Northeast FFP Compact Stress Testing Project

Quebec Fire History and Implications

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Highlights

This document is a chartpak with minimum text designed to test ideas, initiate discussion, and model a possible approach to analyzing data from other jurisdictions. This analysis applies only to the zone of intensive protection, for which we have data. Some initial observations:

- We have a longterm fire history record, corrected by MRN in 2012, from 1922.
- Based on this data, the recent decades have seen burning as active as at any time since the 1920's, and variability form year to year has not decreased in recent times.
- Average annual area burned increased significantly between 1970-89 and 1990-present, in contrast to other parts of the Compact. Fire numbers, however declined.
- Analysis of return periods suggest that a fire of 90,000 Ha will recur once, on average, in every decade, while an annual area burned of 240,000 ha will also have a 10 year return period.
- Comparing fire experience with nearby Newfoundland and the USA states, there have only been a few years when Quebec's peaks matched the others.

While analysis of annual fire histories is useful, the rubber hits the road where we dissect monthly and even daily activity. Sopfeu's 1994-2010 dataset of almost 13,000 fires supplies abundant detail. For example:

- Quebec's fire season is usually unimodal, with a sharp peak in June, July or August.
- The peak months can be extreme. The worst was June 1996 with 642 fires. In that month alone, more fires occurred than in many entire years since. Individual months exceeding 300 fires occurred in five years since 1994.
- In US states, this season typically is a lull, fire seasons there tend to concentrate in the March-May months. Occasionally, in July or August large fires do occur.

- Individual fires can reach spectacular sizes, the largest being 107,000 Ha in 2010. Over 1994-2010, 126 fires 5000 Ha (12,350 A) and larger occurred. There were 77 fires above 10,000 hectares.
- Fires can burn for long periods. In this period, 826 fires burned ten days or longer.
- Over most of the range of fire sizes, a given fire is 2 to 4% larger than the next largest. For the largest and most dangerous, however, this breaks down. For fires 20,000 Ha in size, there is no reason the next larger fire cannot exceed it by ten to thirty percent. Lest this seem a modest amount, the record (1994-2010) 107,000 Smoky Lake fire of 2010 was only 16% larger than the next largest ever experienced. But that 16% amounted to 17,000 Ha, or 42,000 acres.
- Very large fires are normal in Quebec, not frequent, but normal. A return period analysis shows that fires of 90,000 Ha or larger can occur, on average, once every decade.
- Fire sizes are highly skewed; fewer than 1% of the fires – the largest ones – do about 70% of the burning.
- Additional historical background shows the risks of thinking of fire occurrence in terms of longterm averages. More useful is to think of return periods for given levels of annual burn.
- The “Fire Triangle” in the Northwest of Quebec accounts for about 40% of cumulative area burned 1994-2010, and offers a strong example of extreme value behavior.
- Lightning fires accounted for 90% of area burned in Quebec in the past decade.

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Introduction

This note summarizes a line of analysis of Quebec fire history, hopefully to be used as a base for further analyses by others. Further studies will enable us to be much more specific about the implications of past history for future possibilities in developing plausible wildfire threat scenarios.

Quebec, with its protected area of 120 million –plus acres, is almost double the total land area of the Northeast US compact members taken together. Its vast size and diversity, plus its northerly location and ecosystems, make it a fire region all its own –actually, several distinct fire regions.

This Working Paper is basically a pack of charts with minimal comment and interpretation This note discusses 4 points:

1. Longterm fire history, 1922-2010
2. Recent history, 1970 to 2010
3. Individual Fire history, 1994-2010
4. Connections to weather, based on existing literature for the moment.

We discuss Quebec in detail not only because of its size and importance but because it is the first Canadian jurisdiction for which we've been able to obtain longterm fire history and also a good set of individual fire data (almost 13,000 fires over 17 years). We have reviewed principal histories of fire and fire programs as well (Pyne, 2007, Blanchet, 2003)

In this paper we analyze only the fire experience in the protected zone. The fire occurrence in the province as a whole has been quite different[1]. Here, we will not give any attention to the growing literature assessing potential effects of future climate change.

