools to treat logged areas to promote natural tree regeneration and prepare sites for planting. Mechanical treatments include removing logging debris, preparing seedbeds, and preparing planting sites. Site preparation herbicides to control competing vegetation such as *Calamagrostis* grass are less common. Finally, prescribed burning for site preparation is a rarely used option in Alberta and Saskatchewan. The type of tool and prescription reflects an ecological assessment of sites and options needed to meet reforestation requirements.

Challenges

> *“Fire could be a really useful site preparation tool if we can overcome liability and public opposition because of smoke.”* (Anonymous SME).

- Stand establishment treatments are substitutes for natural processes. Ecological community responses differ but appear to be more related to changes in composition rather than diversity.

- Reforestation requirements lead to more use of stand establishment tools than may be necessary. Establishment and performance requirements are short and foresters can't chance "wait and see" prescriptions that might or might not work.
- Delays between logging and site treatments can increase costs as competing vegetation gets a head start.

Recommendations

> *"EBM could reduce reforestation costs if we work more with Mother Nature instead of using blunt force."* (Anonymous SME).

- Review reforestation requirements to see if more natural regeneration is possible.
- Look for opportunities to use prescribed fire more as an establishment tool because logging/fire is a closer natural analogue to wildfire than other mechanical and chemical treatments.

F4.8 Herbicides

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Herbicides are used to manage vegetation in forests. The most common application is to control vegetation competing with future crop trees several years after logging. Herbicides are also used to control noxious weeds and to prepare ecosystems for prescribed fire (brown and burn treatments).

Challenges

> *"Public opposition to herbicides is huge and only getting bigger. It won't be available as a tool for much longer. Affordable cost-effective alternatives are urgent."* (Anonymous SME).

- Herbicides generally act to reduce variation in species composition and structure.
- Herbicides are widely opposed as a forest management tool, especially in situations where there are other effective alternatives.
- In certain regeneration situations forest companies use herbicides as the most cost-effective way to meet government requirements that act to reduce natural variation and complexity.

Recommendations

> *"There is potential for the TRIAD approach to help deliver EBM. We would need to intensify management on a portion of the landbase. There is little incentive to do that, and costs are significant. Land rent makes it not economical on private land, if we could do it on a portion of land close to mills it could be viable. It's likely to become essential and provides a way to get out of herbicide use, which is getting more and more opposition. There may be good social buy-in."* (Anonymous SME).

> *"Use an ecological approach for mixedwoods reforestation. Leave white spruce seed trees to get spruce ingress. Reduce planting costs, get better growth performance, and there is less need for herbicides."* (Anonymous SME).

- EBM regeneration alternatives in appropriate ecosystem and community types that would help to maintain natural complexity and variation and reduce the need to use herbicides to meet mandated requirements for establishment, performance and strata balancing.

F4.9 Riparian Management

"*Riparian lands are transitional areas between upland and aquatic ecosystems. They have variable width and extent above and below ground. These lands are influenced by and exert an influence on associated waterbodies, including alluvial aquifers and floodplains. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and hydrological processes.*" (Alberta Water Council 2013). This ecological definition extends the concept of *riparian* beyond distinct vegetation to include adjacency, hydrological processes, and landforms as important aspects of riparian functions in interaction zones between terrestrial uplands and aquatic environments and ecosystems (Knopf et al. 1988).

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Riparian lands are subject to all of the natural ecological processes associated with upland terrestrial ecosystems (wildfire, weather events, insects and diseases, etc.) and also unique processes that are related to aquatic ecosystems such as the hydrological flow regime (Poff et al. 1997), especially floods, and biotic disturbances such as the ecosystem alterations caused by beavers (Thompson et al. 2021). Wildfires are also an active process in riparian areas (Andison and McCleary 2002; Newaz et al. 2020).

In the last half of the 20th century there was a shift from widespread human exploitation of riparian areas to the view that they should be protected to conserve water quality, fish and wildlife habitat, aesthetics, recreation, and other values (Naiman et al. 1993; Tolkkinen et al. 2020). In forested areas, protected strips adjacent to waterbodies (buffers) were designed to protect riparian and aquatic ecosystems from damage associated with logging and roads (Welsch 1991; Richardson et al. 2012; Sweeney and Newbold 2014).

In Alberta, buffers were first introduced in 1958 for the Northwestern Pulp and Power FMA (Hinton Wood Products 2013). Buffers were defined by a fixed distance on either side of a channel or surrounding a waterbody from the ordinary high-water mark (the non-vegetated channel border) based on stream width and water flow or waterbody size. The current Alberta riparian area delineation is based on fixed width buffers (no disturbance) that vary by waterbody type (e.g., streams, lakes) and size (e.g., channel width) (Lee and Smith 2003).

Saskatchewan implemented a protected buffer system in 1976, using 90 m beside waters with permanent fish populations, 30 m beside intermittent or seasonal fish bearing waters, and 15 m for waters that had connectivity and contributed to fish bearing waters. Measurements begin at the treeline, not the high-water mark.

A Weyerhaeuser Canada proposal for a new variable retention riparian management system for the Prince Albert Forest Management Forest Management Area was approved in 2011 (Sakâw Askiy Management Inc. 2018).

Saskatchewan now allows most companies to choose, in their FMP, between the fixed-width protected buffer system or a variable retention system comprised of a 10 m no logging or limited logging machine free zone coupled with an additional limited logging zone for some waterbody categories (Government of Saskatchewan 2012b, 2019b). Both provinces reduce required buffer widths and operating conditions as waterbody size or watercourse size decreases, and sometimes allow some logging for some categories.

The planning and application of riparian management is further complicated because forest management requirements and approval are under the jurisdiction of both federal and provincial regulatory agencies (Morissette and Donnelly 2010). Clause 35(1) of the Fisheries Act (Government of Canada 2019) says: "*No person shall carry on any work, undertaking or activity that results in harmful alteration, disruption or destruction of fish habitat*." (HADD). Fish habitat protection provisions under the Fisheries Act came into effect in 1977, and the federal and provincial governments had agreements for the provinces to administer most riparian management, with the exception of HADD authorizations. Recent critical habitat designations for fish species at risk in the Alberta foothills mostly follow the Alberta buffer system (Government of Canada 2019, 2020a, 2020b) but will likely lead to more direct Fisheries and Oceans Canada involvement with riparian management.

