Natural Levels of Forest Age-class Variability on the Alberta-Pacific FMA

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BANDALOOP

LANDSCAPE-ECOSYSTEM SERVICES

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A report prepared for Alberta-Pacific Forest Industries

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EXECUTIVE SUMMARY

Alberta-Pacific has placed a high priority on managing old forest values on its' FMA. Towards this, they required a means of establishing an ecologically defendable foundation for establishing long-term old forest objectives over coarse scales. This information can then be used as a starting point for establishing robust old forest objectives that include other ecological, social, and economic considerations. Unfortunately, attaining knowledge of historic levels of old forest empirically is challenging, if not impossible, due to the difficulties of observing historical landscape conditions. As an alternative, this study explores historical patterns of seral-stage variation over time through a computer model simulation exercise.

The main objective of this project was to estimate the nature of the range of the proportions of various seral-stages across the Al-Pac FMA over time. The landscape disturbance simulation model LANDMINE was used to generate 50 possible landscape "snapshots" based on empirically-derived historical burn rates and sizes. For simplicity, the model assumptions and input were kept very simple, very broad classes of age and forest cover-class were imposed, resolution was low (4 ha), and only non-spatial output was recorded. The only model input open to debate was the historic level of fire activity, represented by the average "fire cycle". Based on a) Al-Pac inventory age data, b) fire cycle estimates from adjacent Mistik Management FMA in Saskatchewan, c) the scarcity of stand ages over 200 years, d) the dominance of aspen, and the absence of abies, and e) highly complex recent fire patterns from an adjacent Saskatchewan landscape, my own estimate of the historical fire cycle for the Al-Pac FMA is 40-60 years. Other experts felt the average historical fire cycle was longer. Al-Pac dealt with this issue by having two sets of model runs completed at two different fire cycle averages; 60 years and 80 years. This tests how sensitive old growth levels are to different levels of burning. Both sets of output are presented.

The most important attribute of the results is the high amount of variation demonstrated by *all* seral-stages – including the oldest, or "overmature" seral-stage. In each of the five major cover-classes, the percentage of overmature forest is best expressed as a distribution – averages are largely meaningless. In other words, there is no single representative level of overmature forest for each of the five cover-types, but rather a wide range of possibilities. This is typical of "natural range of variation" (NRV) forest patterns.

Since the data are presented as percentages of the total area in each cover-type, the levels of overmature forest can be compared directly between cover-types. From the model runs using an average 80 year fire cycle, the greatest amount of overmature forest occurs in hardwood dominated types (14-42%) closely followed by mixedwood-dominated (16-38%) and pine-dominated forest (16-36%). The least amount of overmature forest historically occurs in white and black spruce (10-34% and 12-28% respectively). These trends are consistent with what we know about the relative levels of flammability of each cover-type, as well as the age limits defined for "overmature" forest. Pine, aspen, and mixedwood stands are "overmature" once they are beyond 100 years of age, while for black and white spruce the lower age limit for "overmature" is 120 years. The fact that these trends are logically consistent is encouraging. It suggests that the model output is at least representing relative levels of disturbance accurately.

The model runs using the 80-year average fire cycle assumptions resulted in an average of between 3-6% more overmature forest compared to the model runs using the 60-year average fire cycle. This may seem insignificant at first glance, but consider that 4% of the forested portion of the FMA (which is not necessarily either the *merchantable*, or *productive* portions) is about 21,000 hectares. The corresponding decrease in the levels of young forest between a 60-year and 80-year fire cycle, on average, is 3-8%, or about 26,000 hectares. In other words, the level of disturbance necessary to achieve 80-year fire cycle levels of overmature forest is quite a bit lower than that of 60-year fire cycles.

Overall, these analyses will prove valuable input for long-term, coarse-scale planning. Until now, estimates of historical overmature forest levels were static and based on weak data. Now Al-Pac at least has estimates of dynamic ranges of overmature forest, based on a very simple series of assumptions projected over time and space. In addition, the sensitivity analysis (between the two fire cycle assumptions) revealed the cost of assuming a longer historical fire cycle in hard numbers, which can be weighed against natural disturbance risks, economics, and social acceptance. Furthermore, the output can be incorporated directly into long-term management planning. In other words, Al-Pac now has a mechanism to understand how applying management practices to a landscape compare with historical, "natural" ranges. This is a significant step beyond the more traditional method of subjectively choosing minimal or maximum levels of different seral-stages in long-term planning, and represents a dramatic improvement in the degree to which such planning can incorporate more “natural” patterns at the very broadest scales of planning.

Aside from the ecological and evolutionary advantages of deliberately imposing familiar levels of vegetation change over large areas, there are other benefits. Managing for a range of age-class percentages allows for more flexible, integrated management planning. The ranges can also be used directly as targets for monitoring programs.

DISCLAIMER

The views, conclusions, and recommendations in this report are those of the author and do not necessarily imply endorsement by Alberta-Pacific Forest Industries Ltd.

It is the intention of the author to publish the results of this report in a refereed journal.

INTRODUCTION

The evolution of forest management in North America has been an ongoing process, but one that has inevitably been moving towards the means of sustaining all forest values. Forest management is now expected to manage for a wide range of biological values including water and nutrient conservation, toxin filtration, carbon cycling, fish and wildlife habitat, food, pharmaceuticals, and timber (Davis 1993).

Under the auspices of this task, the concept of emulation or the approximation of forest patterns created by natural processes, is gaining favour in North America (Franklin 1993). The theory is certainly attractive: by maintaining the type, frequency, and pattern of change on a given landscape, we are more likely to sustain all biological values therein. So-called “coarse-filter” knowledge can also be applied directly and immediately to planning and management programs.

Natural pattern knowledge can be applied to a wide range of forest management planning issues, at virtually all levels of planning. Alberta-Pacific was one of the first forest management companies in western Canada to develop operator guidelines for residual material, and has more recently been using natural stand boundaries to guide block layout. However, they have incorporated little or nothing of natural patterns at coarser scales of planning. During the development of their second long-term forest management plan, there is now an ideal opportunity to investigate and consider incorporating natural patterns at very broad scales.

The most critical coarse-scale issue for Al-Pac is defining ecologically defendable levels of old forest. This is not particularly surprising given that old forest is both a value unto itself, as well as a coarse-filter indicator of habitat for many species.

Unfortunately, quantifying the historical levels of old forest in an area like the Al-Pac FMA is challenging. First, the effects of harvesting, fire control, and other cultural activities negates the possibility of using the current landscape to characterize natural conditions. Even if it were, it would still only represent one of many historical landscape “snapshots”. What we do know about the disturbance history of these types of landscapes suggests that they are highly dynamic, and the age-class distribution from one time to another can vary widely (Romme 1982, Turner and Dale 1991, Payette 1993). As Baker (1989) and Cumming et al. (1996) demonstrated, average age-class conditions on boreal-type forest landscapes are extremely difficult to observe over large areas, and as Andison (1998) suggests, percentages of different seral-stages have historically fluctuated widely. This means that historical levels of old forest will be equally variable over time, so a single snapshot in time is of limited value to us.

The objective of this study is to generate a number of landscape snapshot possibilities on the Al-Pac FMA using available fire history data, and a stochastic landscape simulation model. The output could be used to represent the historical natural range of overmature forest, mature forest, immature forest, and young forest, which can then be compared to long-term plan projections.

STUDY AREA

The Alberta-Pacific Forest Management Area covers approximately 6.87 million hectares of land, of which approximately 5.2 million hectares is forested (although not necessarily “productive”). The remaining land includes embedded “donuts” of forest not administered by Al-Pac, plus a mixture of water, bog, fen, brush, and grassland. Black spruce, aspen, and jack pine dominate the forested portion of the landscape, with a minor component of white spruce. Topography is flat to gently rolling. All but a small northern portion of the FMA is in the boreal plain eco-region.

The coarse-scale pattern of age-class across the study area is largely a function of the disturbance regime. The most common disturbance event on this landscape is stand-replacing forest fires, but incidents of insect and disease outbreaks, flooding and wind events also occur.

METHODS

Several steps are involved in estimating the natural range of different forest age-classes on the Al-Pac FMA. Each is outlined below.

A) THE MODEL

LANDMINE is a spatially explicit, Monte-Carlo landscape simulation model that was developed for landscapes dominated by stand-replacing disturbance events. LANDMINE uses a dispersal algorithm to spread fires from one pixel to another in such a way that fire movement responds probabilistically to various input layers such as fuel-type, topography, even wind. Fire movement thus favours uphill movement, older forest, higher percentages of conifer, or prevailing winds, and so on. Controlling layers can be added or removed depending on available data. The nature of the fire movement can also be calibrated to create different fire shapes and residual numbers, sizes, and locations to match empirical data as available. Fire size is controlled by an equation that represents the actual fire size distribution for each landscape. Ignition location probabilities can also be calibrated – usually using historical lightning probabilities. Finally, the total amount of forest burnt in any single time step (20 years in this case) is established through another equation describing the historical areas burnt. Each of these steps is stochastic, meaning that LANDMINE never burns the same way twice. However, over the long term it is consistent with internally defined probabilities. Clarke et al. (1993) also demonstrated that this method of growing disturbances created fractal images, meaning that the model could use spatial data at any scale of resolution. Finally, a set of self-defined rules governs successional pathways deterministically depending on stand composition and age.

Overall, LANDMINE is thus a powerful landscape disturbance model (i.e., it is good for exploring long-term burning trends over space and time), but not necessarily a good fire behaviour model (i.e., it is not very good at predicting individual fire events). LANDMINE was developed in 1996 (Andison 1996), and has since been used on the Weldwood FMA (Andison 1998), the Alberta Newsprint FMA, and the Prince George TSA (Andison and Marshall 1999). It is currently being calibrated and prepared for use on the Sunpine FMA in Alberta, and part of the north-eastern region of Alberta.

B) MODEL ASSUMPTIONS

Since the modelling objective is a very general one, LANDMINE was run with minimal rules and assumptions. No topography was included; ignition probability was spatially random, very broad seral-stage and cover-type classes were adopted, and succession rules were turned off. In other words, the stand composition of each pixel never changes, only the stand age. This is obviously not realistic from a local perspective (*i.e.*, site-level shifts in species composition is common), but is a safe assumption from a landscape perspective (*i.e.*, the site-level shifts in species composition will more or less balance out across the entire FMA). For those pixels that are not disturbed for long periods of time, the estimated age at which such stands “break up” was included in the model rules. For mixedwood and hardwood stands, the maximum allowable age was 200 years, and for spruce and pine stands, the maximum age was 250 years. Considering that few, if any, Alberta Vegetation Inventory (AVI) stands on the Al-Pac FMA exceed these ages, this is likely a conservative assumption. It should be noted that the classes for seral-stages and cover-types, and the way in which LANDMINE deals with succession, were adopted directly from the rules that Al-Pac used for their timber supply analysis – which this work is meant to dovetail with (see details below).

