FINAL REPORT

# Grid-Based Natural Wildfire Patterns

## In Northeastern Saskatchewan

Final Report
fRI Research Healthy Landscapes Program

September 16, 2015

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fRI Research
Informing Land & Resource Management

# About the Authors

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**September 16 2015**

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# Report Summary

The integration of Natural Range of Variation (NRV) indicators into forest land management in western Canada boreal requires knowledge of wildfire patterns. Towards this effort, fire size research has featured prominently. It has been universally determined that the area disturbed by fires in the western boreal larger than 10,000-hectare size in the western boreal account for 70–90% of the historical area burned. Current NRV guidelines limit the upper size of disturbance events to 3–10,000 hectares to meet other social, economic, and ecological requirements. The gap between NRV and NRV guidelines in this case can potentially create future landscapes that are less diverse, less sustainable, and less resilient than natural landscapes.

In an attempt to overcome this disconnect, this study analysed pre-industrial wildfire patterns over time and space over 60 years and 23 million hectares of northern Saskatchewan using a grid-based system. Wildfire activity was summarized at spatial scales ranging from 10,000 to 100,000-hectare cells, and over a time period of 10 and 20 years. The results suggest that historical disturbance patterns are highly clustered at all time and space scales tested. Even during periods of very high fire activity, a significant number of cells had no disturbance.

There are currently no NRV-based requirements for the distribution of disturbance events over space or time. Considering the relevance of this natural pattern to critical landscape condition metrics such as contiguous areas of intact or old forest, the results from this study could be used in combination with, or as a replacement for fire size metrics as part of an NRV assessment. Moreover, the nature of the results makes it well-suited for not just forest management planning, but fully integrated planning at a strategic level.

# Acknowledgements

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# 1. Introduction

The complexity of the task at hand for land managers and regulators in the boreal has grown considerably over the last 20 years. Today, the list of values for which one is expected to manage includes timber, water, soil productivity, carbon, biodiversity, aesthetics, mining, access, fishing, bitumen, natural gas, hunting and recreation, and habitat for a number of species. The current systems used for planning relies heavily on tools, practices, and policies that attempt to balance these many values. The sheer magnitude of the problem-to-be-solved today makes a value-based planning system increasingly unsuitable (Franklin 1993).

Almost 20 years ago, an alternative management system was proposed that shifted away from value-based approaches. The aptly named ecosystem-based management (EBM) paradigm advocates the management of the system as a whole, as opposed to individual pieces (Grumbine 1994). While EBM is predicated on several key principles, arguably the most central element of EBM is the use of pre-industrial ecosystem patterns as guides for identifying desired future landscape conditions (Hunter 1993). So-called Natural Range of Variation (NRV) requirements are mandated for forest management activities by provincial governments (e.g. OMNR 2001) and international certification agencies (e.g., FSC 2004) and are currently under consideration by the Canadian Boreal Forest Agreement.

In support of this initiative, knowledge of historical ecosystem patterns is necessary. Given that wildfire is the dominant agent of change in western boreal Canada (Johnson 1992), this need has advanced wildfire research efforts in Canada over the last 20 years. Research activities have largely focused on three spatial scales; landscape (e.g. the amount of different seral stages), disturbance event (e.g. fire size and shape), and residual (e.g. the amount and type of within-fire residuals).

Once the research phase is complete, the next step is to translate this new knowledge into a usable form. Although this particular stage of applied science activities has proven to be challenging for natural resource management (Roux et al. 2006), one of the advantages of NRV science is that it is often presented in a form that is already in a readily usable format. For example, percent forest level is both a research outcome and a planning input. So-called coarse-filter indicators are thus by definition already SMART (Specific, Measurable, Achievable, Relevant, and Time-bound).

The final phase of the transition from science to application is the construction one or more rules using the baseline NRV knowledge coupled with the new indicator(s), but also filtered through other social, economic, and ecological considerations. Using filters to define NRV-based requirements is a common practice. However, it raises the question of if, or when, such filters compromise the original intent. For example, very large fires account for most of the area burned in the boreal forest (Johnson 1992). In northern Saskatchewan (one of the few places in Canada with a long fire record and no fire control activities) 86% of the area burned over the last half century is accounted for by fires larger than 8,000 hectares, and 28% of the area burned is created by fires >100,000 hectares (Figure 1).

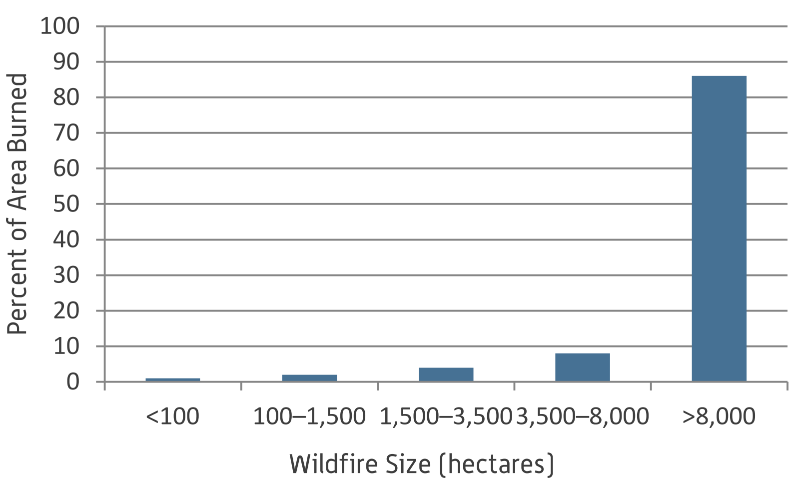


*Figure 1. Historical area burned in northern Saskatchewan by fire size class (1945–2013).*