Note: In this version of the paper we are using MNR data which show major differences pre-1973 from the data used in previous version of this Working Paper. We are making inquiries about these differences. They are large enough to materially affect a few important points. In this revision we will concentrate on post-1970 data.

[1] Recent studies based on tree ring reconstructions and forest age estimates argue that the overall occurrence of fire in Quebec actually fell materially since about 1850, up to the early 90's. See Girardin and Bergeron cites in References. See also Wallenius, 2011. If so this suggests we have been in an era of unusually low fire incidence. Could this be affecting fuel buildups?

1. Longterm Fire History 1922-2011

Quebec longterm fire history is available for the period since 1922, for the intensive protection zone (Fig 1). This area covers some 47 million ha, of which 76% is public land allocated to timber production, 19% is unallocated public land and small holdings, and the balance is larger private holdings. The usual concerns with data comparability over time apply, so we cannot offer extremely precise conclusions on these longterm trends. Further, the area under intensive protection has changed since the 1920's. The information applies only to timberland area, and not to agricultural and settled portions of Quebec served by municipal fire departments. Fire years of 100,000 ha or less occurred 76% of the time over this period. Half of the cumulative area burned was burned in the 7 worst years[2]. The extraordinary range of annual area burned is striking (Fig. 3). Just under 7% of the fire years exceeded 200,000 ha -- since 1945 these have occurred on average once every five years. From the mid 60s to the early 80s, area burned this high occurred only once. Since the mid 80's, Quebec displays much more variability in area burned than any other jurisdiction of the Compact. On the basis of these numbers, roughly 7 million ha burned over from 1922 to 2010, fully 4.2 million since 1950. For comparison, this total area is about the size of the entire state of Maine. As some of this area was likely nonforest, and many fires re-burned previous burns, from this information there is no way to know the actual cumulative area of forest affected by fire over this period. Despite the immensity of these numbers, the average percentage of Quebec forest burned annually is below 1%. (Bergeron et al, 2006, p. 2741)

[2] These were the years that all exceeded 250,00 Ha: from low to high – 2007, 1922,1991, 2005, 1968, 1932, and 1923. Note that 4 of these occurred post - 1960.

Fig 1. Intensive Protection Zone. Source: Sopfeu.

Within Quebec, the fire situation varies dramatically. Generally south of the St, Lawrence, and in settled areas to the Southwest of Montreal (areas labelled 5 and 11 in Fig 2), fire is rare to nonexistent. At the other extreme, the northwestern areas consist of fire-adapted ecosystems and exhibit the lowest natural fire return intervals.

Fig 2. Homogeneous zones of fire influence and recurrence intervals. Source: Sopfeu.