Another simplifying assumption made for the model was that the Al-Pac FMA represents a single major fire regime. Since the FMA is dominated by a single ecological zone, and there is little empirical evidence to suggest that historical fire behaviour differs significantly from east to west or north to south, this also seems a fairly safe assumption. Certainly there will be some variation in ignition probability or climate conditions, but likely not significant enough to affect overall patterns of burning. Similarly, while it is possible to argue with most of these assumptions in the details, the point is that for the purposes of a very coarse-level simulation exercise that will only be generating non-spatial output, they are not relevant, and therefore extraneous.

C) MODEL INPUT DATA

Since these runs are meant to represent “natural” conditions, it was necessary to create natural forest conditions. This was done by assigning any culturally modified polygons the age and cover-type attributes of the adjacent polygon with the greatest length shared boundary. In some cases, the attributes of the previous features were available and used directly. Thus, all roads, cutblocks, mines, and other developments were replaced by attributes of the last known, or the most likely last existing, polygon.

This “natural” inventory polygon layer was then converted to raster format using 4 ha pixels. The inventory data was then used to define one of five forest cover-classes as follows:

- White spruce (Sw) = at least 80% Sw.
- Black spruce (Sb) = at least 80% Sb.
- Jack pine (Pj) = at least 80% Pj.
- Hardwood (Hdwd) = at least 80% hardwood.
- Mixedwood (Mix) = everything else.

Note that if a polygon had a leading tree species, it could be modelled regardless of whether or not it was productive forest. Non-forested land was included in the actual spatial modelling, but not tracked and summarized for the output.

Inventory age data was used to define four broad “seral” stages of stand development (consistent with the rules used by Al-Pac for other analysis) for each of the five forest cover-classes above as follows:

- Young = <20 yrs. for Pj, Sw, and Sb, and <10 yrs for Mix and Hdwd.
- Immature = 21-60 yrs for Pj, 21-70 yrs for Sb and Sw, and 11-60 yrs for Mix and Hdwd.
- Mature = 61-100 yrs for Pj, Mix and Hdwd, and 71-120 yrs for Sb and Sw.
- Overmature = >100 yrs for Pj, Mix and Hdwd, and >120 yrs for Sb and Sw.

It is important to keep in mind that the age breaks are meant to represent stages of stand development, and reflect the major tree species attributes such as tolerance to competition and light, growth rates, and senescence rates and causes. For example, spruce grows more slowly, is less light tolerant, less prone to disease, and lives much longer than aspen, and thus takes longer to reach the "overmature" stage of stand development where individual tree deaths are causing gaps, large woody debris, and a complex vertical structure.

The use of only a few, broad classes for both vegetation and age are appropriate for the intended broad-scale objectives of the exercise. It also means relying far less on the accuracy and precision of the forest inventory. The number and the boundaries of the classes were designed to match those used by Al-Pac for other broad-scale analysis.

D) MODEL CALIBRATION

The two most important pieces of model input are the sizes of fires, and the frequency of burning. Fire sizes are less important in this case because we are only interested in non-spatial output from the model. In any case, the provincial historical fire database, and knowledge of fire sizes from an adjacent FMA in Saskatchewan were used to generate the following cumulative equation for fire size, in hectares:

$$FireSize = 10^{\left(1.85 \times (-\log(1-RN))^{.65}\right)} - 0.14$$

Where RN = a random number between 0 and 1. This equation allows for a very high probability of very small fires and very low chances of very large ones – consistent with the pattern of fire sizes observed virtually across the boreal forest in Canada (Ward and Tithecott, 1993Taylor *et al.* 1994, Andison 1996, Andison 2003).

Disturbance rate (or the percent of the landscape disturbed per unit of time) is a far more critical model parameter in this case, and was considered in some depth. The model needs an area to disturb for each 10-year timestep, and it is important that a natural range of disturbance levels is represented (and not just a single number representing an average). Estimates of decadal fire activity from historical records are short, and are reliable only for the period since fire control efforts were common. Alternatively, stand age data can be used to make rough estimates of decadal fire activity by "rolling back" age-class distributions (Andison 1996). Essentially, it peels back the most recent age-class, and assumes that the age of the forest underneath is proportional to the age-class distribution of the remainder of the landscape. It thus assumes that fire susceptibility is not related to stand age.

The method is more reliable for estimates of fire activity in more recent decades, and becomes progressively less reliable over time. We can be fairly sure that the actual area disturbed during the 1960's is close to 4.3%, but we are far less sure of the 26.7% in the 1910's. However, keep in mind that the objective of this exercise is not to reconstruct the exact fire history of the last several decades, but rather to estimate the variability of fire behaviour. The fire cycle can be estimated and accounted for separately (see ahead). In any case, the patterns of fire behaviour are certainly consistent with other observations. For example, the high levels of fire activity during the first half of the last century are consistent with detailed fire evidence found on a 100,000 ha study area about 70km due east of the Al-Pac FMA in Saskatchewan. This work is currently in progress, but our stand origin mapping has already shown at least 15 different fire years between 1880 and 1950 in the study area.

Also note that the disturbance levels from anytime after 1970 were not used for this analysis since fire control and harvesting have been active. The area either burnt or logged from 1970 onwards was either reverted to its original age (if available), assumed to be older forest (if logged), or assumed to be aged proportionally to the remaining landscape (if fire). The inclusion of the 1960's was questionable given fire control efforts at that time were at a low level, but still active.

The six estimates (Table 1) were used to represent the variation of disturbance levels, but still had to be calibrated to match the average level of disturbance – the fire cycle. The fire cycle is the average number of years required to burn the number of hectares represented by the landscape. For a 100,000 ha landscape, that means the number of years for a total of 100,000 ha of fires to burn. Thus some areas burn several times during a fire cycle and others not at all.

Table 1. Estimated percent area burnt on the Al-Pac FMA by decade.

Decade	% Forest Today	Estimated original % disturbed.
1961-1970	4.0	4.3
1951-1960	9.4	10.5
1941-1950	22.9	28.6
1931-1940	14.6	25.7
1921-1930	12.8	30.2
1911-1920	7.8	26.7
Average	10.2 (98 yrs).	21.0 (48 yrs).

The average fire cycle can be estimated from the average decadal disturbance level. For example, the average burning rate from Table 1 was 21% per decade, which is 2.1% annually, which is a 48 year fire cycle (48yrs x 2.1% = 100% of the landscape area. But keep in mind that the primary reason for making decadal estimates of fire activity was to understand the variation in fire activity. This 48 year fire cycle estimate is interesting and valuable information, but a secondary outcome.

Fire cycles have been the focus of considerable research in the boreal forest. Unfortunately, fire cycles are notoriously difficult to estimate for many of the same reasons outlined above. These difficulties have resulted in a variety of creative empirical and modelling techniques. In a national overview, Ward and Tithecott (19??) found a range of fire cycles of between 20 and 500 years for the boreal forest, although in most cases, figures were between 50 and 150 years. This is more or less consistent with figures estimated for Alberta and Saskatchewan.

Unfortunately, no formal estimates of fire cycles have been made for the Al-Pac FMA. In my opinion, the historical (pre-industrial) fire cycle of the Al-Pac FMA is between 40-60 years, based on the following reasoning / evidence:

- The decadal fire rate based on AVI ages using the rollback technique (sensu Andison 1996) shows a 48 year average. However, inventory ages have already proven to be both inaccurate and biased (Andison 1999a, Andison 1999b). An intensive stand age validation program on the adjacent Mistik FMA in Saskatchewan showed the errors to be moderate, and that the age of young forest stands is under-estimated (which would actually decrease our fire cycle estimates) (Andison 1999a). The rollback method is admittedly imperfect – but consider that if we simply took the existing area in each of the six decades from Table 1 (the column on the left), the fire cycle would still be 98 years. However, that assumes that no fires for 60 years ever burned over another one, which is a very unlikely scenario. The same aging exercise in Saskatchewan showed a high proportion of stands with evidence of multiple burn years.

- Estimates of historical fire cycles in adjacent landscapes in Saskatchewan range from 42-55 years (Andison 1998b), which is consistent with the 48 years found using the decadal rollback estimates. The two landscapes have very similar topography, climate, and vegetation composition. An extensive age validation field program subsequent to this calculation showed that while inventory ages are inaccurate and show some age bias, they are more than adequate for making reliable estimates of fire cycles (Andison 1999).

- No evidence of stands older than about 250 years exist on the FMA, and very few older than 200. This paralleled the findings from the Mistik FMA in Saskatchewan in 550 field ageing plots, many very close to the Al-Pac FMA (Andison 1999). A general rule of thumb is that 1/3 of a landscape should be older than the fire cycle. It is true that many trees (such as aspen) would not be expected to live this long, but at the very least, we should be finding a substantial amount of (unburnt) woody debris on the ground on a substantial part of the FMA if fire cycles were more than 100 years. This is also not observed.

- Dominance of aspen, and the paucity of abiess (ie, balsam fir) suggests that disturbance frequency is very short. Aspen is a short-lived "pioneer" species, encouraged by fire. Balsam fir only invades many years after a stand is established. Abies dominates the extreme eastern Canadian landscapes where fire cycles are in excess of 200 years.

- We know (from both historical and recent empirical evidence) that this landscape is susceptible to very large fires. Extended fire cycles would therefore mean that these events are extremely rare, and dominate the disturbance regime. However, a detailed stand origin map completed in 2003 of 100,000 ha area in Saskatchewan (approximately 70km east of Cold Lake) reveals highly complex fire patterns, with a large number of key fire years very close together in time. This suggests that fire is more or less consistently active across the landscape.

Other experts felt the fire cycle was much longer. This fire cycle decision is important because it affects the amounts of overmature forest that survives. Longer fire cycles will generate more older forest. The importance of this model parameter was such that the model was run using two fire cycle estimates: one for 60 years, and one for 80 years.

The following equations were derived to describe the 10 year disturbance levels used for the model:

$PctAreaDisturbed = -12.97 + \sqrt[3]{29.44}$ Representing an 80 year fire cycle

$PctAreaDisturbed = -16.35 + \sqrt[3]{41.89}$ Representing a 60 year fire cycle

For each of the two scenarios, the model was run forward a minimum of 20 timesteps to eliminate any bias associated with initial landscapes. Then, another 50 runs were completed and the output at the end of each 10 year period was captured both as digital snapshots, and non-spatially as simply summaries.