CHALLENGES

> *"Fixed width riparian buffers and fire suppression have been done for so many years that the public expects it. Few have thought about the long-term ecological consequences of excluding fire from ecosystems that naturally burned. The same applies to other ecological values that change slowly over longer time cycles."* (Anonymous SME).

> *"EBM riparian management is a major challenge. Many fish biologists accept or support, and many terrestrial biologists are opposed. We can currently disturb close to small streams but not to larger streams. There's no particular reason why that should be so."* (Anonymous SME).

- Riparian management EBM challenges include:
  - Moving to an ecological basis for management by using ecological boundaries and integrating riparian management with aquatic and upland management at watershed scales.
  - Finding ways to carefully increase riparian disturbance to protect existing ecological values and functions and to rejuvenate them over the long-term. This includes both logging and fire.
  - Building cooperation and partnerships between forest companies and the provincial and federal governments to plan and implement EBM in riparian areas.
  - Gaining public support for an EBM approach in riparian areas.
- Fixed width buffers are clear and relatively unambiguous and have low implementation costs, but they are perceived as arbitrary, have a poor science basis, and are insensitive to local conditions (Stadt 2009; Richardson et al. 2012).

- Waterbody classifications used to determine buffer width are not ecologically based.
- Riparian management requirements in Alberta and Saskatchewan do not use ecological boundaries (Greenlink Forestry 2013; Lidberg et al. 2020) to define protected buffers and, in some cases, related special management in adjacent areas. This results in buffers that may extend beyond the ecological riparian area or do not include portions of the ecological riparian area where it is wider than the required buffer.
- Creating accurate maps of ecological riparian areas is a challenge because of costs (Greenlink Forestry 2013) and uncertainties about definitions (Alberta Water Council 2013).
- Buffer requirements are applied at the reach scale, which does not incorporate an ecological approach to hydrological and riparian processes within watersheds (Richardson et al. 2012), such as the changing dynamics of large woody debris movement by channel type and size (Piégay and Gurnell 1997; Powell et al. 2009). Riparian management is largely disconnected from watershed management and aquatic ecosystems management.
- Implementation of fixed width buffers in the field is not as simple as it sounds and has resulted in compliance issues related to not following rules but for the most part not to causing significant environmental effects.
    - Variation in channel width makes it hard to choose the correct buffer width to apply, especially near category breaks.
    - Waterbody and channel presence and bank locations for smaller water features can be difficult to identify in snow-covered conditions.
    - Ensuring minimum buffer widths is difficult when the waterbody is not visible at the prescribed distance.
- Most streamside protection requirements allow some local modification for site and watershed-scale considerations, but the option to deviate from fixed-width buffers is frequently not approved because of application costs and uncertainty about outcomes (Richardson et al. 2012).
- Effectiveness evaluation of current riparian buffer guidelines has been uneven and produced mixed results (Richardson et al. 2012; Stutter et al. 2019), which raises the question of whether or not riparian buffers are adequately maintaining the values they were intended to protect (Marczak et al. 2010; Jyväsjärvi et al. 2020). Maintaining riparian disturbance regimes has not traditionally been considered a value to protect.
- Most riparian buffers in commercial forests are currently protected from both fire and logging, which significantly reduces the overall disturbance rate and alters proportions by disturbance type, when compared to the natural disturbance regime. This will lead over time to ecological conditions outside NRV which increase ecological integrity risks.
- Fires and floods constitute large-scale disturbances that help structure aquatic and riparian ecosystems (Pettit and Naiman 2007). Both types of disturbances result in short-term habitat alteration and what is sometimes considered degradation, such as raising water temperatures and adding fine sediment to streams, but they confer long-term habitat benefits in terms of channel complexity by recruiting large wood and boulders, maintaining natural sediment

regimes, etc. The challenge is to recognize the vital role of disturbance in maintaining ecological integrity and find ways to introduce managed disturbance that minimizes short-term ecological impacts, and support ecological recovery following large natural disturbance events such as floods.

- Alternative models for stream protection have been proposed (Kreutzweiser et al. 2012; Sibley et al. 2012), often without adoption by managers, perhaps because of the uncertainty of outcomes (Richardson et al. 2012) and regulator risk aversion.
- In Alberta, the GOA did not approve a proposed Hinton Wood Products riparian management strategy designed with an EBM approach (Hinton Wood Products 2013). The challenge is for companies that wish to implement EBM in riparian zones and their respective regulators (in this example these are the GOA and the GOC) to continue discussions toward approving and implementing EBM riparian management.
- The management challenge is to plan and implement changes to the current riparian management approach to more closely approximate natural disturbances and patterns, while maintaining the current focus on conservation of all values and maintenance of ecological processes and functions.
- Managers will need to overcome challenges related to describing EBM and comparing it to existing approaches in ways that lead to acceptance and support.
- Management requirements are infrequently revised and thus do not quickly incorporate new knowledge and approaches as they arise (Morissette and Donnelly 2010).

Recommendations

> *"Now that the critical habitat for fish species at risk has been defined and the feds have signalled interest in a watershed approach there may be good opportunity to try a watershed approach with EBM riparian management again. Show regulators how their world will be better through pilot projects."* (Anonymous SME).

- Protected riparian buffers are based on the view of ecosystems as static and stability as a desired management objective (Holling 1973). Recognition of the need for ongoing periodic watershed and riparian disturbance to maintain long-term ecological function is increasing (Florsheim et al. 2008; Kreutzweiser et al. 2012), and EBM is well-positioned as a supportive approach.
- Support to use EBM in riparian forests will depend on identifying and resolving uncertainties related to societal values and concerns (Sibley et al. 2012), and continuing to build a strong science foundation.
- Research – in Saskatchewan there may be opportunities to compare fire disturbance and logging disturbance where companies are using the variable-width riparian management system. In general, more research is needed to compare logging and natural disturbance. Past research has focussed on comparing logged sites to unlogged sites. The need for research is somewhat

related to whether or not riparian logging is allowed. Research could be linked to demonstrations and operational trials.