In contrast to the NRV, the maximum size of disturbance events allowed in boreal Canada is 3–10,000 hectares, depending on the jurisdiction (e.g. OMNR 2001). There are several barriers to creating very large disturbance events. First, this is still an evolving, and to some, an unproven concept, so the social acceptance of very large harvest events is limited. Second, the number of years required to harvest events increases with size, which means the potential for other, negative biological impacts (such as that from long duration roads) increases. Thirdly, in many parts of the boreal, finding enough merchantable forest within reasonable spatial proximity can be challenging (Andison et al. 2015).

The gap between the NRV and the defined upper size limits of event size can be significant. To demonstrate, consider the images in Figure 2. On the left is the outline from a 300,000-hectare wildfire in northern Saskatchewan. On the right is the equivalent disturbed area distributed evenly in 10,000-hectare events—not unlike how NRV guidelines might distribute harvesting today across a landscape. The natural image on the left leaves vast parts of the landscape undisturbed, and demonstrates how boreal landscapes with very high disturbance levels can still have significant area of old forest in larger patches. The disturbance pattern on the right will ultimately create a very different landscape. Andison (1996) found that restricting the maximum size of wildfires to 10,000 hectares on a sub-boreal landscape in British Columbia created significantly less interior forest, higher levels of edge density, smaller (same-aged) patch sizes, less landscape-scale diversity, and smaller old forest patches. In other words, landscape fragmentation from harvesting patterns has not been eliminated; it just now occurs at coarser spatial scales and longer timelines.

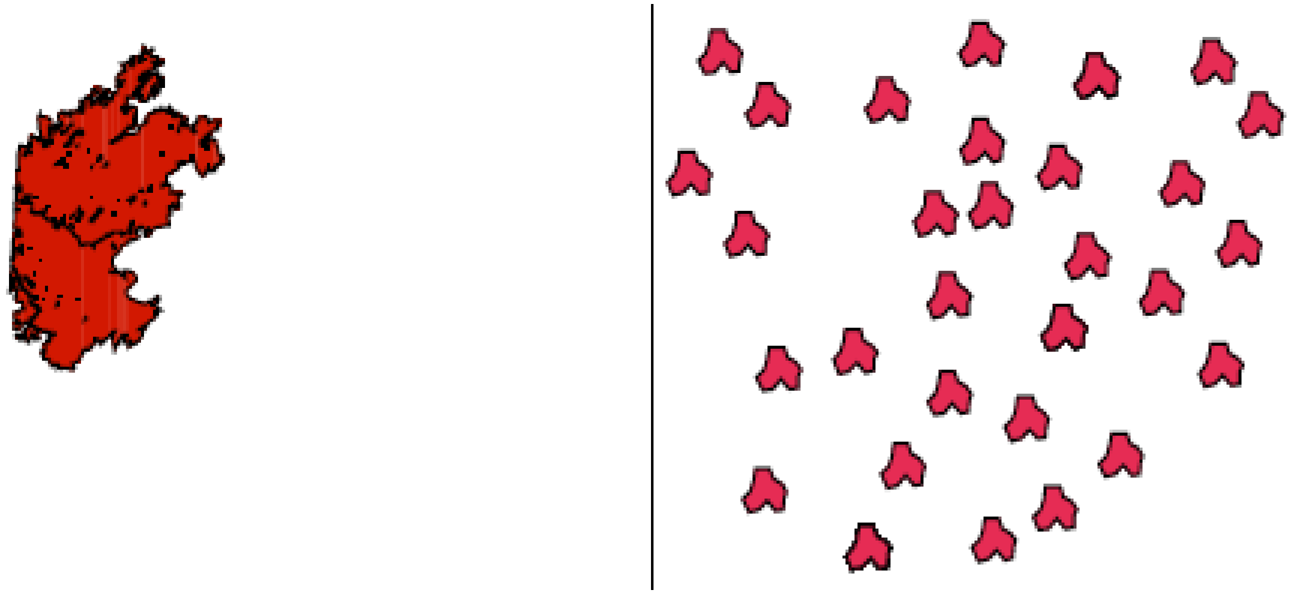

*Figure 2. Comparison of a single 300,000-hectare wildfire (left) with thirty 10,000-hectare disturbance events (right).*

The concern is not the lack of NRV-based science on fire sizes, but rather a disconnect between research needs and the management application. Given the strong role of value-based thresholds as regards event size, the NRV question extends beyond simple fire size to the distribution of disturbance over time and space across a landscape. Towards this critical gap, this study explores pre-industrial disturbance patterns using a time/space grid on a natural western boreal landscape in Saskatchewan. The output has the potential to augment or even replace all (value-adjusted) event size NRV requirements with something more historically and ecologically relevant.