RESULTS

The modelling output is presented as frequency distributions for each of the 20 forest cover X forest age classes. The y-axis was standardized to represent the percent of model snapshots in each percentage class on the x-axis. The x-axis is presented in 2 percent intervals up to 50%. The x-axis represents the amount of forest in that particular age-class as a percentage of the total area in each of the five cover-classes. For example, Figure 1 represents the percent of mixedwood forest that is <10 years of age – and not the percent of the entire landscape that is young mixedwood.

A) Fire Cycle Assumptions

Before getting into the details, it is worth discussing the difference between the two disturbance scenarios run by LANDMINE. The impact of assuming a fire cycle difference of only 20 years is easily visible in both the youngest and oldest forest age-classes of each cover-type. For example, In Figure 1, the average amount of Young mixedwood jumps from 19.3% for the 80 year cycle to 23.6% for the 60 year cycle. And since more area is being burnt, the average percentage of overmature forest declines by almost 5% between the 80 and 60 year fire cycles (Figure 4). In fact, for each of the ten graphs representing either young or overmature forest, the percent area distributions for the 60 and 80 year fire cycle are almost perfect overlays, but shifted either up or down by 3-7%.

Note that there is a slight positive influence on the amount of mature forest age-classes when the fire cycle increases from 60 to 80 years, and a slight negative impact on the amount of immature forest for a fire cycle increase.

This is a classic “sensitivity analysis”, where the impacts of major model assumptions are tested by choosing different levels of that input variable to see how they affect the model output. In this case, a shift of 3-7% on the average level of overmature forest has practical significance. The discussion will elaborate further on the impact of fire cycle choice.

B) Estimated Historical Ranges

To simplify the explanation of the ranges, I will only refer to the 80 year fire cycle data in the graphs (*e.g.*, the dark red bars).

The most important aspect of the model output is the high amount of variation demonstrated by *all* seral-stages – including overmature forest. For example, overmature pine historically ranges between 16-36% of the total area of pine on the landscape according to the model output (Figure 4), and overmature hardwood ranges between 14-42% of the total area of hardwood (Figure 8).

However, these ranges are more than just simple probabilities – they represent the most likely ***temporal*** patterns of overmature forest levels on the FMA, and the distributions themselves tell us something about those temporal patterns. So, not only do we know that the minimum amount of pine forest that was historically “overmature” was about 16%, but we also know that it was a rare occurrence – 6% of the time (or, six years in one hundred) in this case according to the model output in Figure 4. On the other hand, the existence of 22% of pine-dominated forest as “overmature” was much more common (26% of the time, or 26 years out of one hundred) (Figure 4).

This is typical of “natural range of variation” (NRV) forest patterns, and demonstrates the difficulty of representing dynamic patterns with averages or medians. No single number *at any single point in time* is any more or less “natural” than any other within the range. In other words, there is no single representative level of overmature forest for each of the five cover-types on the Al-Pac FMA, but rather a wide range of possibilities.

It is also interesting to note the direction and degree of differences between the levels of different cover-classes in the same seral-stage. For example, the levels of young pine, black spruce and white spruce are much higher than the levels of young hardwood and mixedwood. This difference is a reflection of the classification rules used for the modelling, which dictate age-limits for the different seral-stages. Recall that young pine and spruce are less than 10 years of age, and young hardwood and mixedwood or less than 20 years of age. The difference of 10 years is causing the difference in percentages from the model output.

The explanation for the levels of overmature forest are similar, but a bit more involved. The highest amounts of overmature forest are in pine, hardwood and mixedwood stands, for the same reason as above – the cutoff for the “overmature” class was set at 100 years, as opposed to 120 for both spruce types. The 100 year limit allows an extra 20 years of forest to be included in the class. But within that group of three forest types there is a difference as well. There is less overmature pine than mixedwood, and more overmature hardwood than either pine or mixedwood. This is due to differences in flammability – also an inherent assumption of the model. Pine is the most likely to burn, pure hardwoods the least likely. This pattern of relative flammability is reflected in the probability of burning within the model, and is expressed in the output. Those cover-types more prone to fire (pine) will thus have slightly less overmature forest than those cover-types less prone to burning.

Figure 1. Estimated Historic Range of Mixedwood-Dominated Forest <10 Years Old on the Al-Pac FMA

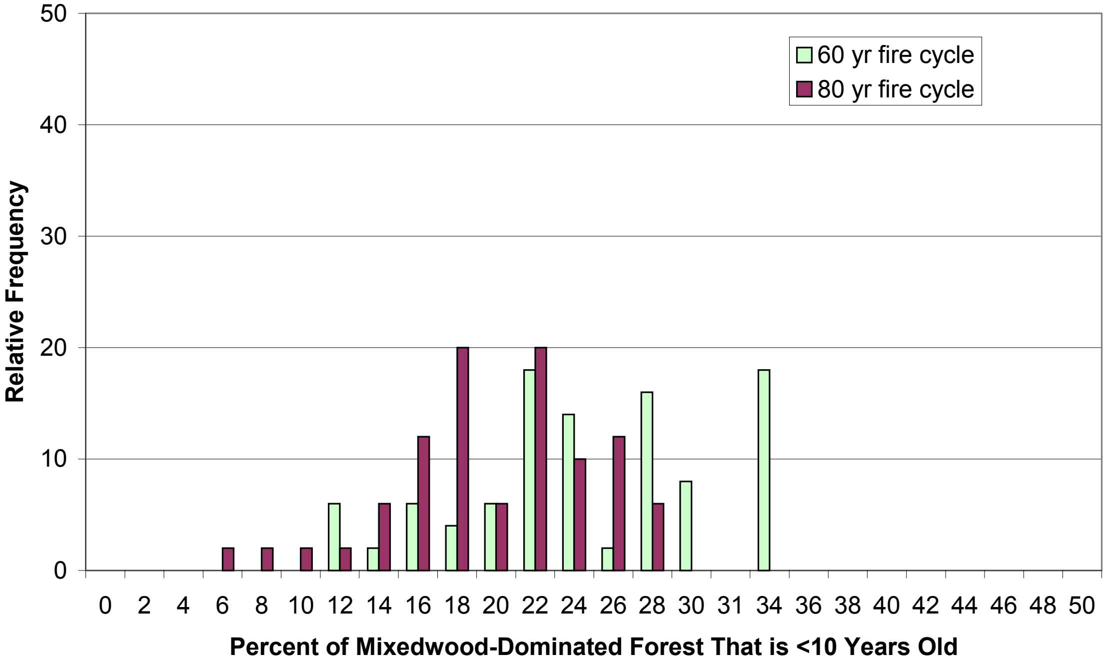


Figure 2. Estimated Historic Range of Mixedwood-Dominated Forest 11-60 Years Old on the Al-Pac FMA

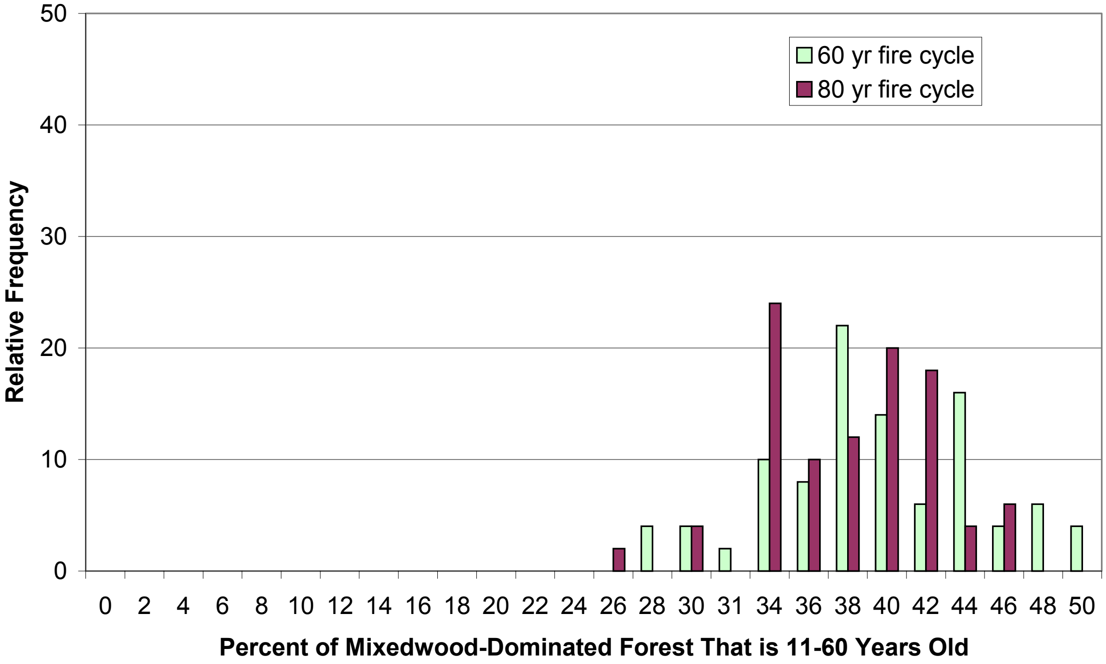


Figure 3. Estimated Historic Range of Mixedwood-Dominated Forest 61-100 Years Old on the Al-Pac FMA

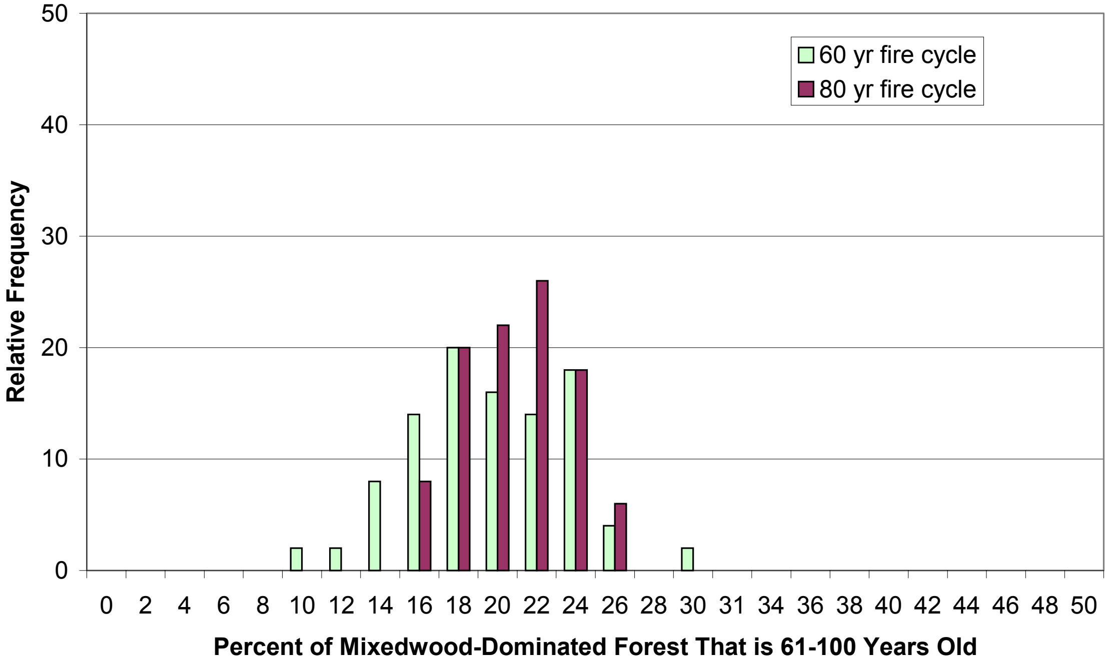


Figure 4. Estimated Historic Range of Mixedwood-Dominated Forest >100 Years Old on the Al-Pac FMA