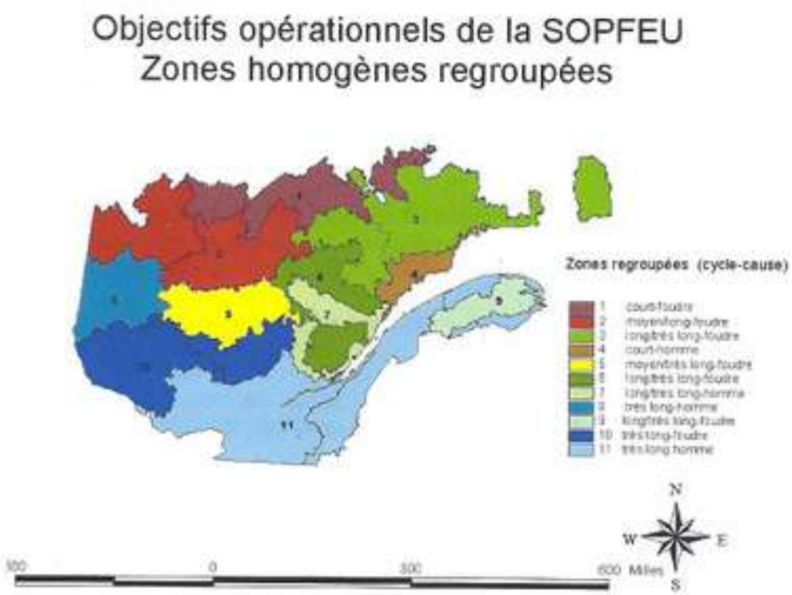
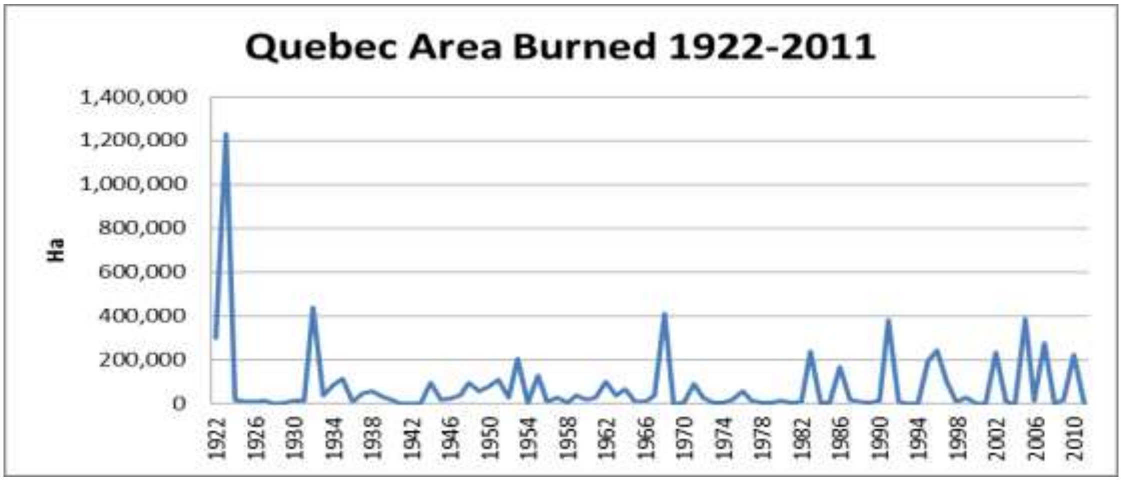


Figure 3.



A mild Quebec peak is concurrent with the early 60s Northeast Drought, but not with the '47 fires. Other areas in the Compact experienced very large fire years during the World War II years, but Quebec apparently did not; we are not sure why. The large fire seasons of recent years do not match heavy fire years elsewhere in the Compact.

Historic fire numbers (Fig. 4) are highly variable but on average show a distinct hump in the middle of the period. Though highly volatile, average fire sizes show an increasing trend after the early 1980s (Fig. 4).

Figure 4.