- Pilot study, demonstration, operational trials, etc. – Although there are a number of riparian logging trials most were put in place without attached research. More trials, perhaps as part of rollout of EBM riparian management, could be opportunities. With the recent designation of 3 fish species at risk in the Alberta foothills there may be opportunities to develop pilot watershed plans for demonstration watersheds that include riparian EBM within a watershed approach. Over the longer term if prescribed burning in riparian zones proceeds to research trials research to quantify the effects and compare to wildfires and logging could be an opportunity. These could include log-burn trials.
- Policy discussion – Alberta could use a policy discussion paper with literature review, comparisons with other jurisdictions, and a comparison of the existing RMS with one based on EBM based on actual sample watersheds. Pros and cons, policy alternatives, recommendations, etc.
- Negotiation – the opportunity here would be if West Fraser or other forest companies should propose riparian EBM. Three-way negotiation between company, GOA, and GOC.
- Proposal – Opportunity to develop proposal for pilot watershed plans incorporating riparian EBM (see watershed demonstration projects)
- Planning – the West Fraser 2013 riparian EBM proposal did not include an actual mapped comparison of the status quo approach and the new EBM approach. A comparison with maps that show the differences might help to gain support.
- Communication – in addition to communications between companies and governments there may be opportunities for communications to general public, Indigenous, ENGO, anglers and water recreationalists, etc. what Mother Nature does, what humans do now, what al alternative EBM approach might looks like and why it could be better for riparian and aquatic ecosystems and species.
- Partnership – There may be an opportunity for partnerships between the GOA, GOC, and 1 or more forest companies for watershed demonstration pilots in the Alberta foothills.
- Regulatory practice or policy change – Alberta has the authority to allow riparian EBM through approval of OGR variances and or FMP riparian management strategies. The opportunity is to work with the GOA to define expectations and conditions that would result in them using the provisions. Eventual change to OGR policy could follow. Nothing is needed in Saskatchewan because they already allow EBM riparian, although I would rather they take a landscape approach.
- Voluntary actions – West Fraser is still interested in riparian EBM implementation and has continued to do research and monitoring. They may reapply at some point, probably in conjunction with an FMP revision. Other companies would have similar opportunities to participate in watershed pilot programs and demonstrations, etc. Link to stream crossing remediation and access management planning.

- The effects of riparian logging on stream habitat and ecology are qualitatively similar to those of wildfire, except for recruitment of large woody debris (Moore and Richardson 2012). There is an EBM opportunity to use riparian logging and prescribed burning as a substitute for wildfire to maintain the role of wildfire in maintaining ecological integrity of riparian ecosystems (Kardynal et al. 2009; Sibley et al. 2012). Where large woody debris recruitment is important, LWD can be assured by leaving trees within a LWD recruitment zone. In the Alberta foothills almost all large woody debris that interacts with a stream channel originates within 10.2 metres of the channel (McCleary 2005). Leaving trees that lean toward channels and even deliberate placing of LWD could be used to help ensure LWD recruitment and conservation.
- Regulatory frameworks and social acceptance do not allow unrestricted fires or unconstrained logging in riparian areas. A balanced approach must be employed to maintain variability and ecological functions within acceptable social limits. In particular, disturbance must be managed to maintain variability without unacceptable impacts to aquatic ecosystem values, which still have primary importance. One way to do this is to "*identify crucial processes and habitats at the stand and landscape scale and find ways to maintain these at sufficient levels*" (Granström 2001; Government of Canada 2015).
- Use ecological waterbody classifications such as the process-based channel classification system (McCleary et al. 2012) to replace the existing non-ecological classifications used in Alberta and Saskatchewan. Use the ecological classifications of aquatic ecosystems to determine the important ecological processes and functions that riparian disturbance should protect.
- Ecological classifications of riparian landforms, ecosystems, and communities and their role in maintaining ecological processes and conditions would provide an improved basis for management decisions (Ledesma et al. 2018). Variable-width hydrologically adapted riparian classifications allow more effective protection of ecological and biogeochemical processes without incurring additional costs over fixed-width buffers (Clare and Sass 2012; Tiwari et al. 2016).
- Riparian mapping using environmental and ecological criteria would be a good first step to improve riparian management in line with EBM (Greenlink Forestry 2013; Lidberg et al. 2020).
- Linking riparian management to management of aquatic and upland ecosystems within watersheds represents an important opportunity to extend integrated EBM to hydrologically-connected multi-scale ecological unit landscapes.
- As regulators begin to adopt ecologically based riparian management (Naylor et al. 2012) there are good opportunities for governments and others to share information and collaborate.
- Saskatchewan already offers companies an option between fixed-width and variable-width buffers, and Alberta offered a similar choice in the past. Governments could provide opportunities for companies that wish to employ EBM by providing conditional choices between an EBM approach, fixed-width, or variable-width buffers. The EBM option could be conditional on commitments to riparian inventory and mapping, alternative silvicultural systems, integration with upland EBM management, and a monitoring and evaluation program.

Managers and regulators could then use adaptive management to evaluate EBM riparian programs and work toward eventual general adoption of an EBM approach everywhere if it proves to be successful and superior to buffer approaches.

- Riparian areas have high ecological significance. Risks associated with carefully implementing EBM in riparian areas are likely to be low over periods sufficient to evaluate outcomes. Riparian areas are small proportions of forest landscapes and of these the proportions that are suitable for logging as a disturbance are also small. Most riparian areas would not be logged because they do not produce merchantable timber or can't reasonably be operated while maintaining ecological values and functions (steep slopes, inaccessible, etc.). Additional areas would be excluded for economic or social reasons.
- Seek opportunities to design and trial through research and adaptive management ways to use logging as a disturbance tool in riparian areas, possibly coupled with prescribed fire, to maintain disturbance processes and ecological integrity over the long term while not creating unacceptable short-term impacts (Kreutzweiser et al. 2012).
- To reduce perceived risks, an alternative EBM approach to riparian management could be developed and implemented on a trial basis. The approach developed by Hinton Wood Products, which was not approved by the GOA, is an example (Hinton Wood Products 2013).
- EBM riparian costs for inventory, planning, access, and reforestation may initially be substantially more than EBM management of upland ecosystems (Hinton Wood Products 2013). These may be partially offset with contributions to wood supply and higher value of wood logged. The opportunity is for companies and governments to work cooperatively to ensure that costs do not increase to levels that preclude EBM in riparian areas.
- Objectives for protecting aquatic ecosystems from forest management include protecting fish and fish habitat, intercepting sediment, shading, moderating temperature, maintaining organic matter inputs and bank stability including large woody debris, providing wildlife habitats and dispersal corridors, and enhancing nutrient uptake (Richardson et al. 2012). There is an opportunity to use an EBM approach to conserve these values while resolving the shortcomings of fixed width buffers and increasing long-term ecological integrity, especially when integrated with complementary EBM management in adjacent uplands. Among other benefits, this may increase ecological resilience and help to mitigate some of the ecological effects of climate change on values such as water temperature (Bowler et al. 2012).
- Societal acceptance of prescribed fires in forest management is low (Arkle and Pilliod 2010), and so is acceptance of logging in riparian areas (Sweeney and Newbold 2014). A science-informed EBM approach that uses a combination of careful logging and prescribed fire approximate the natural effects of fires in riparian areas may be more acceptable (Nitschke 2005; Sibley et al. 2012). Disturbance of riparian forests must be thoughtfully planned because some operations may be incompatible with other ecological, social, or cultural objectives (Naylor et al. 2012).