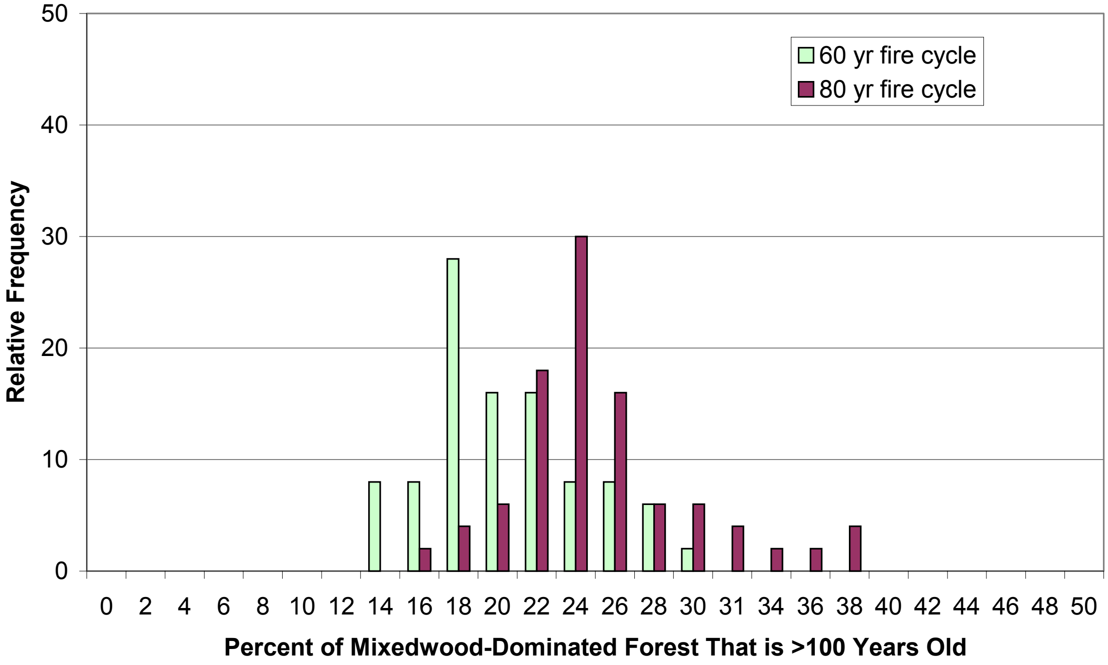


Figure 5. Estimated Historic Range of Hardwood-Dominated Forest <10 Years Old on the Al-Pac FMA

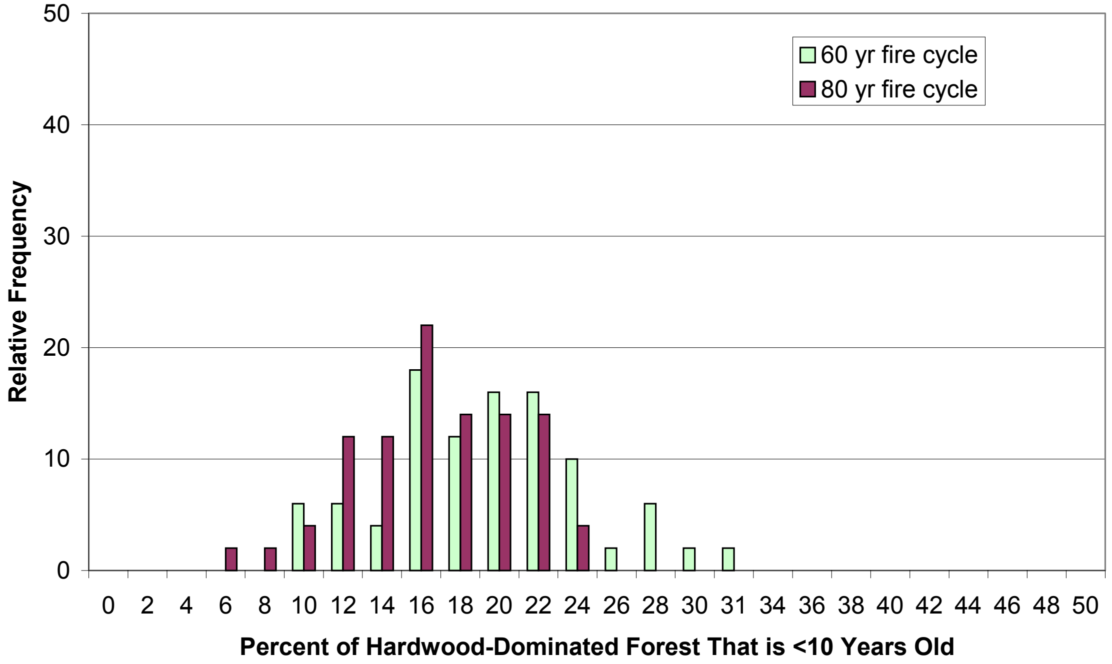


Figure 6. Estimated Historic Range of Hardwood-Dominated Forest 11-60 Years Old on the Al-Pac FMA

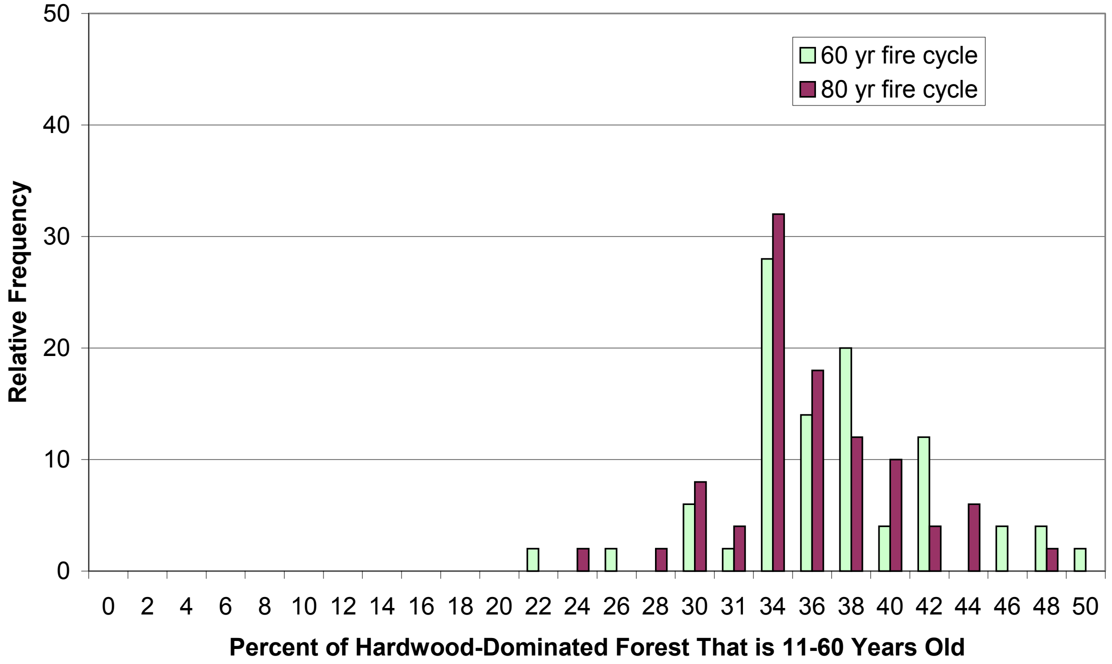


Figure 7. Estimated Historic Range of Hardwood-Dominated Forest 61-100 Years Old on the Al-Pac FMA

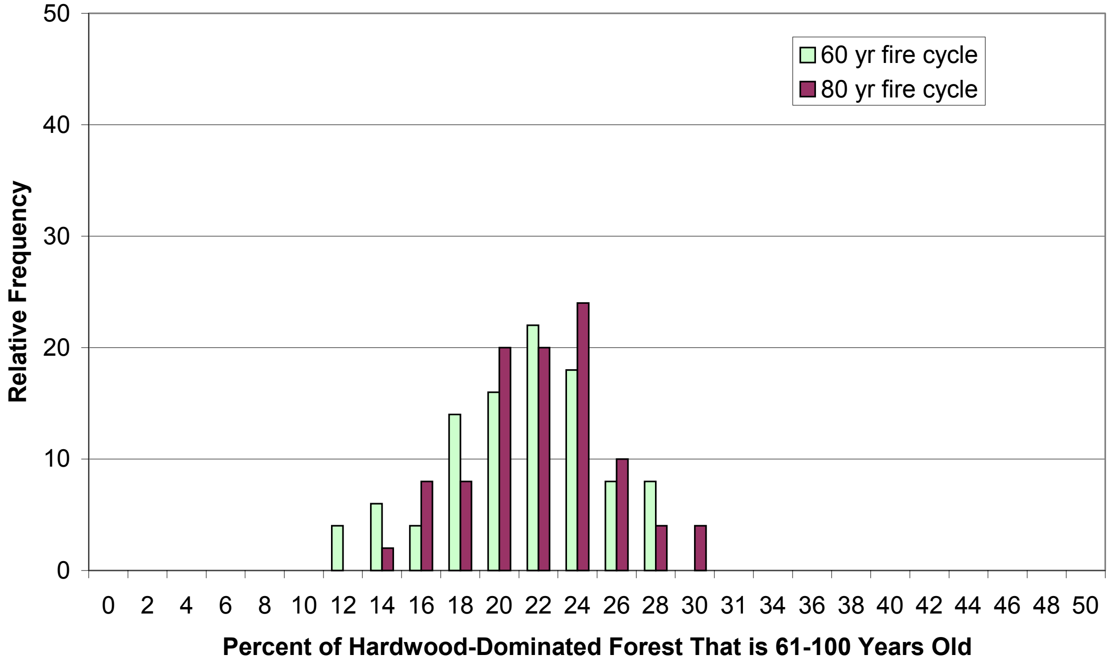


Figure 8. Estimated Historic Range of Hardwood-Dominated Forest >100 Years Old on the Al-Pac FMA