# 2. Goals and Objectives

The time-space array of wildfire activity across boreal landscapes has until now been understood from the perspective of the location and size of individual fires; what parts of the landscape are more (or less) susceptible to burning? Were are fires more likely to ignite and why? Which ones are more likely to grow to size X, and why? Although this type of information is valuable, it does not always translate easily into management guidance. A more practical question for managers seeking to use knowledge of wildfire patterns as management guides might be: How is historical disturbance distributed across a landscape over time and space? This is a much simpler question that can be addressed using historical fire data.

The goal of this study is to understand when and where natural wildfires burn in a more robust format that is can be readily integrated into forest land management.

The objective of this study is to quantify the historical wildfire activity levels at multiple time and space scales using a grid-based system across a western boreal landscape.

# 3. Methods

## 3.1 Study Area

Northern Saskatchewan has not been significantly influenced by fire control activities, has little or no industrial or settlement activities, and fire records extend back to the mid-1940s. Although historical fire records extend further south, I used the boundary between the boreal plains and boreal shield Ecozones to define the study area (Figure 3). The study area includes 23.3 million hectares, including 18.7 million hectares of the boreal shield, and another 4.6 million hectares of the taiga shield. The most distinctive feature of the shield is the high frequency of water and poorly drained areas created by the glacial retreat across surface bedrock. The area is dominated by forests of black spruce, white spruce, jack pine, and balsam fir. Although both areas are influenced by Hudson Bay, the climate is continental.

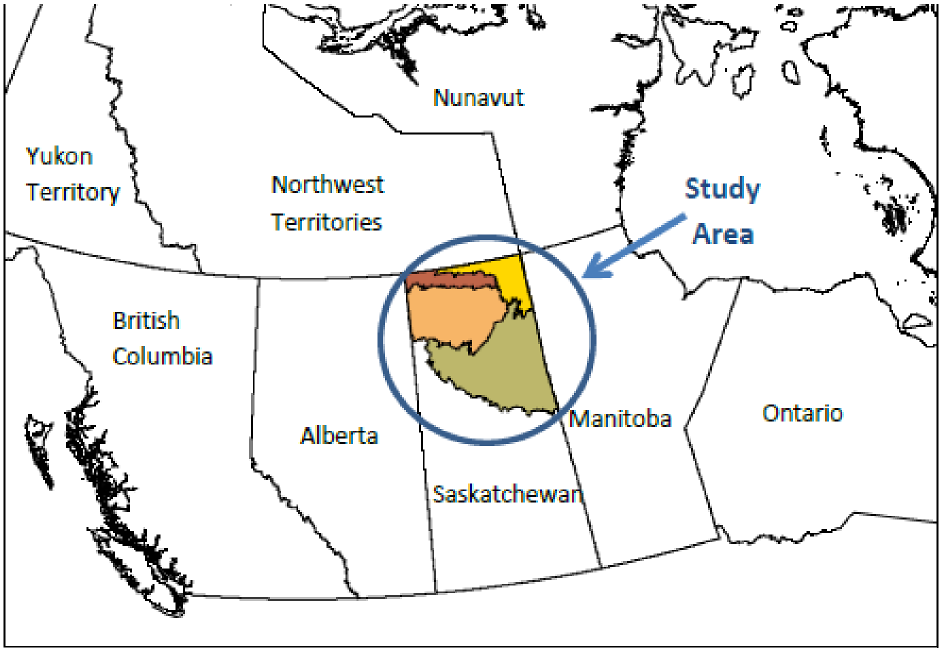


*Figure 3. The study area in northern Saskatchewan includes parts of the boreal shield and taiga shield ecozones.*

## 3.2 Data Preparation

The Saskatchewan wildfire database includes all wildfires recorded by the province since 1945 (MSE 2013). These data were converted into summaries at four spatial scales and two time scales using ArcView 3.2 (ESRI 1999). Four spatial files were created with square grids covering the entire province, one each at 10,000 hectares, 20,000 hectares, 50,000 hectares, and 100,000 hectares. These were applied to the provincial water layer to calculate the area of land in each cell. These four layers were then overlaid on the raw wildfire database. For each grid cell in each of the four new files, the net area burned was calculated for both a 10-year period and a 20-year period starting in 1954. In other words, areas that burn more than once were not counted. The percentage of area burned per time period for each cell was calculated as follows:

% Area Burned = Net Area Burned / Land Area X 100

The resulting spatial files were then clipped to the provincial boundary and the border between the boreal shield and boreal plains. Ecozones with less than 50% of their area in the boreal shield and any cells smaller than 10% of the respective maximum cell sizes were eliminated. This process created six space-time wildfire summaries for the ten year periods, and three for the 20-year periods for a total of 36 summary options (Table 1). Also calculated for each time-space option was the associated average fire cycle (sensu Johnson 1992). An example of the spatial files created for the 10,000-hectare cell, 20-year period are shown in Figure 4 (the shaded area of Table 1).