- EBM for riparian areas could be part of an integrated EBM approach to management of entire watersheds from upland through riparian to aquatic ecosystems. This is an opportunity to bridge the traditional divides between upland and aquatic ecosystems management. As an example, pilot programs on selected watersheds could involve interested companies, provincial and federal agencies, and other stakeholders and interested parties (Bonar 2020).

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F4.10 Variance Clauses

The federal and provincial regulatory and policy frameworks contain considerable flexibility through contingency and variance clauses that provide opportunities for alternative approaches and proposals that require regulatory approval prior to implementation. These clauses are usually included to account for unforeseen circumstances and allow for changes without having to update and change legislation.

Challenges

"Governments gave themselves flexibility to consider and approve rules alternatives but they are hugely reluctant to use them." (Anonymous SME).

"Government regulators are "risk averse" and this is a significant barrier to trying something new." (Anonymous SME).

"Industry is reluctant to push too much on EBM because they don't want to damage government relationships and single themselves out for unwanted opposition." (Anonymous SME).

- Fixed targets in many regulatory instruments "*are expressed in absolutely rigid terms, so they can't be dynamic, and generally they don't take account of any other ecosystem service delivery*" (Waylen et al. 2015).
- Variance clauses are usually somewhat generic and do not include much detail compared to the 'standard' direction contained in the instrument. This makes it difficult for managers and regulators to contemplate and compare potential alternatives.
- Many instruments are oriented towards processes and activities and not outcomes. Where outcomes are not quantitatively specified it is difficult to evaluate alternatives in terms of desired outcomes to see if alternatives may be superior.
- Regulators are often reluctant to consider or approve variance requests.
  - Relying on the false certainty of expected acceptable outcomes implied with current systems.
  - Risk aversion to trying something different.
  - Real and potential risks in relation to outcomes.
  - Time and resources to consider alternatives.
  - Real or perceived social support and acceptance of alternatives.

  - Lowest common denominator minimum standards. Opposition to doing less (unfair advantage) and doing more (others can't afford, implication that minimum standards are too low, etc.).
  - Concerns that variances may have unacceptable or unintended effects on other values (e.g., concerns that variable stocking standards to increase ecological variation may have negative effects on AAC).

Recommendations

> *"Governments will use their authority to approve innovation when proponents come up with compelling arguments, preferably backed by a powerful coalition of society demanding change."* (Anonymous SME).

- Rethink variance clauses as opportunities for innovation that are actively encouraged and supported in an adaptive risk management framework (research, demonstration, trials, operational practice progression).
- Explore and develop variance alternatives that support or allow EBM innovation through partnerships or other cooperative arrangements between proponents and regulators (e.g., ecosystem-based approaches to species at risk conservation).
- Use variance clause projects as active adaptive management experiments.

F5 Monitoring, Communication, and Research

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Considering that all management is an experiment, a critical aspect of management systems is monitoring both actions taken and the expected targets, and to use the knowledge to inform the next round of setting targets and actions. Reporting is valuable because it encourages management rigour (the actions were taken the monitoring was done, and the targets were achieved), and it provides information for those who have an interest in forest management so they can participate in the next round of management planning. Research to acquire new knowledge also informs the management process.

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F5.1 Monitoring

Monitoring of multiple indicators related to ecological integrity and human wellbeing in Alberta and Saskatchewan forests is relatively well developed but it exists as a complex jumble of disconnected programs administered by different actors. Processes are in place to monitor some key EBM ecological integrity indicators such as disturbances, seral stage and patch size, and many human wellbeing indicators such as production of goods and services, human use, etc.

Most management plans (e.g., FMPs and Park Management Plans) have a required monitoring program which generates new knowledge through the process of performance assessment. Monitoring includes both management actions and outcomes.

In protected areas managers have the responsibility to do comprehensive monitoring but are severely constrained by funding.

Provincial governments do compliance monitoring and audits, and industry certifications require self-monitoring verified by third parties in relation to standard requirements. Programs such as the Alberta Biodiversity Monitoring Institute, which monitors and reports on biodiversity status throughout the province of Alberta, provide valuable information about ecological conditions and trends over time.

CHALLENGES

> *"Probably one of the more trying areas has been in performance-based policy evolution toward extremely complex, expensive stewardship tracking and reporting schemes. Even the government is challenged in internal capacity of staff to provide timely, meaningful review and response to such submitted reports, which tend to be very large and data-heavy across a large collection of individual measurables (multiple objectives, indicators, targets). Government expectations on such reporting quickly becomes unviable when multiple commercial parties hold tenures on a common shared landscape. The present reality that only some commercial land-users are mandated participants in the direct forest management planning-process renders the actual success in managing for and achieving desired landscape-scale targets somewhat unachievable at the outset. The tallied performance published in this mandated reporting can unfortunately create an incorrect public perception that the principal commercial author of the stewardship reports is solely or primarily at fault for missed targets, or the inaccurate conclusion that ecosystem-based approaches themselves are ineffective."* (Anonymous SME).

- The current monitoring framework in both provinces is a diverse mix of required and voluntary indicators and programs conducted by multiple organizations.
- Monitoring is largely ad hoc and is driven by individual requirements, values, and issues.
- There is a widespread tendency to disconnect monitoring from management. For example, the Saskatchewan state of the forest reports are done every 10 years. They report on some good EBM indicators, but those aren't linked to targets and actions previously set for those indicators. The monitoring is passive, after-the-fact, and not as useful as performance monitoring for adaptive management. Federal state of parks reports similarly focus on current conditions and not whether or not management targets were achieved. The knowledge is too often not set up to facilitate learning (Price and Daust 2009).
- Monitoring is often intended to detect after-the-fact issues which then triggers response. Monitoring for large-scale cumulative effects by programs such as the ABMI and the Saskatchewan Focus on Forest reports is commendable but would be more valuable if it was linked to EBM targets set through land-use plans and subregional EBM plans.
- Monitoring may be focussed on specific activities more than targets. The challenge is to measure both activities and targets to learn where there are opportunities for improvement.