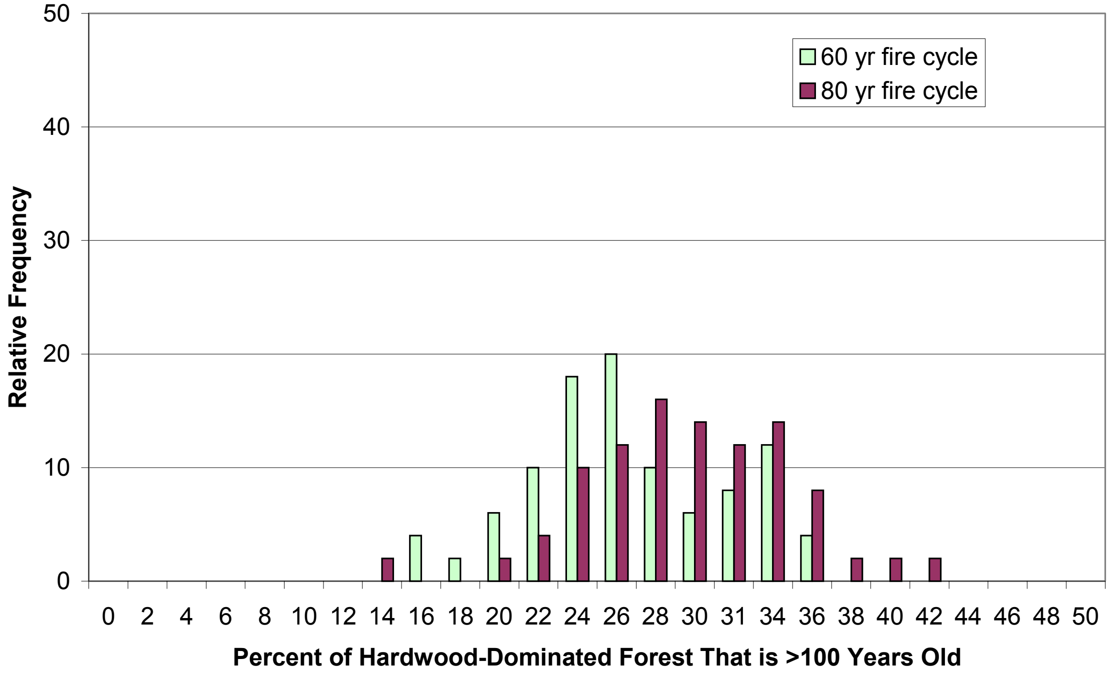


Figure 9. Estimated Historic Range of White Spruce-Dominated Forest <20 Years Old on the Al-Pac FMA

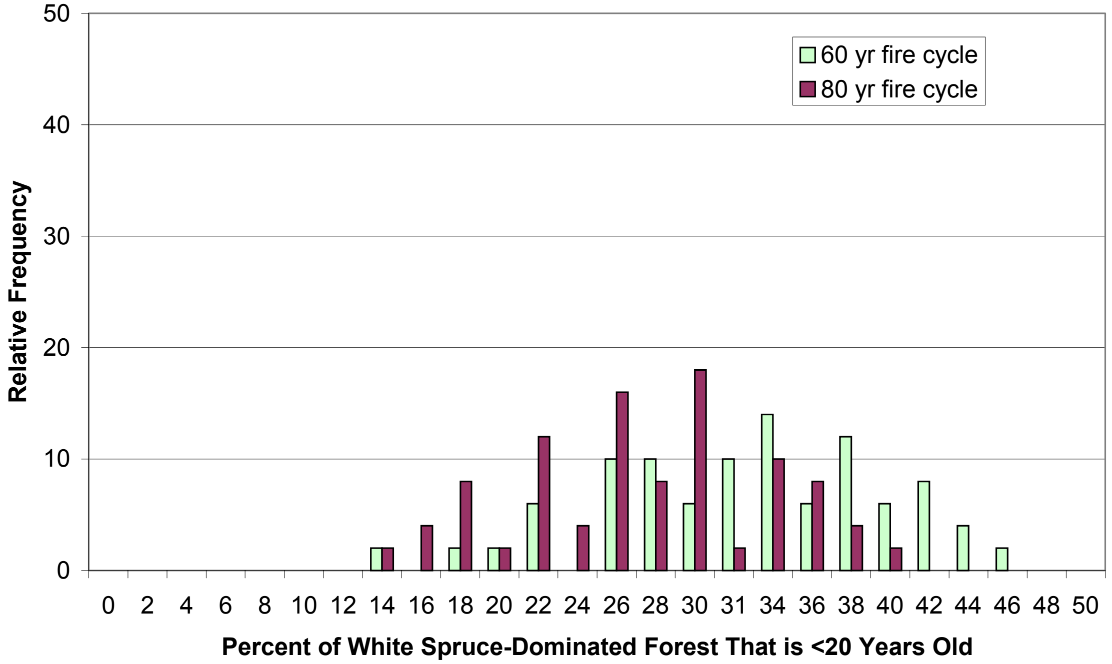


Figure 10. Estimated Historic Range of White Spruce-Dominated Forest 21-70 Years Old on the Al-Pac FMA

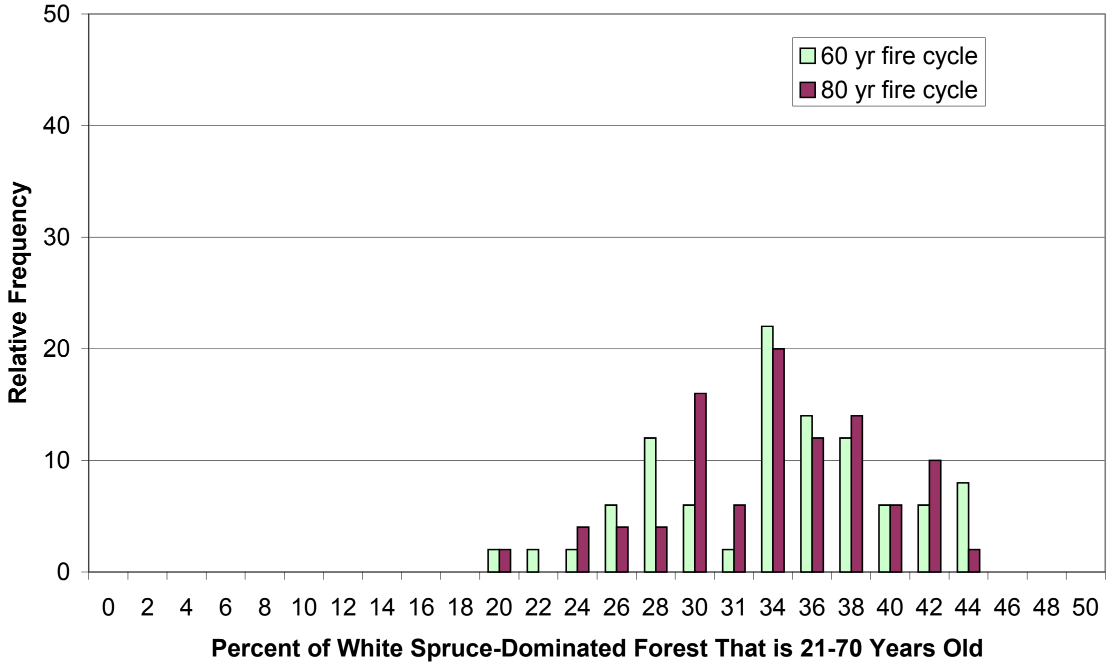


Figure 11. Estimated Historic Range of White Spruce-Dominated Forest 71-120 Years Old on the Al-Pac FMA

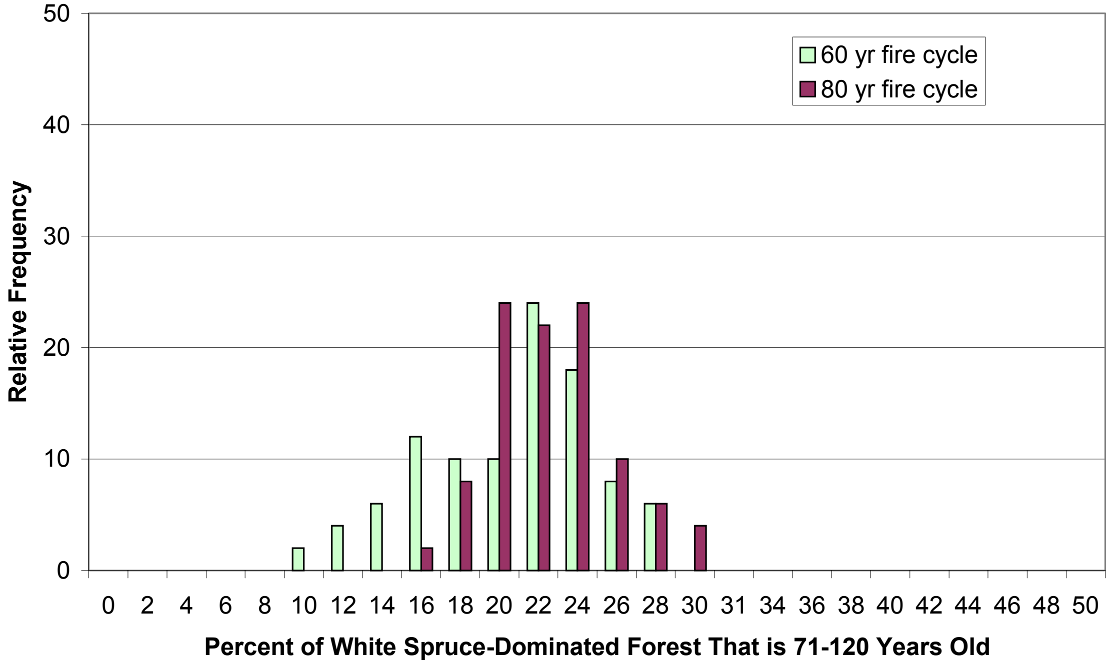


Figure 12. Estimated Historic Range of White Spruce-Dominated Forest >120 Years Old on the Al-Pac FMA