*Table 1. Summary of the cell sizes and time periods used to summarize historical wildfire data in northeastern Saskatchewan. Average fire cycle for each time-space option is shown in brackets.*

| Cell Size (hectares) | Measurement Period (Fire Cycle) | |
|---|---|---|
| | 10 years | 20 years |
| 10,000 | 1954-1963 (224 years)<br>1964-1973 (102 years)<br>1974-1983 (57 years)<br>1984-1993 (128 years)<br>1994-2003 (66 years)<br>2004-2013 (41 years) | 1954-1973 (141 years)<br>1974-1993 (79 years)<br>1994-2013 (52 years) |
| 20,000 | 1954-1963 (216 years)<br>1964-1973 (99 years)<br>1974-1983 (55 years)<br>1984-1993 (124 years)<br>1994-2003 (67 years)<br>2004-2013 (41 years) | 1954-1973 (139 years)<br>1974-1993 (77 years)<br>1994-2013 (52 years) |
| 50,000 | 1954-1963 (222 years)<br>1964-1973 (101 years)<br>1974-1983 (54 years)<br>1984-1993 (123 years)<br>1994-2003 (67 years)<br>2004-2013 (41 years) | 1954-1973 (140 years)<br>1974-1993 (76 years)<br>1994-2013 (52 years) |
| 100,000 | 1954-1963 (224 years)<br>1964-1973 (102 years)<br>1974-1983 (57 years)<br>1984-1993 (128 years)<br>1994-2003 (66 years)<br>2004-2013 (41 years) | 1954-1973 (141 years)<br>1974-1993 (79 years)<br>1994-2013 (52 years) |

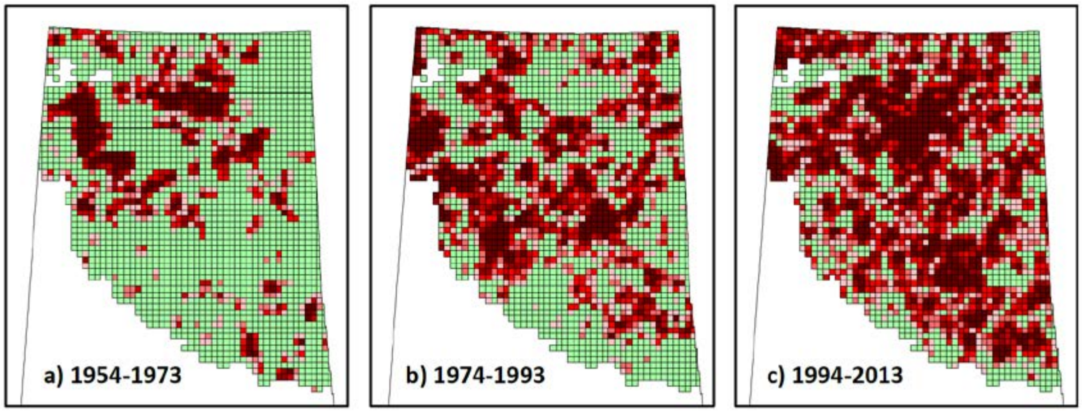


*Figure 4. Historical fire occurrence for northern Saskatchewan using a 10,000-hectare grid over 20 years. Green cells have no disturbance, and darker shades of red signify increasing proportions of disturbance.*

## 3.3 Analyses

The 36 spatial files created as described above calculate the (net) percent area of each cell that is disturbed. The percentages of cell disturbance were summarized as frequency distributions for each of the 36 space-time options. While each of these 36 summaries represents historical conditions, they also represent different historical time-space scenarios in terms of overall fire activity. The average fire cycle for the study area over the 60-year span of the data was 75 years. However, fire frequency varied from 41 years to 224 years across the 36 time-space summary options in Table 1. It is reasonable to presume that fire frequency will influence the spatial distribution of wildfire activity. For example, the proportion of cells of size (X) over (Y) years that is undisturbed will decrease as the total area disturbed during any given period increases.

To account for the influence of disturbance frequency on the spatial distribution of fire activity, the results were further grouped according to three fire cycle classes: Short (40–60 years); Medium (70–100 years), and Long (120 years+). Note that the names chosen only reflect the relative relationship to the longer-term average fire cycle of 75 years. This classification allowed the 24 10-year options to be collapsed into 12 by averaging the relevant frequency distributions. Note that this also conveniently allows the results from the 10-year options to be comparable to those from the 20-year options. The resulting 24 frequency distributions are presented here. I also calculated the proportion of the cells in each of the 24 time-space options with no disturbance, and those with >60% disturbance.

# 4. Results

## 4.1 Frequency Distributions

Cell size, disturbance period, and disturbance frequency were all significant factors in determining the spatial distribution of wildfire activity. Fire frequency was inversely related to the frequency of cells with unburned forest. For example, 77% of 10,000-hectare cells were undisturbed over a 10-year period under a Long fire cycle assumption compared to 64% for a Medium assumption, and just 47% for a Short (Figure 5A). There was also a corresponding increase in the number of cells with high levels of disturbance. Using the same 10-year 10,000-hectare options used above, the proportion of cells in which >80% of the area was burned increased from 2% for the Short fire cycle option, to 5% for the Medium option, to 11% for the Long option. This relationship held for all time-space options tested.

Cell size also influenced the distribution of disturbance. As one moves down the two columns in Figure 5, the frequency distributions shifted from being dominated by the extremes (at the top), towards an increasingly central tendency (at the bottom). For example, using a 20-year period and the Medium fire cycle option as a baseline, the percentage of cells with 20–80% disturbance increased from 27% for 10,000-hectare cells to 43% for 50,000-hectare cells (Figure 5B and H). If this analysis included larger cell sizes, this centralizing trend would be more evident.