- Monitoring systems, which are essential for adaptive management, have suffered from lack of funding and leadership (DeFries and Nagendra 2017).
- Monitoring costs can impact economic viability (Robertson et al. 2004). The challenge is to choose indicators that effectively monitor the key EBM aspects within an affordable monitoring cost framework.
- Monitoring in commercial forests is limited by management responsibility which is divided by the public land model. Forest companies monitor their own activities and related outcomes but are not responsible for other aspects such as species at risk monitoring, which is divided between provincial and federal governments depending on species.
- Monitoring in National Parks is used to inform management planning but is not closely linked to targets.
- Information from monitoring is owned by different organizations and may be closely held for various reasons. This makes it challenging to take advantage of monitoring information and use it for adaptive management.
- Databases that hold required monitoring information may be very unwieldy and rigid. For example, the Alberta Regeneration Information System is very rule oriented and difficult to upload data to.
- Databases are not always accurate and up to date, especially when changes are continual and multiple organizations contribute information. For example, the Alberta Digital Integrated Dispositions (DIDS) is a sharable digital mapping program that keeps track of activities on Alberta's public land. DIDS is often out of date and can contain inaccurate information. The Foothills Landscape Management Forum uses aerial photography and other options to maintain digital map information that is more accurate than DIDS.

Recommendations

> *"We could sure use a review of all the monitoring information that's out there and recommendations for an idealized, practical, and affordable core set of EBM indicators."* (Anonymous SME).

- Good monitoring starts with a good EBM process to identify indicators and management actions to achieve targets. There are significant opportunities to fill gaps and improve efficiencies in monitoring programs by focusing monitoring on the key indicators identified in EBM plans.
- Look for opportunities to revise existing and design new monitoring to show indications of potential opportunities or difficulties in advance (Delacámara et al. 2020).
- Look for opportunities to use innovative monitoring methods to increase availability of information for low costs. Citizen science programs such as eBird, the Breeding Bird Survey, and Christmas Bird Counts have been valuable to science and could be extended to other aspects of ecological integrity and human wellbeing.
- The landscape assessments (Box F4) done for Alberta Land-Use Framework regions (Forcorp Solutions Inc. 2012) and the Saskatchewan Focus on Forests report (Government of

Saskatchewan 2019b) are good examples of baseline monitoring that could be expanded and refined to report on key EBM indicators and targets.

Box F4. Alberta Regional Forest Landscape Assessments

Alberta commissioned a series of regional forest landscape assessments for the six Land Use Framework Regions that contain forests (e.g., Forcorp Solutions Inc. 2012). The information was summarized by Natural Subregion ecological units within the regions and could be recompiled for units between regions and other ecological units such as watersheds and species distributions. Alberta could use the assessments to plan and monitor EBM and provide relevant ecological contexts information and direction to DFA managers.

- Monitoring done by the ABMI provides a comprehensive status assessment of Alberta biodiversity and ecological integrity. Opportunities to expand the ABMI program or develop something similar for Saskatchewan could be investigated.

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Adaptive Management

Definitions of adaptive management (Holling 1978) all center around the notion of *learning by doing* (Walters and Holling 1990) as a way to address uncertainty and continually adapt and improve management. Adaptive management is based on the philosophy that knowledge is incomplete and much of what we think we know is actually wrong (Allen et al. 2011). Adaptive management is useful where there are uncertainties about the impacts of management actions on indicators that respond to actions (Williams 2011).

Adaptive management is widely considered to be the best available approach for managing biological systems in the presence of uncertainty (Westgate et al. 2013). Ecosystem processes and functions are complex and variable and their response to human intervention is inherently uncertain. EBM seeks to build or strengthen adaptation capacities by maintaining critical aspects of ecological integrity and supporting human abilities to respond to a range of possible future scenarios (Delacámara et al. 2020). Integrated adaptive management programs as part of EBM help managers and interested parties to consider contexts, options, and probable outcomes of decisions through an explicit and repeatable process (Chambers et al. 2019).

Adaptive management is frequently mentioned in all aspects of management planning and is practiced to some degree in many aspects of the regulatory management framework in Alberta and Saskatchewan. Many companies and government agencies utilize some form of adaptive management in their decision-making process (Dzus et al. 2009). Walters (1986) proposed 3 forms of adaptive management: evolutionary (trial and error), passive adaptive, and active adaptive. In passive adaptive management available information is used to develop a single best course of action that is assumed to be correct and informs decisions accordingly. Active adaptive management develops a range of potential actions and a process of determining which is likely to be best before choices are made, and choices could include trying more than one potential action. Passive and adaptive management can be used to develop experiments designed to learn what works and also what doesn’t work.

CHALLENGES

"Adaptive management tends to skip the implementation part, there's need to actually try and show people what is being done." (Anonymous SME).

"Support for adaptive management and/or EBM pilots, demonstrations, etc. still has to come from outside government, with entry at the political level." (Anonymous SME).

- Adaptive management is an attractive option for addressing wicked problems but is not a panacea (Allen et al. 2011).
- Adaptive management may be the hardest EBM aspect to implement because it requires a substantial degree of organizational change, which is risky for managers because it challenges the status quo (Butler and Koontz 2005).
- Adaptive management is most often applied to ecological uncertainty, but reported experiences tend to be more about governance and about social learning (Fabricius and Cundill 2014). This suggests that an important challenge is to find adaptive ways to improve governance, integration, partnerships, participation, and learning.
- Adaptive management focussed on mechanistic understanding of learning over short time scales through experiments has to extend to learning and change that occurs over many decades within both individuals and organizations and creates opportunities for social change (Lee 1993).
- Adaptive management is considered to be daunting and expensive by government and industry, and as an excuse for using less ecologically conservative practices by ENGOs and some government agencies that revealed some very real conflicts about environmental values (Walters 1997; Price and Daust 2009).
- Adaptive management has been hampered by risk and cost aversion which prompts decision-makers to do minimal things to resolve complex problems. For example, try a cheap or easy option, find it doesn't work, become frustrated with lack of success and continuing controversy to get it right, and try something else until success is achieved or the value being managed collapses (Webster 2009).
- Entrenched interests may see adaptive-policy development as a threat to existing research programs and management regimes, rather than as an opportunity for improvement (Walters 1997). This creates strong opposition to experimental policies by people protecting various self-interests in management bureaucracies.
- Detailed modelling of scenarios cannot be substituted for field experimentation to confirm assumptions.
- Entrenched bureaucracies and social and legal limits of authorities constrain opportunities for flexible decision-making and the ability to change course once a policy is put into place.