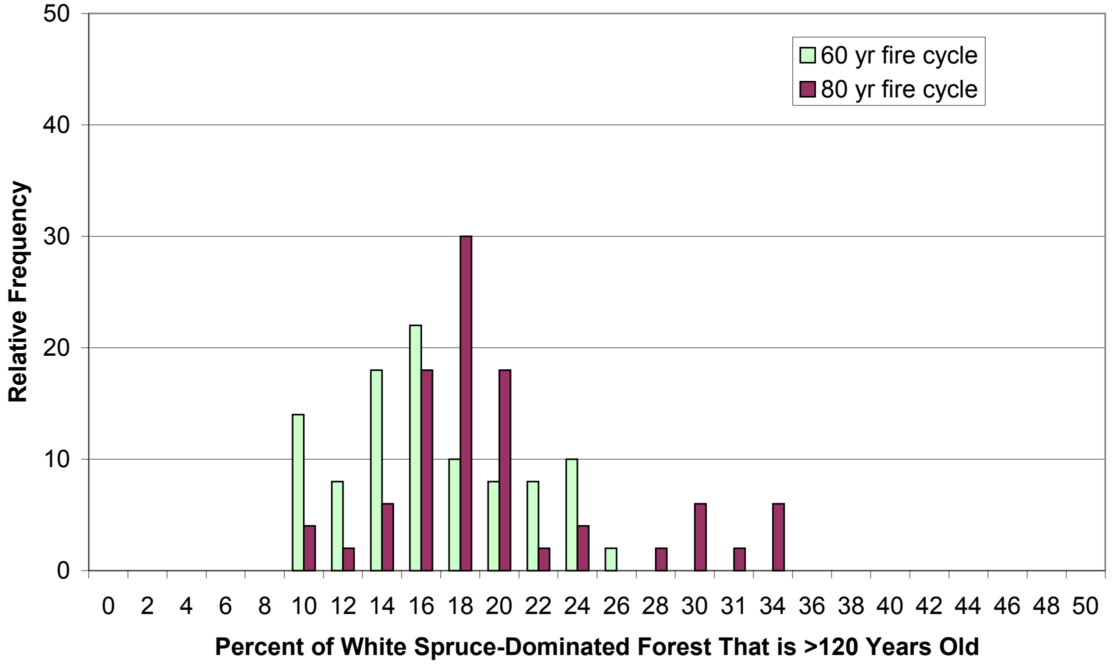


Figure 13. Estimated Historic Range of Black Spruce-Dominated Forest <20 Years Old on the Al-Pac FMA

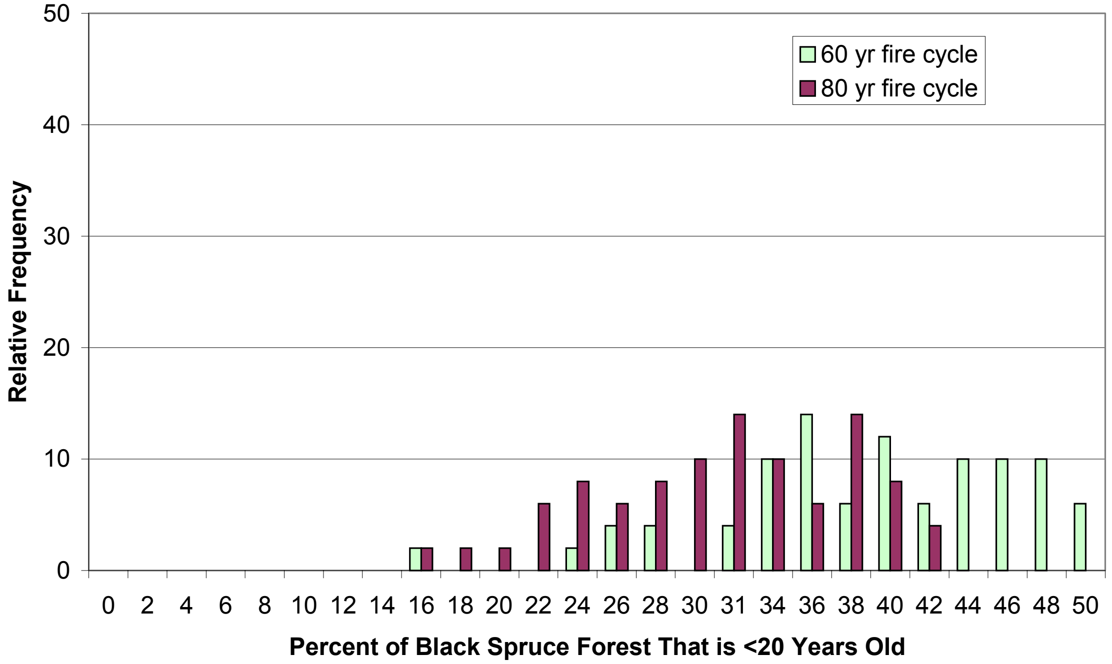


Figure 14. Estimated Historic Range of Black Spruce-Dominated Forest 21-70 Years Old on the Al-Pac FMA

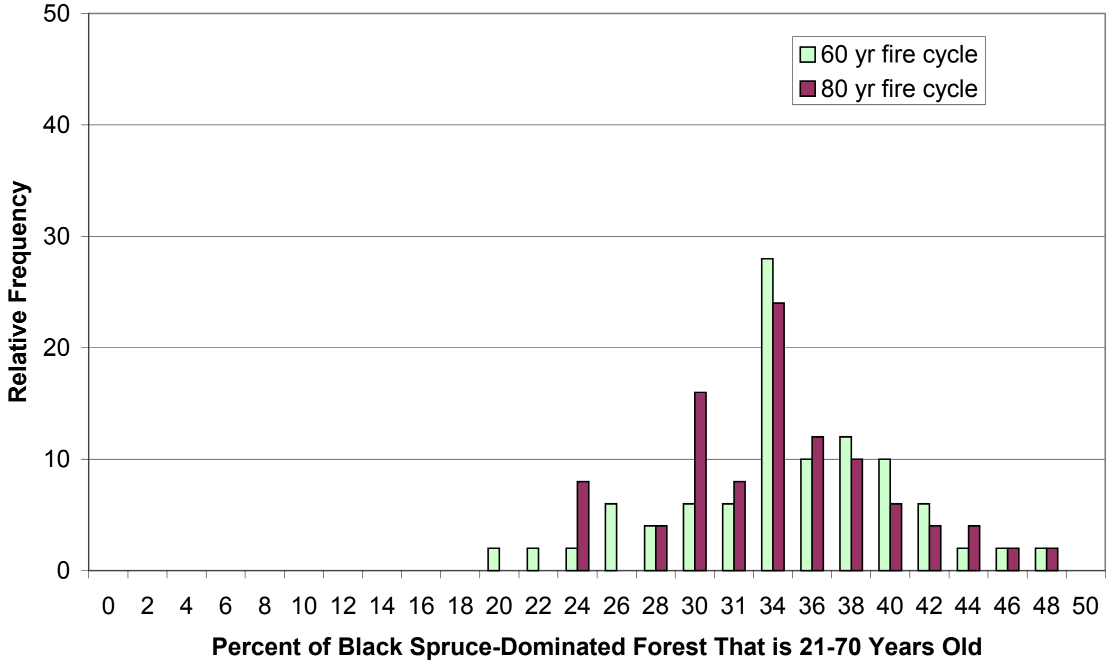


Figure 15. Estimated Historic Range of Black Spruce-Dominated Forest 71-120 Years Old on the Al-Pac FMA

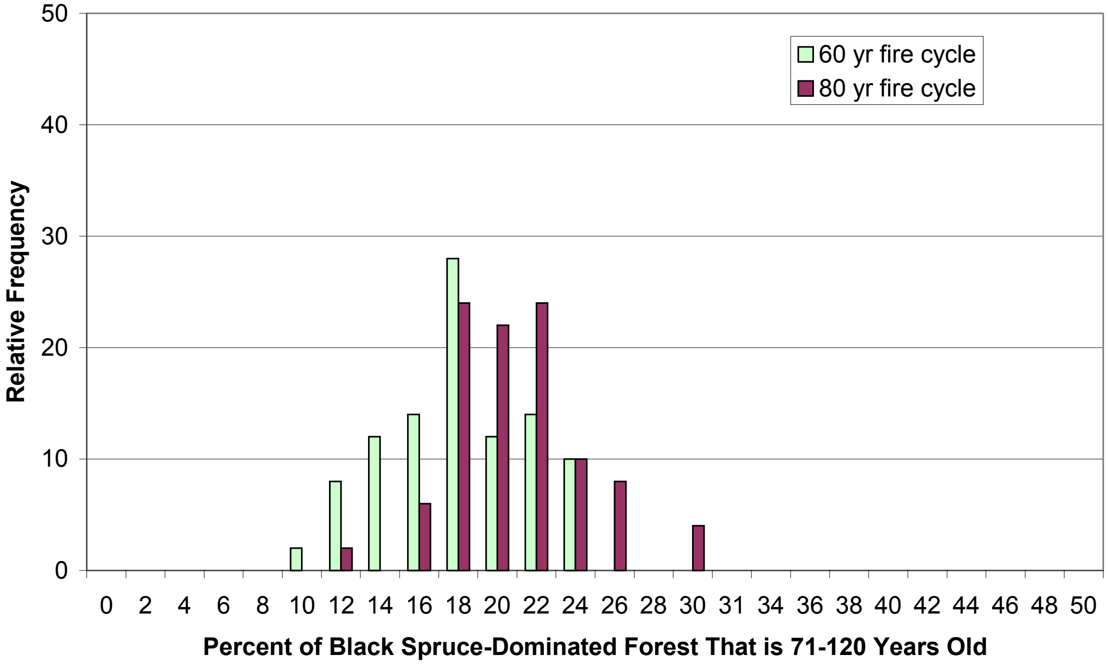


Figure 16. Estimated Historic Range of Black Spruce-Dominated Forest >120 Years Old on the Al-Pac FMA

