


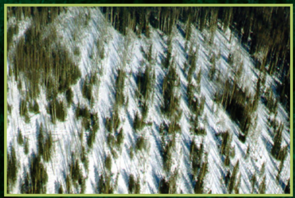


EMEND

ECOSYSTEM-BASED MANAGEMENT EMULATING NATURAL DISTURBANCE

EMEND Insights #23

The use of topographic wetness to inform forest retention design in the western boreal forest

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Ecological Messages:

- Recent research suggests site wetness may be an effective proxy for some measures of biodiversity, productivity and soil carbon in the Canadian boreal forest, and thus it can be used to inform sustainable forestry.

Management Implications:

- Prioritization software can be used to produce spatially explicit retention plans that balance operational, economic and ecological goals.
- This approach is highly versatile and capable of examining a range of constraints and undertaking very simple to highly complex scenario testing.
- Scenario outcomes were highly sensitive to cost constraints, which overrode wetness constraints for specific biodiversity goals, underlining the importance of defining objectives at the start.

Biodiversity conservation has, for decades, been an important objective for sustainable forest management in Canada. One of the prevailing strategies for biodiversity conservation has been ***emulating natural disturbances***, primarily by shifting harvest patterns away from checkerboard clear-cuts and toward patterns that more closely resemble those left by fire. ***Retention forestry*** is one of the most common methods for emulating natural disturbances in harvested stands.

However, deciding ***where to place retention*** to best achieve management objectives is an important operational challenge. Managers and planners must balance conservation goals with economic and operational realities, including but not limited to foregone timber values and worker safety. Indeed, even linking the type and location of retention patches to biodiversity outcomes is an important challenge, and evidence-based approaches to operational applications are rare.

We used prioritization software (Zonation) to to create scenarios in which placement of retention was variously constrained by: site wetness (reflecting biodiversity), aggregation (habitat patch size), or cost (volume of timber left in patches). Our results highlight the potential for users to "move the slider" on different objectives, and reveal important considerations for future iterations of the model. ***Read on to learn more…***



This study employs the results of studies from EMEND including biodiversity studies of bryophytes (mosses and liverworts), understory plants and ground beetles (Carabids). Photo credits: Richard Caners (left), Sonya Odsen (centre).

Retention: what, where, how many, how big…

Determining where to place retention patches is an important question faced by forest managers and planners. Where, how many, what size, what tree composition—these decisions affect not only the conservation outcomes but also the economic cost of retention forestry.

With all this complexity to manage, managers and planners need tools to help them plan retention in ways that are systematic, evidence-based, and strategic. Choosing where to leave retention is complicated because there is no one-size-fits-all approach (see Box 1). However, it may be possible to harness this complexity and support decision-making using prioritization software.

About EMEND:

The Ecosystem-based Management Emulating Natural Disturbance (EMEND) Project is a multi-partner, collaborative forest research program. The EMEND project documents ecological responses to experimentally-delivered variable retention harvesting and prescribed fire treatments. The research site is located in the western boreal forest near Peace River, Alberta, Canada, with monitoring and research planned to continue for an entire forest rotation (i.e. 80 years).

Box 1: Applying the findings of Wet Areas Mapping at EMEND

Several studies, including studies performed at the EMEND project, have linked patterns of productivity and biodiversity to site wetness (see Further Reading).

These patterns are variable: some species or processes were positively associated with wetter sites, while others were associated with drier sites. But these research findings have important implications for achieving conservation objectives by demonstrating which species or processes (e.g., productivity) may benefit by placing retention in areas of varying wetness (Table 1).

These relationships suggest that it may be possible to prioritize certain conservation targets indirectly by prioritizing site wetness categories using Zonation. For example, a scenario that prioritizes wetter sites would be expected to improve conservation outcomes for bryophytes (mosses and liverworts), vascular plants and specialist ground beetle species in coniferous forests.

Table 1. Associations between site wetness and ecosystem biodiversity and function, as found by prior studies conducted at EMEND.