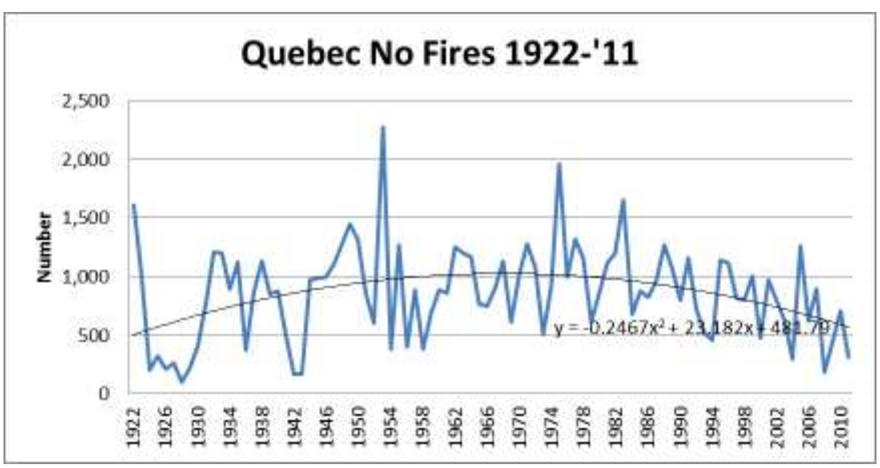
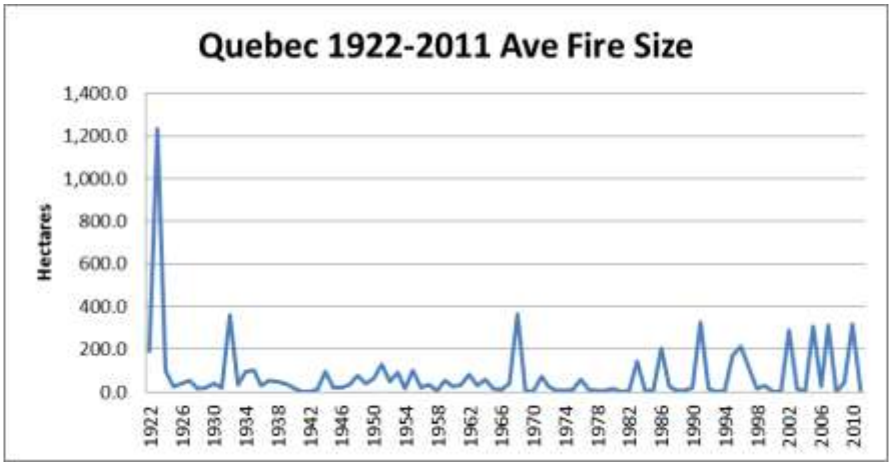


Figure 5.



Decadal Averages and Variability

The decadal averages (Table 1) make it possible to see past the high variability, though there is nothing magic about decades compared to other periodizations. The 1991-2010 period displays decadal averages exceeding any period since the 1920s.

Table 1. Decadal Averages

	Quebec		
Decade	Area Burned (Ha)	Area Burned (acres)	No. Fires
1901-1910			
1911-1920			
1921-1930	178,128	439,976	483
1931-1940	85,297	210,684	930
1941-1950	41,212	101,793	894
1951-1960	57,143	141,143	862
1961-1970	70,282	173,595	967
1971-1980	23,295	57,539	1,069
1981-1990	47,332	116,911	1,045
1991-2000	96,350	237,983	822
2001-2011	105,959	261,718	647

Standard measures of variability of fire experience are shown in Table 2. These show that the second half of the period does not display any material reduction in variability compared to the period as a whole. For area burned, the CV is actually somewhat higher after 1970.

Table 2.

Table	Quebec Analysis of Variability, 1944-2011 and 1970-2011			
Year	**Area Burned (Ha)**	**Area Burned (acres)**	**No. Fires**	
1944-2011				
Maximum 1944-present	410,823	1,014,733	2,272	
Mean	67,400	166,477	934	
Median	20,934	51,708	905	
SD same	99,793	246,488	364	
Ave + 1 SD	167,192	412,965	1,298	
Ave + 2 SD	266,985	659,452	1,662	
Ratios:				
Max /mean	6.1	6.1	2.4	
Mean/Median	3.2	3.2	1.0	
CV	1.48	1.48	0.39	
1970-2011				
Maximum 1970-2011	386,671	955,078	1,963	
Mean	69,210	170,949	907	
Median	13,186	32,570	892	
SD same	108,712	268,519	346	
Ave + 1 SD	177,922	439,468	1,253	
Ave + 2 SD	286,635	707,987	1,598	
Ratios:				
Max./ mean	5.6	5.6	2.2	
Mean/median	5.2	5.2	1.0	
CV	1.57	1.57	0.38	

Ranked Area Burned and Return Periods

When the fires are ranked, they display the same behavior we have seen in other areas: the very largest fires do not follow the trend of the smaller ones (Fig. 6). Conditions in the worst fire years clearly are quite different from those in "average" years. We discuss further in presenting the individual fire data below. But from our exploratory analysis it appears that, considering the entire period, there will be no statistical or mathematical law that will fully described Quebec's fire history numbers. The annual number of fires recorded also displays a sharp upturn at the extreme end, but generally these are not the years of greatest area burned (Fig 7).