Time-period was also significantly related to historical fire activity. As one would expect, longer time periods were associated with higher levels of disturbance and lower proportions of undisturbed cells. This relationship was evident in the shift to the right in the frequency distributions as one goes across the four rows in Figure 5. For example, under a Medium fire cycle scenario, the proportion of cells in which <10% is disturbed decreased from 72% for 10,000-hectare cells to 48% for 20,000-hectare cells (Figure 5C and D).

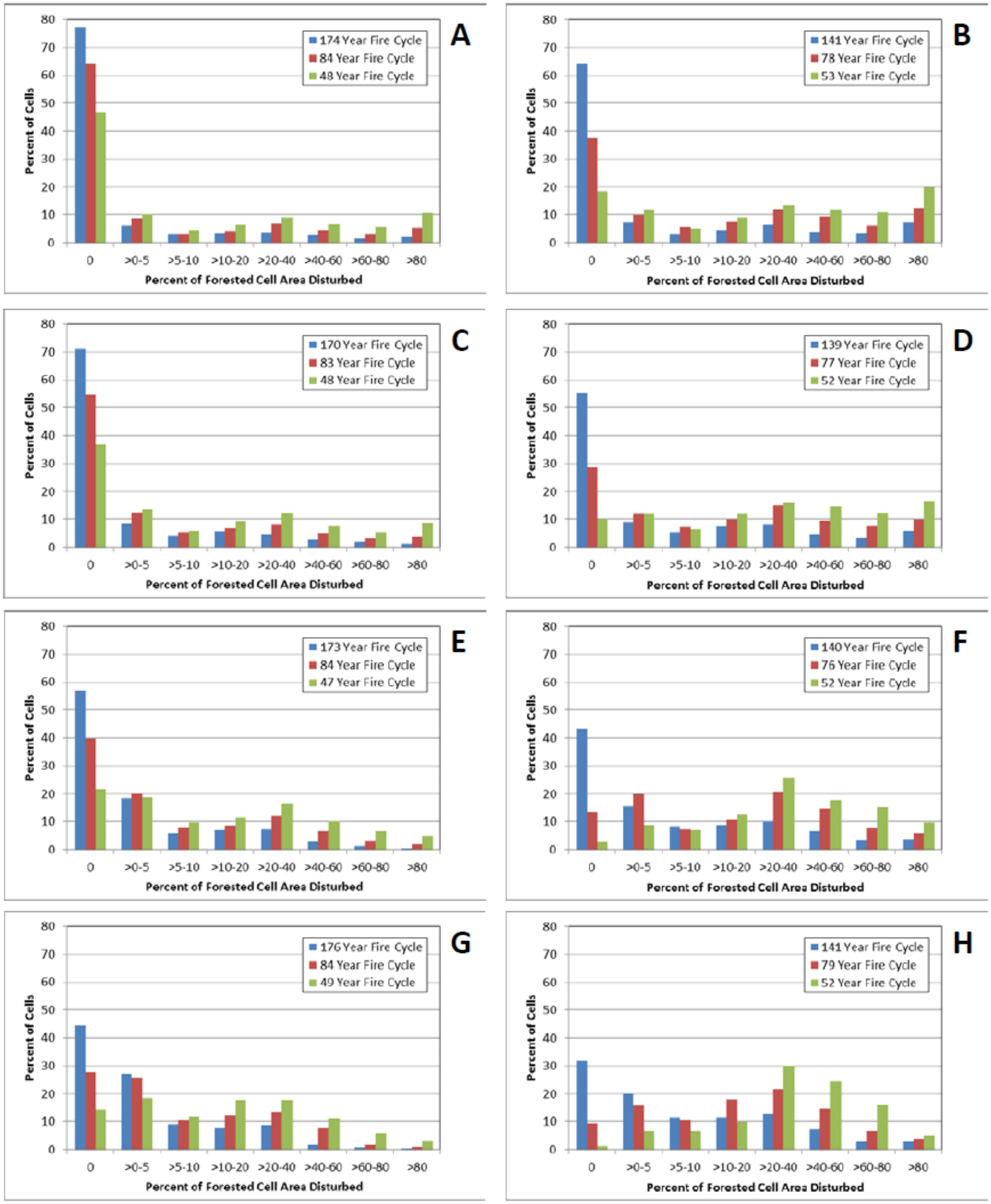


*Figure 5. Frequency distribution of the historical percentage of net area disturbed by wildfire per cell, per time period for northern Saskatchewan. Eight main scenarios, each with three different associated fire cycles: A—10,000-hectare cells captured over 10 years. B— 10,000-hectare cells captured over 20 years. C—20,000-hectare cells over 10 years. D—20,000-hectare cells over 20 years. E—50,000-hectare cells over 10 years. F—50,000-hectare cells over 20 years. G—100,000-hectare cells over 10 years. H—100,000-hectare cells over 20 years.*

## 4.2 Capturing the Extremes

As a reminder, the two extremes of wildfire behaviour tested in this study were the proportion of cells in each of the 24 time-space options with a) no disturbance, and b) high levels of disturbance (using >60% disturbed as an indicator).