- Natural resource managers have traditionally not been rewarded for experimenting, monitoring, and adapting (Grumbine 1997).
- Scientific and institutional challenges hamper adaptive management implementation (DeFries and Nagendra 2017).
- Monitoring required for adaptive management is costly (Yaffee 1996; Butler and Koontz 2005) and it is difficult to secure support and funding for sustaining efforts over time (Butler and Koontz 2005).
- Many claim to practice adaptive management but few seem to really understand it (Murray and Marmorek 2003).
- Poor communication is a primary challenge to adaptive management implementation (Westgate et al. 2013).
- US Forest Service adaptive management initiatives were limited by administrative, technical and financial obstacles resulting in piecemeal, inconsistent and often inefficient application (Cushman and McGarigal 2019).
- Low-hanging fruits of management interventions in the short term should be weighed against longer-term benefits of alternative actions (Delacámara et al. 2020).
- Adaptive management is limited by legal requirements and processes with specifically enforceable standards which are often preferable to open-ended guidance (Nie and Schultz 2012). This makes implementation of alternatives more challenging.
- Adaptive management methodologies are of limited value unless they can be employed within highly complex, often overlapping regulatory frameworks (Allen et al. 2011).
- Necessary compromises should be clearly stated and not suppressed by the urge to influence policy (Seppelt et al. 2011).

Recommendations

> *"In Saskatchewan we had 2015 evacuations for fires. Then drought in Regina and flooding at Quill Lakes. Big windstorms. Extreme weather. Adaptation is needed, but there's not much appetite to move the bar. EBM could be used as an adaptation tool."* (Anonymous SME).

> *"Active adaptive management is not being done in its true form, we tend to do trial and error. Mixedwood and riparian management are big adaptive management opportunities."* (Anonymous SME).

- Management decisions must still be made, and opportunities to incorporate learning into management should be taken whenever possible (Allen et al. 2011).
- There are opportunities to improve communication about what adaptive management is, the risks of not doing it, and the benefits that can be gained through thoughtful and determined adaptive management (Westgate et al. 2013). These could include value examples of how improved management practices can save money (Murray and Marmorek 2003).

- Using a management system approach to define and implement EBM provides a structured framework to deliver continual improvement and adaptive management. Good examples of these include the ecological integrity indicators used by Parks Canada, the Saskatchewan State of the Environment Focus on Forests reporting system, the FMP process in both provinces, and the requirements of forest certification and environmental management system standards.
- Using adaptive management as part of EBM to address wicked problems is intuitively appealing and managers should seek opportunities to continue existing programs and initiate more. Examples of long term projects include the Tri-Creeks (Sterling et al. 2016), EMEND (Spence et al. 1999), Gregg Burn (Johnstone 1981) and Calling Lake (Schmiegelow et al. 1997) research trials in Alberta and the Mistohay project in Saskatchewan.
- Research trials, demonstrations, and pilot programs are low risk opportunities to learn about new management options. Projects that can provide new data and insights within one to two years to demonstrate an approach and its value can then be transitioned or followed by larger-scale issues that may take decades to resolve (Murray and Marmorek 2003).
- Collaboratively-based, iterative processes such as EBM are well suited to promote flexibility and facilitate adaptation (Gunderson and Light 2006).
- Implement active adaptive management through controlled experiments to identify causes and effects among policies and outcomes (DeFries and Nagendra 2017).
- "*When you have information, use it: analyze it, map it, simulate it, scenario it, experiment. Only thus will you consider possibilities, start to anticipate change and surprise, test your assumptions, and figure out what else you most need to know.*" (Slocombe 1998).
- Organizations and partnerships need innovation and permission to design, prioritize, and invest in management, monitoring, and research in ways that will best address uncertainty and lead to improvements in effective EBM. Partnerships and relationships established as part of EBM planning can be used to explore opportunities and secure the approvals and resources to more extensively implement adaptive management.
- Adaptive management can be used to rigorously assess the necessity and sufficiency of standards and guidelines, and to foster creative EBM solutions (Murray and Marmorek 2003).
- Adaptive management requires managers to embrace uncertainty and take risks, and organizational structure will have to change so that these traits are rewarded rather than discouraged.
- EBM at large scales needs institutions that will be in place long enough to measure large-scale responses that may take decades to unfold (Walters and Holling 1990). The Alberta Biodiversity Monitoring Institute in Alberta and the Saskatchewan State of the Environment Focus on Forests reporting system are examples.
- Opportunities to control costs including starting with EBM indicators that are already being monitored, preparing lists of other desirable indicators and gaps, looking for ways to cost-effectively obtain monitoring information including partnerships to share costs, looking for

opportunities that can be investigated inexpensively and deliver short-term payoffs, improving monitoring that could be made more efficient, and discontinuing items that aren't necessary.

- Permanent sample plots established to measure tree growth and yield in both provinces may provide good opportunities for measuring other indicators of interest. ABMI sample plots have similar objectives, and there may be value in collaborating between systems.
- Opportunities to start new adaptive management initiatives could start with high-profile aspects with widespread societal questions and demands that are likely to be funded (Murray and Marmorek 2003).
- Adaptive management experiments are opportunities to test alternative management actions that arise from different hypotheses and are supported by different stakeholder groups. Designing the experiments identifies uncertainties and opportunities for creative solutions to reduce them (Murray and Marmorek 2003).
- Adaptive management opportunities may be improved by better collaboration between forest management and the science community and ensuring projects "pass the test of management relevance" (Westgate et al. 2013).

F5.2 Communication

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The success of any forest management approach, and EBM in particular, rests on excellent participatory communication. Reporting is a key aspect of communication because it closes the management system loop by telling everyone what happened and informing the next round of continual improvement.

There are numerous reporting processes and products related to forests from multiple sources in Alberta and Saskatchewan. Increasing capacity to gather, store, and communicate information continually expands information and reporting. Any person with access to the internet and basic familiarity with search functions can quickly access huge amounts of information.

Examples of reports related to forest management include:

- State of Parks reports for National Parks.
- Federal State of Canada's Forests reports
- Forest Management Plans for commercial forests in Alberta and Saskatchewan.
- FMP Stewardship Reports in Alberta (Government of Alberta 2006, 2017b).
- Provincial reports such as the Sustainable Forest Management Statistics in Alberta and State of the Environment Focus on Forests in Saskatchewan.
- Corporate reports prepared by forest and energy sector companies.
- Reports prepared by non-government organizations.