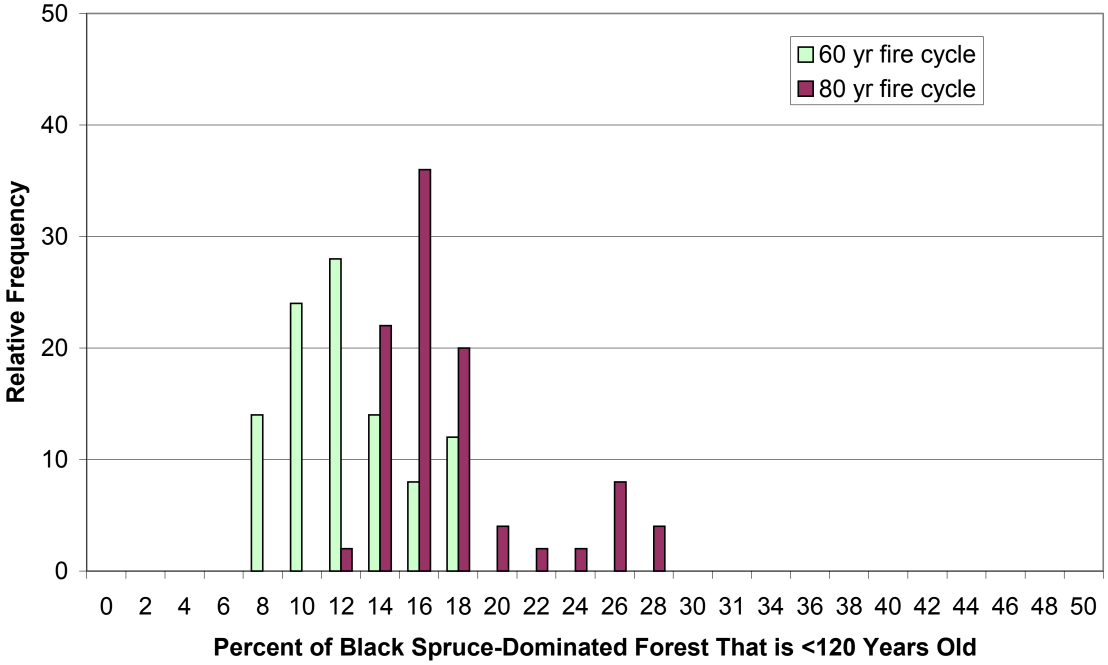


Figure 17. Estimated Historic Range of Pine-Dominated Forest <20 Years Old on the Al-Pac FMA

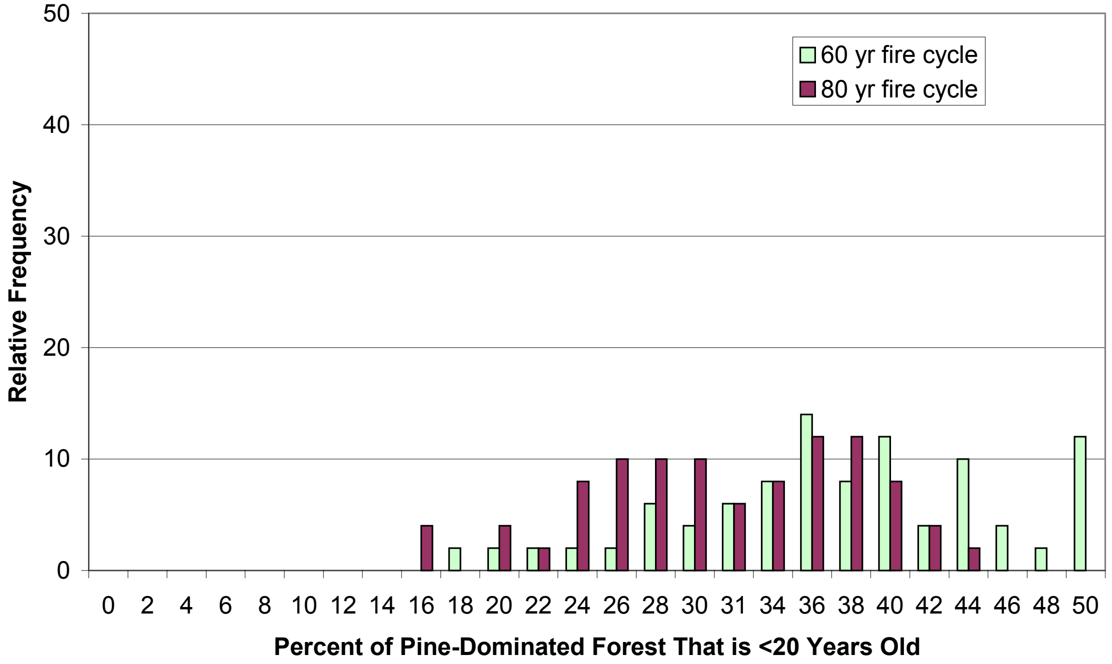


Figure 18. Estimated Historic Range of Pine-Dominated Forest 21-60 Years Old on the Al-Pac FMA

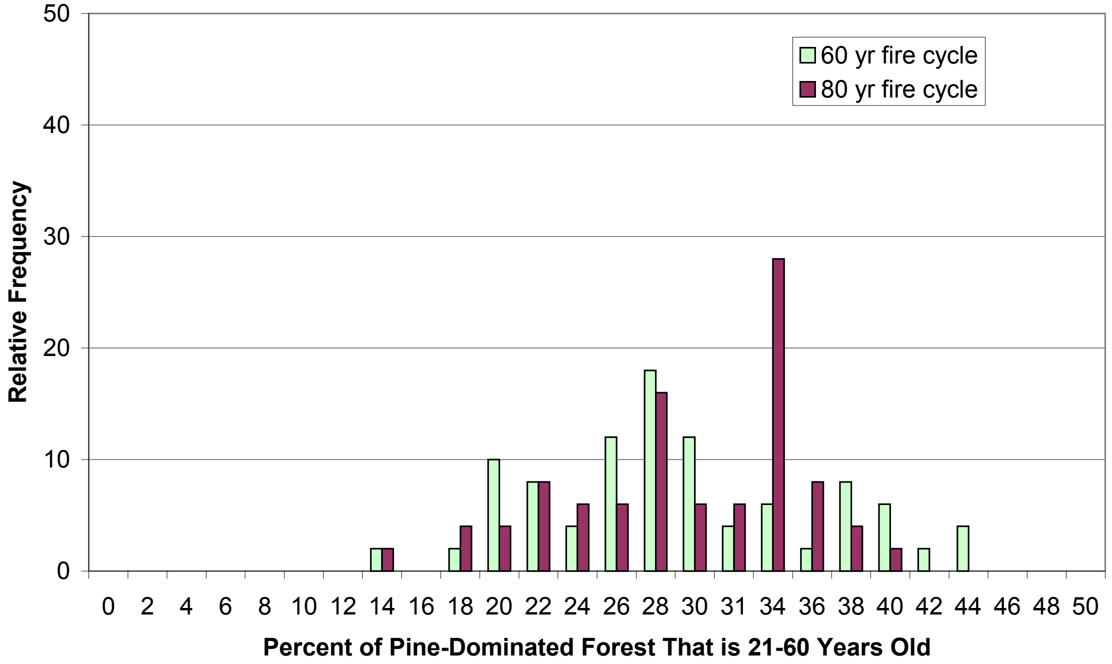


Figure 19. Estimated Historic Range of Pine-Dominated Forest 61-100 Years Old on the Al-Pac FMA

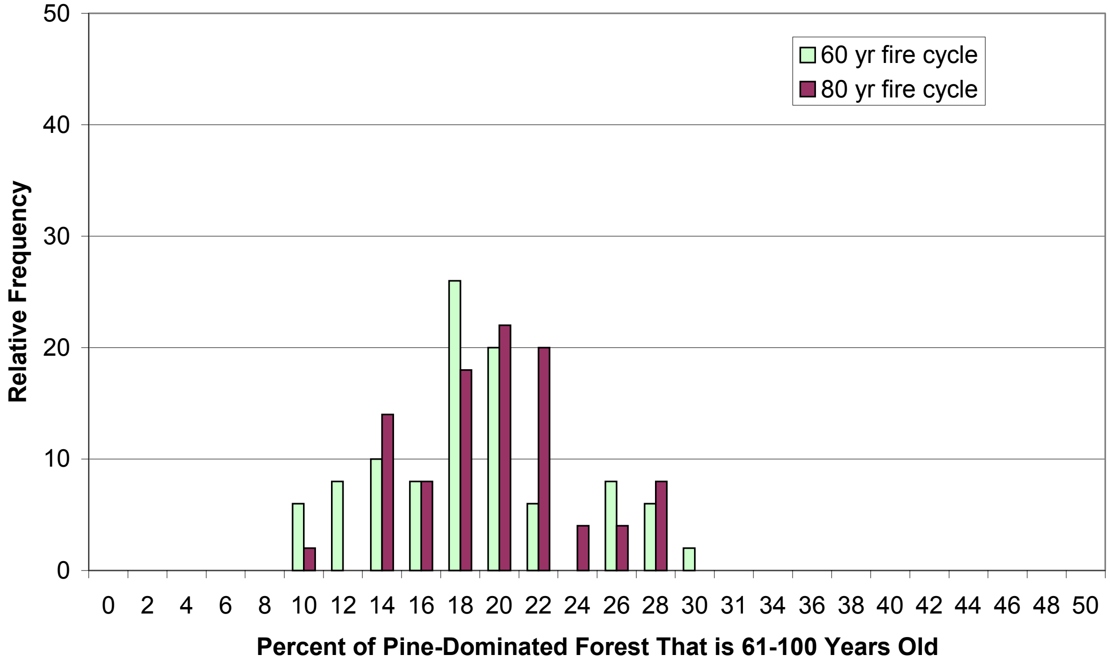
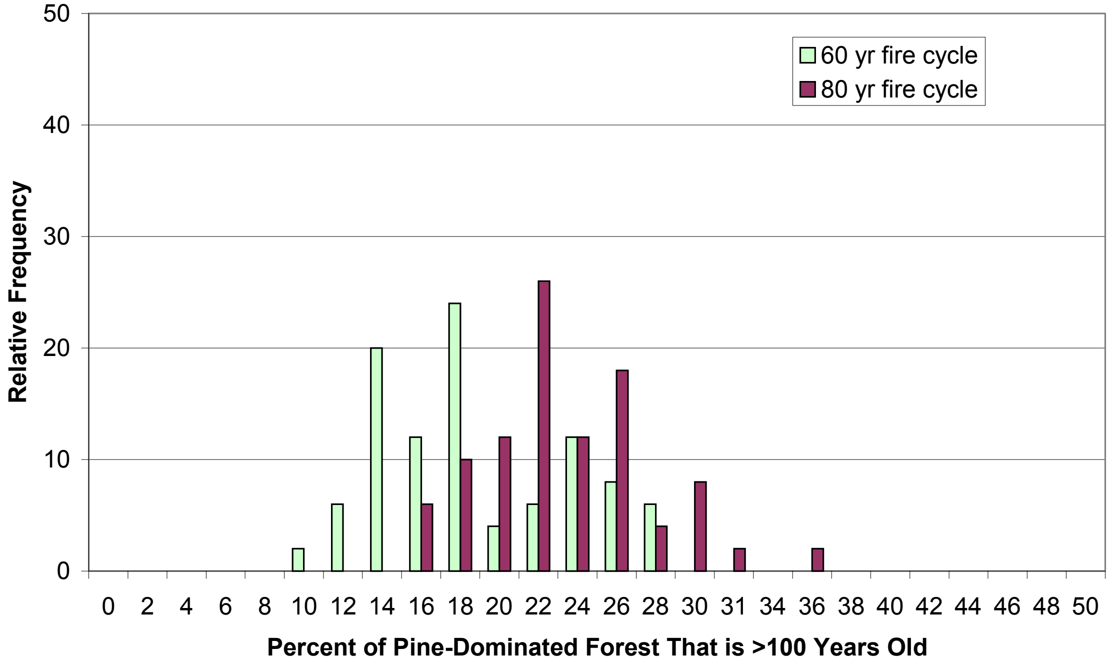