The proportion of cells with no disturbance ranged from 1–77%. Higher proportions of cells with no disturbance are associated with longer fire cycles, shorter time periods, and smaller cell sizes. For example, the proportion of cells under a 10,000-hectare cell, 10-year period, and a Long fire cycle is 77%, compared to 47% using 10,000-hectare cells, a 10-year period, and a Short fire cycle, and just 18% for 10,000-hectare cells, a 20-year period, and a Short fire cycle (Figure 6). The shading shown in Figure 6 is in 25% increments.

| Cell Size (ha) | Fire Cycle (yrs) | Measurement Period | |
|---|---|---|---|
| | | 10 Years | 20 Years |
| 10,000 | Long | 77 | 64 |
| | Medium | 64 | 37 |
| | Short | 47 | 18 |
| 20,000 | Long | 71 | 56 |
| | Medium | 55 | 28 |
| | Short | 37 | 10 |
| 50,000 | Long | 57 | 43 |
| | Medium | 40 | 13 |
| | Short | 22 | 3 |
| 100,000 | Long | 44 | 32 |
| | Medium | 28 | 9 |
| | Short | 14 | 1 |

*Figure 6. Percentage of cells of northern Saskatchewan wildfire data with no disturbance. By cell size, fire cycle, and period.*

| Cell Size (ha) | Fire Cycle (yrs) | Measurement Period | |
|---|---|---|---|
| | | 10 Years | 20 Years |
| 10,000 | Long | 4 | 11 |
| | Medium | 8 | 19 |
| | Short | 16 | 31 |
| 20,000 | Long | 3 | 9 |
| | Medium | 7 | 18 |
| | Short | 14 | 29 |
| 50,000 | Long | 2 | 7 |
| | Medium | 5 | 14 |
| | Short | 12 | 25 |
| 100,000 | Long | 1 | 6 |
| | Medium | 3 | 10 |
| | Short | 9 | 21 |

*Figure 7. Percentage of cells of northern Saskatchewan wildfire data with high (i.e., >60%) disturbance. By cell size, fire cycle, and period.*

The proportion of cells that have high (i.e., >60%) levels of disturbance are somewhat more complicated to interpret. As cell size increases, the proportion of cells with very high disturbance levels decreases, because the influence of very large fires diminishes. For example, 31% of the cells in the 10,000-hectare / 20 year / Short fire cycle scenario had >60% disturbance, compared to only 21% for the 100,000-hectare / 20 year / Short fire cycle scenario (Figure 7). However, as fire cycle shortened and the measurement period increased, the probability of disturbance increased, which created more cells with high disturbance levels.

# 5. Discussion

## 5.1 Overview

There are many ways of interpreting historical wildfire data depending on the question(s). Past efforts have used similar historical data to further our understanding of how and why fire activity varies across large landscapes (Heyerdahl et al. 2001, Parisien and Moritz 2009), the critical role of very large events (Dale et al. 1998), and the influence of human interference (Parisien et al. 2011). The question in this case was whether it was possible to create a practical alternative for capturing the distribution of natural wildfires over time and space that is representative of NRV. This question is more pattern-based than most fire research, and would not be necessary if not for the truncation of historical disturbance event sizes in forest management NRV applications. However, the findings from different methods are largely saying the same thing, just in different ways: natural boreal wildfire activity is highly clustered in time and space, regardless of the time period and cell-size used. In this case, higher levels of disturbance clustering occurred with smaller cell sizes, shorter fire cycles, and shorter timelines. This is almost certainly a direct result of the prominent influence of very large wildfires.

## 5.2 Management Implications

NRV strategies work best when pre-industrial patterns align closely with that which is desirable or possible from a management perspective. An example of a successful alignment in the western boreal is old forest levels. Allowable harvesting levels in Alberta have been linked to the predicted forest growth levels for many decades. In other cases, the observed pre-industrial patterns are adjusted to suit the needs of other values. For example, in some areas the amount of old forest may be adjusted upwards over concerns of woodland caribou habitat.

The objective of ecosystem-based approaches is not to emulate Mother Nature, but rather to use natural patterns as guides. Adjusting NRV output to suit management needs is consistent with this idea. However, is there a point at which an NRV-inspired range ceases to be consistent with the spirit and intent of an ecosystem-based approach? A related challenge is, when NRV estimates are compromised by other needs and wants, to what degree are the purported biological consequences compromised? The results from this study suggest that boreal wildfire activity clusters over both time and space at scales well beyond the 3–10,000-hectare upper limit that many NRV guidelines propose today. To the second challenge, we have evidence that future landscape conditions managed to these artificial limits will deviate from historical conditions, although we lack specific evidence that this will, or in what way this will reflect lower levels of sustainability or resilience.

The results from this study offer an alternative method of presenting fire size and location data that potentially bypasses the biological risks of adjusting NRV for social or economic purposes without violating existing policies and practices. The grid-based system described here encourages clustered disturbance activities within target cells. Whether that disturbance is distributed in one or several different disturbance events is irrelevant. Thus, event size restrictions can still be respected; overlaying the grid system would just cluster disturbance events into a small number of locations.

Another practical advantage of a series of grid-based results of fire activity is that it decouples the pattern (of wildfire) from the underlying process(es). Expressed in this way, there is no “correct” time or space scales at which to manage disturbance patterns—and forest management planning need not adjust to new scales. The eight different time-space summary options tested here were designed to represent eight practical planning and management application options. The choice of which combination is most relevant can be determined based on the landscape and the planning needs. Detailed spatially-explicit operational harvesting plans typically involve areas between 10–20,000 hectares, and more general spatial planning is now occurring in the 50–100,000-hectare range. The 10- and 20-year timelines used in this study represent disturbance durations, which refer to the length of time that the disturbance lasts. Although the duration of wildfires is typically days to weeks, cultural activities such as harvesting often take several years. This is one of translation challenges between NRV and CRV: At what point do we consider adjacent disturbance activities to be a part of the same event in time? In general, most boreal jurisdictions use 10–20 years.