Challenges

> *"It's hard to communicate something that still has no widespread commonly understood definition. That's the first communication challenge."* (Anonymous SME).

> *"There are inconsistent interpretations and application within agencies. For example, front line forest staff from government say different things, and there are individual inclinations. It's very frustrating. More communication is needed to make sure everyone is informed and implementation is consistent."* (Anonymous SME).

> *"Fire management as an EBM issue, we need better ways to manage than suppression and fire smart around communities. Older forest age class structure means more fire risk. There is a disconnect between old-growth and fire risk wants. How willing is the commercial sector going to be to let fires burn on tenures in the face of AAC loss and liability issues? What about water quality issues? The public has to be careful what they ask for. Not managing fire inevitably leads to fire catastrophes. Any changes need a big communications effort considering fears and entrenched views about fire. People have to understand and support what we are working toward."* (Anonymous SME).

- EBM is a work in progress in both provinces, and there are as yet no reporting processes or products that specifically apply to comprehensive EBM for all forest lands.
- Much information is available, but it is diverse and scattered and not easily accessed.
- Reporting is still largely oriented toward specific values and uses and not toward overall EBM outcomes.
- Because there are as yet no comprehensive area-based EBM plans, reporting has not been linked to comprehensive EBM targets.
- There are lots of communication products and processes, but few that are focussed on EBM.

Recommendations

> *"We need to keep trying to further EBM and improve over time. Build good communications and partnerships to try new things and get things done. It seems everyone agrees at the highest levels on the emphasis on ecological integrity, use Mother Nature as a guide. The devil is in the details."* (Anonymous SME).

> *"To achieve better EBM understanding we have to figure out the communication paradigm. EBM has a different vocabulary – we must speak to the issues as well. Carbon sequestration, ecosystem services, biodiversity conservation, etc."* (Anonymous SME).

> *"Look at what we've done and if it was over today how would we tell people about it? Lots of work has been done, there's a need to capitalize on that body of knowledge and communicate that."* (Anonymous SME).

> *"Bring more voices into the conversation during policy development. We need more voices who can speak to EBM and the particular issue at hand."* (Anonymous SME).

> *"Forest protection got their act together and developed a universal language and approach, consistent framework, etc. They have a portable template to communicate and function. Could we do something similar for EBM?"* (Anonymous SME).

- There is an opportunity to initiate a research project to review the forest management reporting systems in each province and at the federal level to identify gaps and options for improvement.
- Initiatives such as the Alberta Land-use Knowledge Network and the Alberta Land-use Planning Hub are examples of information warehouses that work to bring together knowledge about land use and EBM.
- The fRI Research Healthy Landscapes Program and associated websites Landscapes in Motion and Ecosystem Based Management in the Boreal Forest are focussed on EBM research and communication and could be expanded into bigger communication portals.
- As more comprehensive EBM planning begins to take hold there are opportunities to link EBM plans with targets to performance reporting.

F5.3 Research

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EBM is strongly based on the concept that management should be applied in an adaptive management learning framework that accepts what we do not know. Alberta has a strong research history in relation to forest management. Saskatchewan's history is less robust but Saskatchewan has worked with Alberta institutions on EBM for more than 2 decades.

Knowledge generation is widespread and employs a variety of funding approaches and methods. Programs exist in subjects such as inventories, observational studies, experimental studies, research trials, demonstration trials, operational trials, and other research initiatives. Collection of Indigenous and western traditional oral knowledge is useful to understand historic conditions and processes and help to inform future choices (Joa et al. 2018).

In an ideal situation generating new EBM knowledge would be through a consensus knowledge agenda with multiple support from those who wish to have new knowledge. In reality knowledge generation is an ad hoc process driven by funding, local issues and priorities, regulation, established relationships, and personal interests of funding agencies and research institutions and their personnel. Even the location of work is subject to this, with funding distinctly directed toward local areas and interests.

Challenges

> *"We know a lot about forest management. We don't know enough about forest management. We need to keep learning. Research has to be more targeted to EBM to help answer questions."* (Anonymous SME).

> *"EBM doesn't have an overarching research vision that could be used to identify knowledge gaps and coordinate research initiatives."* (Anonymous SME).

> *"There's a gap between research knowledge and application. People tend to take what they like and ignore everything else. Different players have different likes and they aren't trying to meet and work it out. It's become a battle about whose version is to win."* (Anonymous SME).

- A February 2021 Google Scholar search returned 42,000 records for the term *forest management Alberta Saskatchewan*. The challenge is to continue to build on the historic research record to support EBM into the future.
- The overall research package is divided by the disconnected forest governance model, with individuals, organizations, and agencies pursing their own research agendas linked to their particular interests. There is currently no strategic framework for EBM research that could be used to help bring the disparate initiatives together.
- Research in many life sciences disciplines has too often suffered from a research-management gap where researchers may not focus studies on the questions managers most need answered and managers may not use available research in their decisions (Carter et al. 2019).
- EBM is a holistic approach to management that cuts across traditional research enclaves. The challenge is to foster collaborative research between and across biological, geological, hydrological, economic, social, etc. research realms. This need also applies within disciplines, because there is little communication and collaboration between them when EBM needs more. For example, research on terrestrial versus aquatic species has traditionally been in separate streams.
- The knowledge systems of Indigenous peoples have been inadequately integrated with western science regimes (Wyatt 2008; Brunet et al. 2016; Indigenous Circle of Experts 2018).
- The research knowledge transfer system where researchers produce peer-reviewed publications and technical reports and then hope managers will use the knowledge has not served either researchers or managers well (Westwood et al. 2020). The challenge is to improve ways of designing, implementing, transferring, and implementing the benefits to be had from new knowledge.
- Forest research has always needed a balance between studying short-term practical questions and longer-term theoretical investigation (Cortner and Moote 1994). The short-term interests of funding partners tend to drive the balance toward applied research. EBM introduces new levels of questions for aspects like geographic and temporal scales that will need to be considered when identifying research agendas and opportunities.
- In commercial forests research has tended to use undisturbed (mature to late seral) as the reference to compare the effects of logging. This makes sense when the objective is to maintain mature/old biodiversity, but not when the objective is to approximate a natural disturbance. In those cases, the comparison should be between burned and logged, or some other disturbance

and logged, or combinations. The challenge is to shift investigations toward more appropriate comparisons.