**Species composition varied along a wetness gradient, meaning the types and abundances of species changed. Brackets indicate the parts of the wetness gradient that were more resilient to harvesting (i.e., where composition changed less after harvest).*

For conserving	Deciduous	Mixedwood	Coniferous
Forest regeneration	Drier	Drier	Drier
Bryophytes			
Cover		Wetter	Wetter
Richness/Diversity	Drier	Wetter	Wetter
Composition	Dry (and wet)*	Wet (and dry)*	Wet (and dry)*
Specialist species	Drier	Wetter	Wetter
Vascular plants			
Cover	Drier	Drier	Wetter
Richness/Diversity	Wetter	Wetter	Wetter
Composition	Dry (and wet)*	Wet (and dry)*	Wet (and dry)*
Carabid beetles			
Richness/Diversity	Wetter	Wetter	Drier
Specialist species	Wetter	Wetter	Wetter
Mineral soil			
Carbon and nitrogen	Wetter		Wetter

Objective

We tested the use of prioritization software (Zonation) to create spatially explicit scenarios of retention harvesting within a set of operational (e.g., aggregation), economic (e.g., cost) and ecological (e.g., site wetness) constraints.

Applying findings from EMEND to retention scenarios

We used an existing Systematic Conservation Planning toolkit, "Zonation", to develop and test a simple retention forestry optimization model for a planned harvest area within the Mercer International Forest Management Area in northwestern Alberta.

To do this, we entered the study area's forest characteristics, site wetness, productivity and merchantable volume into the model. Because there were no direct biodiversity measures for the study area, we used categories of site wetness as a surrogate of biodiversity, based on previous studies in the area.

We compared operationally planned retention ("operational reference") with nine scenarios that incorporated constraints for the following values and resulted in the same total area in retention patches:

- pixel aggregation (a preference for larger patches),
- cost (a preference for patches with lower merchantable volume), and
- site wetness (a preference for either dry, mesic or wet sites, as defined by the user).

We compared the outputs for each scenario with retention patches in the operational reference in terms of:

- their size, number and location;
- their density, height, age, composition, productivity and gross merchantable volume; and
- their representation of wetness classes.

Main Findings

A wetness constraint resulted in quite different retention patterns than the operational reference

The degree of spatial overlap between Zonation outputs and the operational reference was low, ranging from 1.7% to 20.4% across the nine scenarios. Overall, the operational reference had fewer and larger patches: these were located on wetter sites and had higher deciduous density, lower conifer density, and lower gross merchantable volume.

The wetness scenarios consistently resulted in many more, and much smaller (0.42 ha on average), retention patches than the operational reference. In the absence of a cost constraint, the "Dry" scenario yielded patches with higher deciduous density and the "Wet" scenario resulted in retention patches with higher conifer density, greater gross merchantable volume and older forest.

The scenarios also favoured drier retention patches on average. The average depth-to-water for the scenarios was 1.5 m, which is much drier than the average depth-to-water of 0.4 m in the operational reference. Surprisingly, even the two scenarios that prioritized wet sites had a lower proportional area of wet sites than the operational reference. This finding suggests that planners may preferentially select wetter areas for retention.

Finally, the scenarios also produced patches that had considerably more area in grassland/shrubs than the operational reference. Adding the cost constraint slightly decreased this area and resulted in more black spruce in retention.

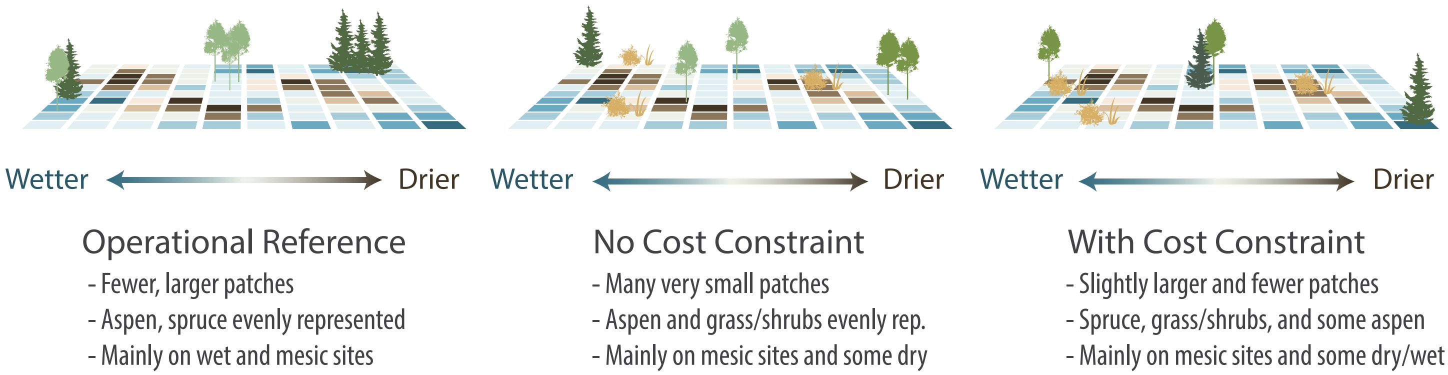

Figure 1. Retention patches that were designed operationally for the study area (Operational Reference) compared with generalized Zonation outputs with and without a cost constraint. The Zonation outputs had very low overlap with the operational reference.