Figure 5 is thus not just a summary of natural patterns, but also a benchmark for comparing existing and future disturbance activities to those that have occurred historically. The inclusion of different fire cycle options expands its applicability to other parts of the boreal. The results as presented here are already in the form of SMART indicators, and Figure 5 provides the NRV.

Applying this new knowledge involves making the same calculations for past, current, or future landscapes of interest. For example, Figure 8 shows the frequency distribution of the proportion of (10,000-hectare, 10-year time period) cell area that was disturbed on a 330,000-hectare landscape in northeastern Alberta relative to NRV. The comparison reveals that industrial disturbance activities are far more omnipresent than disturbance from pre-industrial wildfires (Andison et al. 2015). Disturbance levels were only one of the cells on the Alberta landscape in this study had less than 1% disturbance, or more than 32%. In contrast, the average pre-industrial landscape had almost 30% of its cells undisturbed, and 43% of all cells were greater than 32% disturbed (Figure 8). These results suggest that cultural disturbance activities on this particular landscape were not sufficiently clustered.

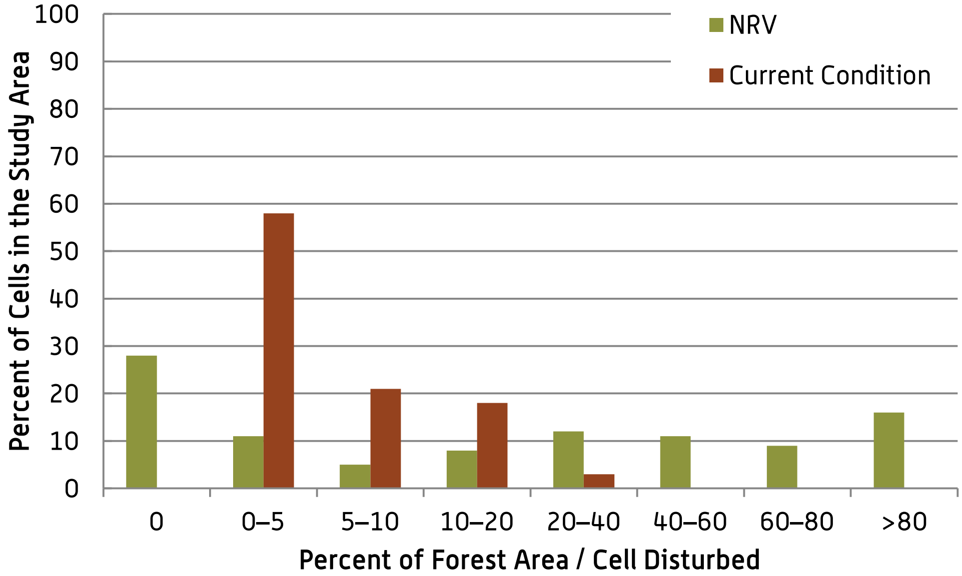


*Figure 8. Frequency distribution of the proportion of cell area that burned historically in northern Saskatchewan (NRV) compared to the current condition for a landscape in northeastern Alberta based on 10,000-hectare and 10-year time period (from Andison et al. 2015).*

## 5.3 WHERE, WYN, and When Does Disturbance Occur?

Figures 6 and 7 are particularly relevant as regards comparisons of NRV with current conditions. Figure 7 represents the highest possible level of clustering of disturbance (which corresponds to harvesting, road building, well-site development and installation, etc.). I refer to these cells as WHEREs, in reference to where disturbance activities are most concentrated. The 60% threshold was an estimate of the likely maximum amount of merchantable boreal forest within a given cell at any one time (but this threshold could easily be changed to reflect local conditions or needs).

Figure 6 captures those parts of the landscape that are entirely un-disturbed during a given time period, and represent Where You and Not (called WYNs). WYNs are important because some of them are potential future old forest habitat. Old forest fragmentation is typically blamed on roads and harvesting patterns, but this suggests that the issue is not necessarily the amount and type of disturbance, but how it is distributed in space. An insufficient supply of WYNs is a likely cause of old forest fragmentation—although on larger spatial scales than we typically use to describe this phenomenon.

The balance of WHEREs to WYNs are related; the more WHEREs you have, the greater the opportunity for WYNs. The application of the NRV WHERE-WYN numbers presented in Tables 6–7 are shown in Figure 9 for the 10,000-hectare cell size for the northern Saskatchewan wildfire data between 1974–1993, which corresponds to a fairly representative long-run fire cycle average for this area of 78 years. The WHEREs are shown in red, and cover 19% of the landscape, and the WYNs (in green) cover 37% of the area. The remaining 42% of the cells experienced low to intermediate levels of disturbance. In contrast, all of the 10,000-hectare cells in the landscape from northeastern BC used for Figure 8 would be grey; with no red or green.