Figure 20. Estimated Historic Range of Pine-Dominated Forest >200 Years Old on the Al-Pac FMA



DISCUSSION

Emulating the patterns and effects of natural disturbance is one of the fundamental elements of practicing "ecosystem management". It is based on the assumptions that a) natural, historical patterns are associated directly with desirable levels and types of biodiversity, and b) the natural pattern in question can be captured and approximated. Both are important to understand here to fully appreciate the meaning of the results of this study.

The first assumption, that "*natural, historical patterns are associated directly with desirable levels and types of biodiversity*", in most cases needs to be rigorously tested. This is a daunting task that will take many years or decades of research to complete. However, the natural disturbance emulation strategy is still considered valuable because this first assumption is conservative. In other words, we are not knowingly guiding the ecological system (through manipulation of the disturbance regime) into unfamiliar territory. We *do* know that imposing disturbance regimes that are unfamiliar to the system can have significant and unpredictable effects. Reducing disturbance frequencies in boreal forest-types can lead to increasing (fire) fuel build-up (Romme 1982), and increase the proportion of shade tolerant species thereby creating more homogenous landscape (Methven and Feunekes 1987). Other potential impacts of altering disturbance regimes are reduced productivity, erosion, lower species and genetic diversity, increased susceptibility to pests, and even local extinction (White 1979, Odum et al. 1987). Thus, by using our understanding of the natural disturbance regime to help us plan disturbance activities, we are far less likely to make significant and irreversible mistakes with respect to maintaining historical levels of biodiversity (which is in many cases a stated goal of forest management planning).

The second assumption that "*the natural pattern in question can be captured and approximated*" presumes a) natural patterns can be defined, b) the future patterns can be defined and, c) natural and future patterns can be compared directly. I will go through these one at a time as they relate to this project.

"*<u>Natural pattern can be defined</u>".* The natural pattern in question in this project was natural levels of overmature forest on the FMA. The decision to represent "old forest" by simple age limits for major cover-types as the "overmature" seral-stage was a simplifying one, but appropriate for the type and scale of the question. It is also consistent with the existing Al-Pac data structure – which I will discuss again for point number 3.

The use of a computer simulation model to approximate historical landscape dynamics was virtually the only method available for making estimates of levels of overmature forest. Fire control and harvesting have influenced the Al-Pac landscape for more than 30 years rendering any recent age data biased. Prior to 1970 historical maps and records were not capable of providing anything more than perhaps a single natural landscape "snapshot".

The mechanics of the computer model are not an issue. Although the code is complex, the basic operation of the model is quite simply to explore how known non-spatial parameters express themselves in space, and over time. Furthermore, the model was operating on the very simplest level since the objective was a general, non-spatial question. For example, regeneration rules were simply "put back what was there", which in this case only requires assuming that over 5.5 million hectares of forest, approximately the same species mixtures will always exist.

Fire size was estimated from historical records and adjacent landscapes, but again, because the output was non-spatial, this becomes a far less critical model parameter.

Fire spread was important, but only in a general sense. Relative levels of flammability were used based on rate of spread levels for different Fire Behaviour Prediction fuel types from the Canadian Forest Fire Danger Rating System (CFFDRS) (Forestry Canada Fire Danger Group 1992). As an aid to fire managers, the FBP system differentiates sixteen fuel-types according to relative spread rates, intensities, and fuel consumption using the original Canadian fire model (fire weather, topography, date and elevation) (Forestry Canada Fire Danger Group 1992). Under low to moderate fire conditions, CFFDRS fire models (and others) do a reasonable, and now well documented, job of predicting relative local fire behaviour. Topographic models could have been included in the data layers to help with probabilities of fire movement, but any gain in precision over 5.2 million hectares was not considered worth the effort – again, remember that the only output from the simulation was hectares burnt, not spatial patterns.

Fire cycle is by far the most critical input variable in the simulation model. Higher fire cycles will always produce lower levels of overmature forest. So we deliberately paid close attention to this parameter. In this case I believed through various pieces of evidence that the fire cycle on the Al-Pac FMA was, on average, between 40-60 years. Al-Pac chose to use 60 and 80 year fire cycle averages in the model to represent two levels of conservative estimates with respect to overmature forest levels (relative to my own fire cycle estimates).

So far, in summary;

1) Old boreal forest is a recognized value for the Al-Pac FMA.
2) Al-Pac chose to identify the historical, natural levels of old forest as a reference or starting point for establishing long-term, coarse-scale management objectives.
3) Natural ranges of old forest are powerful and defendable foundations for establishing biologically meaningful management objectives, but may not necessarily be desirable for other ecological, economic, or social reasons.
4) Since the natural range of old forest cannot be determined directly from available data or observation, a certain number of assumptions must be made.
5) Most such assumptions are quite safe, given the broad scope and nature of the

objectives.

6) The most debatable assumption of fire cycle was isolated and dealt with through a “sensitivity analysis” that explored how different numbers would affect old forest levels.
7) All of the assumptions, analysis, and output are presented in this document for those who wish to understand them further.

At this point we have defined the natural levels of overmature forest forest, and explained in detail how we arrived at these figures.

The presumption that “<u>the future patterns can be defined</u>” may seem simple, but we must consider all possible sources of disturbance. Harvesting is the most obvious source of disturbance only because it is the most predictable. However, recent history tells us that natural disturbances such as forest fires will continue to occur on this landscape despite our best efforts to control it. There are also other cultural disturbance sources (such as oil and gas activity) that are intermediate in terms of predictability.

This creates a challenging task for the future scenario – a predictable element plus a partially predictable one, plus an unpredictable one. However, if we consider the appropriate perspective of long-term planning, the problem becomes somewhat more tractable. Fire activity become less variable over longer periods of time. Predicting annual fire risk is far more difficult than the amount of fire over a 20 year period. Similarly, predictions can be (and have been) made of disturbance by oil and gas companies over time for this area.

Exactly how these different sources of disturbance are combined to generate estimates of expected future levels of overmature forest on the FMA area is well beyond the scope of this project. However, it is worth pointing out that the issue of variable levels of predictability can be an asset, as opposed to a problem. Recall that stability of the FMA age-class distribution is an “unnatural” pattern. The creative combination of a predictable baseline disturbance level (of harvesting, and perhaps oil and gas activity) combined with a stochastic, additive level of fire, a truly “natural” pattern of seral-stages may result over time.

The last point, that “natural and future patterns can be compared directly” follows from the arguments above. This may seem moot at this point, but it is critical that these two match both logically and technically. The reason this may not be possible is that natural patterns are normally generated by scientists, and future patterns by planners and managers. If the final product is vague, or has not been communicated properly, chances are this will lead to an inadvertent and unnecessary failure of the application of a natural disturbance strategy. To Al-Pac’s credit, this vision for this project was quite clear, and considerable discussion with Al-Pac preceded the development of the final quantitative project output such that it would match the output from Al-Pac’s long-term planning data and assumptions.

CONCLUSIONS

This research project marks a critical first step in understanding and integrating natural disturbance patterns into long-term planning on the Al-Pac FMA. If nothing else, Al-Pac now has a defendable ecological foundation on which to build an old forest strategy. This same strategy will allow them to deviate from the traditional deterministic, narrow model of old forest. This will allow them to base decisions of how and where to allocate harvesting activities to optimize the chances for achieving desired levels of old forest when combined with other disturbance agents such as fire, and other economic, social, and ecological needs.

The advantages to adopting such a strategy are obvious. Having the flexibility of how and where and when to manage for old forest fits perfectly with the concept of natural variability. It also creates opportunities for adapting to local and current conditions in long-range planning. For example, wood product markets, local stakeholder demands, technology, and costs can all vary considerably in a 10 year period. Even with the best information and knowledge, it is extremely difficult to anticipate such changes. Having a system for managing old forest that does not allow for these changes is almost guaranteed to fail within a monitoring system. Having the flexibility to respond to these unanticipated events by not restricting outcomes to predetermined patterns generates a wider palate of management solutions for Al-Pac. Given the unknowns of the future, there is little point in fully developing each and every one of those scenarios, but rather allow for their development when the time comes. For example, it is not necessary to identify exactly where every patch of overmature forest will be 20 years from now, but it is possible to identify where *potential* overmature forest areas will be, as well as the probabilities of different levels of overmature forest existing on the FMA.

This represents a tremendous evolution of how old forest, as a value, is managed. Consider that the traditional system of defining minimum levels of old forest do not recognize dynamics (*ie*, variation) as a desirable outcome, nor allow for unforeseen events. This approach allows both to be embraced.

In fact, what I have outlined here is a classic example of true “results-based” management. The concept of results-based management allows for a realistic and defendable level of autonomy to achieve a higher-level, strategic objective through operational and strategic means. Despite considerable assertions, a real example of results-based forestry has never been demonstrated in Canada.

There is also precedent in BC (Andison and Marshall 1999) and Alberta for dealing with strategic old forest values in this way. In Alberta Weldwood of Canada pioneered this approach in their latest DFMP (Andison 1998, Bonar et al. 1993) and it has since been adopted by Alberta Newsprint Co. and Sunpine Forest Products in Alberta.

Considering the high levels of risk associated with managing forests, and the coinciding low probabilities of meeting static management targets, the opportunity to use target age-class ranges, based on historical ranges, is both biologically sound and practical. It also presents a quantitative indicator of "ecological integrity" for biodiversity monitoring programs that is easy and inexpensive to measure, meaningful, and relates directly to management objectives.

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