- While considerable bodies of knowledge are available for public use, significant amounts are restricted by the owners for reasons including sensitive information, commercial information, and lack of communication methods.
- Research funding suffers from short-term variations in availability and interest among researchers and funding organizations. There is a need for more stable institutions such as FRIAA to provide ongoing funding for EBM research.

Recommendations

> *"A generic opportunity is to be prepared for and take advantage of unplanned events such as fires burning over logged and reforested landscapes, flooded etc. Have studies conceptualized in a back pocket for when opportunities arise. We could also look at retrospective studies to gain insight. There is significance in having the research community being adaptive, nimble and ready to go."* (Anonymous SME).

> *"Pilots and demonstrations are a good way to break the ice. Use them and coupled research to learn by doing and build support for broader application."* (Anonymous SME).

> *"More empirical research is needed to measure effectiveness of actual harvest areas over time compared to natural disturbance, to test EBM predictions. Al-Pac has done a project with ABMI looking at 15 years post-disturbance, trying to do for 25 years old, and also broaden to the conifer industry. Provide assurance to public land owners that assumptions are correct, risk management is better and risks are reduced."* (Anonymous SME).

- Apply EBM knowledge to enhance understanding and assess options and trade-offs through an integrated and participatory approach (Marshak et al. 2017).
- Research-policy-practice partnerships that integrate management needs and Indigenous knowledge with climate and ecosystem science and can help to facilitate improved decision-making (Keenan 2015).
- Improve the relevance of research by involving scientists, potential end-users of the science, and communities implicated in or affected by the research and its outcomes as partners in research design, execution, and communication (Westwood et al. 2020).
- A big-picture review project of existing research initiatives could help to identify EBM knowledge needs linked to a framework of EBM knowledge priorities.
- Consider opportunities to expand science-management partnerships to use landscape science to foster efficiencies in the land-use and EBM planning processes (Carter et al. 2020).
- Conservation and management efforts that include Indigenous peoples as full partners have greater relevance and better chances of acceptance and implementation (Westwood et al. 2020).
- There are opportunities to build on existing research partnerships and capacities to create a dynamic capacity to undertake additional EBM research.

  - The University of Alberta NSERC Industrial Research Chair in Ecosystem-based Management for Forest Stand Resilience, funded in part by Alberta forest companies and FRIAA, is an example of a research partnership dedicated to EBM.
  - The Model Forest Program, initiated in 1992, resulted in a long succession of research, partnerships, and other benefits that continue today. FRI Research (originally the Foothills Model Forest) remains a leader in forest research with a large partnership.
  - Canada’s Oil Sands Innovation Alliance (COSIA) is an alliance of Canada's largest oil sands producers with a vision “*to enable responsible and sustainable growth of Canada’s oil sands while delivering accelerated improvement in environmental performance through collaborative action and innovation*”. COSIA has a number of initiatives aimed at EBM.
  - Mitacs is a national organization that brokers partnerships between academic researchers and industry that support industrial and social innovation in Canada.
- The Ecosystem Management Emulating Natural Disturbance (EMEND) Project is a large-scale variable retention logging experiment designed to test effects of residual forest structure on ecosystem integrity and forest regeneration at the forest stand-level. Long-term research trials such as EMEND have been very successful collaborations and research from the project has been very useful in forest management practice. There may be opportunities for similar installations in different forest settings such as coniferous ecosystems and riparian areas.
- The LandWeb Simulation Modelling project uses spatial simulation modelling to generate the historical range of landscape conditions across western boreal Canada. This collaborative research program could be extended to other EBM knowledge areas.
- The Alberta Forest Resource Improvement Program (FRIP) is funded by a portion of the stumpage fees paid to government by the Alberta forest industry. The FRIP supports research and other activities that are not the regulatory responsibility of the forest industry. Administration of the FRIP was transferred to a delegated authority, the Forest Resource Improvement Association of Alberta, in 1997 and $385 million in funding was awarded to more than 1500 individual projects from 2007–2014 (Summers 2014). The success of the program could serve as a model for other areas and industries to provide secure research funding.

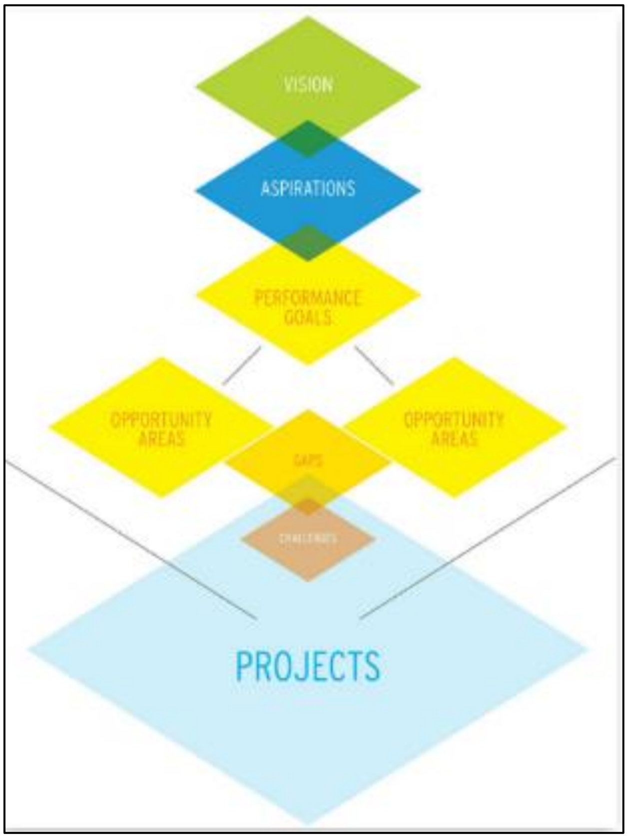

Figure F8. The COSIA research planning framework is structured around four priority environmental policy areas associated with oilsands development: land, water, tailings and greenhouse gases. Projects include pilots or test projects, feasibility analyses, research or any other type of project that produces improved knowledge, practices or technology useful in filling a gap. Source: COSIA website.

- EBM science helps build a credible knowledge base through dialogue between stakeholders and scientists (Delacámara et al. 2020) This process is made easier when stakeholders are clear about the questions they need investigated and there is excellent and continual dialogue between researchers and managers. An opportunity is to build rigorous EBM planning frameworks such as the one used by COSIA (Figure F8).

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