A cost constraint produced more "realistic" outputs

The cost constraint, which favoured patches with lower merchantable volume, yielded outputs that overlapped more with the operational reference. Notably, applying the cost constraint essentially negated the effect of the wetness constraint: retention patches in scenarios that prioritized wet, mesic or dry sites had few actual differences in wetness when cost came into play.

However, even the closest scenario only had 20% overlap of retention patches with the operational reference, meaning other factors driving decisions at the operational level have not been captured by the model. These may have included, for example, accessibility, worker safety, buffers around open water and other wet features, wildlife trees and more.

Management implications

Prioritization software such as Zonation provides an intriguing and compelling alternative to manually planning retention. In theory, it provides an opportunity to make retention patch selection more objective by basing it on quantitative measures of biodiversity and explicitly defined constraints.

In practice, this study reveals both the potential and the challenges inherent to using a tool like Zonation.

By running the model with pre-defined constraints, ***this work demonstrates the potential power of prioritization to take complex needs and provide spatially explicit outputs.*** Not only that, but it makes it possible to, in essence, "move the sliders" on constraints such as cost, aggregation, and biodiversity objectives. In addition, it has the power to provide outputs that prioritize patches according to site wetness and the plant, insect and soil carbon responses that have been documented at EMEND (see Further Reading). For example, it is possible to determine from Table 1 whether prioritizing dry, mesic or wet sites will be most consistent with specific biodiversity objectives and tailor scenarios accordingly. ***In the future, including these and other ecosystem services in prioritization models will provide great value to managers.***

However, there are important challenges—and critical choices—inherent to this approach. In practice, a prioritization model cannot truly be objective because biodiversity surrogates and scenarios are ultimately defined by the user. Direct measures of biodiversity are extremely costly and time-intensive to collect, which means the software prioritizes "biodiversity" using surrogates that are defined by the user. ***The way biodiversity surrogates are defined, therefore, must be very carefully considered and (where possible) incorporate local knowledge.***

The differences between the scenarios and the operational reference also highlight the importance of carefully defining constraints. For example, most scenarios yielded a very large number of very small patches compared with standard practice. Larger patches may be more operationally feasible, and have been shown by some studies to be more effective lifeboats for old-forest species (see EMEND Insights #4 and #9, and SFMN Note No. 74). Future models may need different aggregation constraints to ensure that some larger patches are included. ***However, the model results also suggest that smaller patches across wet, mesic and dry areas may play an important role in meeting biodiversity objectives.***

While there was no single "best" scenario, the results suggest that some scenarios may be effective to meet multiple objectives (cost, habitat (larger patches) and biodiversity). The model tested for this study is in its very early stages and requires future development to further capture the complexity of biodiversity relationships and operational realities. Future iterations of this model may require more representative cost-estimation techniques, and whether both cost and biodiversity can be equally prioritized remains to be seen.

This work was an important first step to demonstrate what may be possible using prioritization software like Zonation. Future work may use different variables, or more variables, that reflect local operational and biodiversity considerations. Achieving the right amount of complexity will also be an important component of future work, as overly complex models are computationally intensive and may introduce many sources of error.

Further Reading

Moilanen, A., Montesino Pouzols, F., Meller, L., Veach, V., Arponen, A., Leppänen, J., et al. 2014. ZONATION Version 4 - User Manual. V4 ed. Helsinki, Finland: C-BIG Conservation Biology Informatics Group, University of Helsinki Available at: https://www.helsinki.fi/en/researchgroups/digital-geography-lab/software-developed-in-cbig

Robinne, F.R., J.J. Stadt, C.W. Bater, C. Nock, S.E. Macdonald and S.E. Nielsen. 2020. A topographic wetness strongly influences forest retention design in the boreal forest of Western Canada. Frontiers in Ecology and Evolution. doi: 10.3389/fevo.2020.584291

EMEND Insights #14 | Seeing the forest through new eyes: using remote sensing data to understand forest responses to variable retention harvesting

EMEND Insights #18 | Using Wet Areas Mapping to plan retention placement: Lessons from the understory

EMEND Insight #21 | Using Wet Areas Mapping to plan retention for bryophytes

EMEND Insight #22 | Adapting harvest practices to climate change: how Wet Areas Mapping can estimate soil carbon stock

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Spring 2021