The balance of WHEREs to WYNs across a landscape at any given time and at a given scale, may be a key (and until now) missing measure of biodiversity and landscape health. Linear feature restoration notwithstanding, large, old, or intact forest patches cannot be created, they must be allowed to occur. A landscape with few or no WYNs is unlikely to ever have large contiguous patches of any forest type(s), and WYNs are difficult to create without having WHEREs. None of the current NRV-based guidelines include indicators or requirements on how disturbance events are to be distributed over space and time.

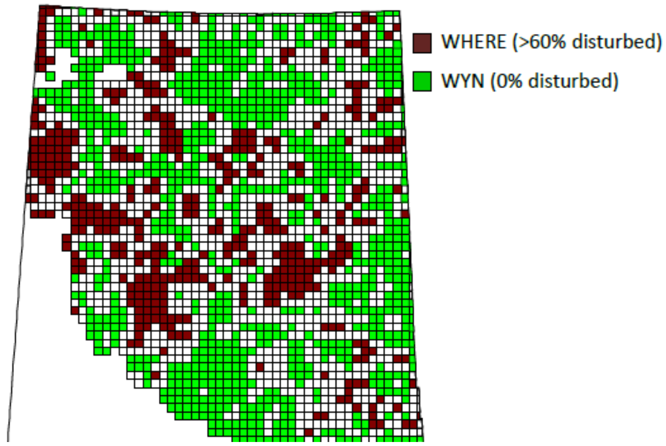


*Figure 9. Application of the WHERE-WYN rules to northern Saskatchewan between 1974–1993 using a 10,000-hectare grid.*

## 5.4 Applicability of the Results

### 5.4.1 What landscapes and where?

With some caveats, I propose the results of this study could apply to any landscape, of any size, in western boreal Canada. The burning patterns presented here are based on northern Saskatchewan because it is the largest part of western boreal Canada with several decades of well documented uncontrolled wildfire activity. However, the analyses were specifically designed to be more generic to make the results more widely applicable. First, the results were standardized to the area of land in each cell, thus eliminating the influence of non-vegetated areas such as water. The results were also summarized under a range of fire cycle assumptions. In western boreal Canada, there are few, if any, reports, manuscripts, or internal studies that suggest historical long-term fire cycle averages of less than 40 years, or greater than 170 years. I would also argue that the grid results are largely a reflection of the natural fire size distribution, regardless of landscape composition, eco-zone, or location. Fire size is strongly linked to fire frequency (e.g. Johnson 1992), which is already accounted for in the output. In any case, there is no evidence to suggest that the fire size distribution of northern Saskatchewan is significantly different than any other (pre-industrial) western boreal landscape.

On the other hand, any extrapolation of NRV results from one landscape to another is always risky, and the risk increases as one moves further away from the study area. The most obvious solution is to repeat this analysis on other large boreal landscapes across Canada. Northern Manitoba, Ontario, and Quebec, and much of the NWT are obvious candidates. It is also possible to apply the results as general guides as opposed to specific thresholds. The WHERE-WYN summaries are an example of more general natural patterns, the principles of which are more likely to be universally applicable.

### 5.4.2 What activities?

The most obvious application of the results of this study is forest harvest planning. Given the temporal and spatial scales involved, integrating the allocation of WHEREs and WYNs (for example) should occur as part of strategic planning. Right now, planning harvest activities usually occurs only in general terms over time and space 10–20 years into the future, so it is an appropriate match. Whether some form of a grid-based distribution of activities (and non-activities) replaces, or is used in combination with current disturbance size requirements depends on the circumstances. In areas where NRV on fire size is lacking or of questionable quality, a grid-based approach may be used in lieu of disturbance size requirements. A grid-based approach could be blended with existing disturbance size requirements on landscapes where there are concerns over the distribution of past and future industrial activities, or where desired future landscapes include larger areas of intact or older forest.

A potentially more powerful application of these results is as a cumulative planning tool at the strategic level. The ideal planning model for managing complex systems is hierarchical, which means planning is partitioned into logical stages that progress from very general guidance, often offered in the form of a narrative, to highly technical details of individual activities (Andison 2003). In most jurisdictions, there is a notable gap in this hierarchy between land use plans (associated with the general form of guidance), and the strategic plans of individual natural resource management companies / agencies (which is the point of first-contact for specific management activities). The gap in this case is that there is no mechanism for coordinating the activities from different management agencies in time or space. This challenge is only exacerbated by the facts thatnot all jurisdictions have land use plans, and not all natural resource management agencies are required to do strategic planning. The (largely negative) ecological result of many overlapping uncoordinated plans on the same landscape is commonly referred to as cumulative effects. Eliminating and/or mitigating the impacts of cumulative effects has become one of the goals of land use plans in the boreal (e.g. GoA 2008).

The WHERE-WYN system proposed here potentially offers a solution to this planning gap: a mechanism for integrating all disturbance activities on a sub-land-use level. For example, Andison et al. (2015) created and tested a planning approach for all industrial-based activities based on the WHERE-WYN model using spatial scenario modelling for the northeastern Alberta landscape noted in Figure 8. The WHERE-WYN plan created twice as much area in large old forest patches and created 75% less disturbance edge compared to the existing management approach. These are dramatic improvements over the status quo in just 20 years, and suggest that the potential exists for a landscape planning approach based on the WHERE-WYN concept to not only arrest, but reverse the impacts of cumulative effects. However, if, or to what degree jurisdictions are willing and able to do fully integrated planning on a strategic scale (regardless of the planning approach) is unknown.

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