Figure 6.

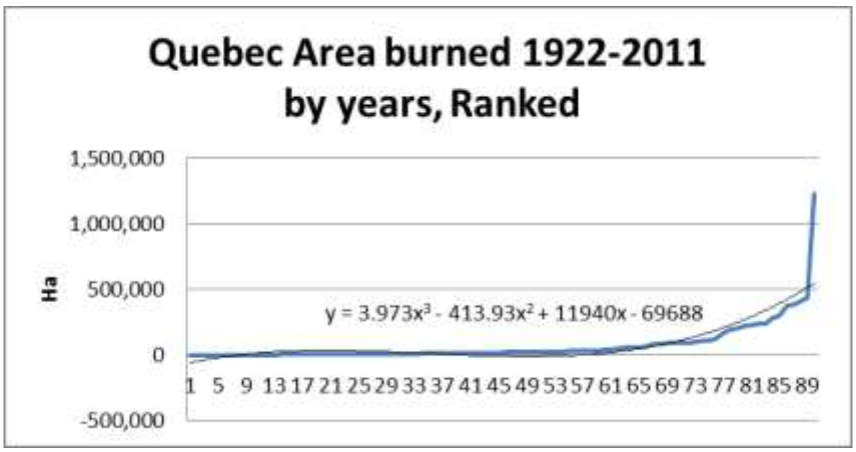
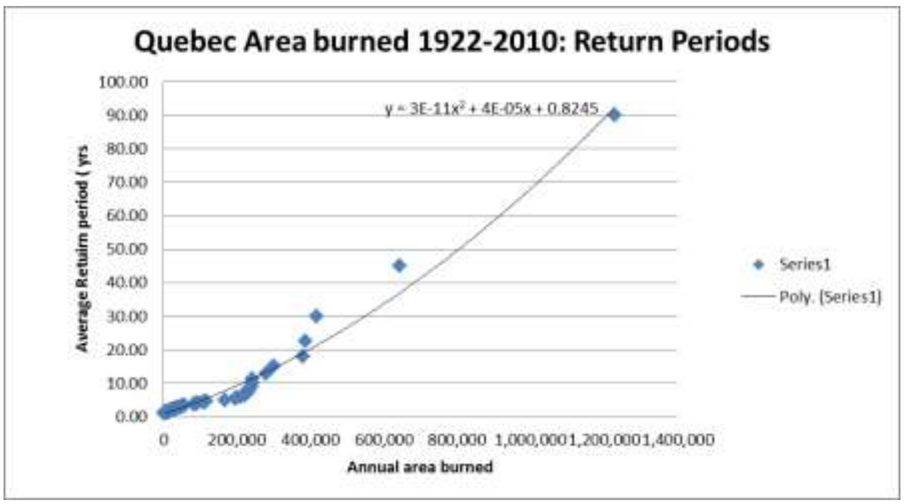


Fig. 7.

Following common practice in analyzing flood peaks, we can analyze the annual area burned to estimate the return period of different levels of annual burning. It is common to plan flood control works to withstand an extreme projected flood based on a historical record. Usually flood control works are designed to withstand a 100 year event. When a shorter record is available, engineers use statistical methods to extrapolate a design flood. This can be done for fire years (Fig. 5). These charts show one statistical fit (polynomial of degree 2) to the data; others might be considered. These are only to illustrate a general point for now, not to propose a final approach.

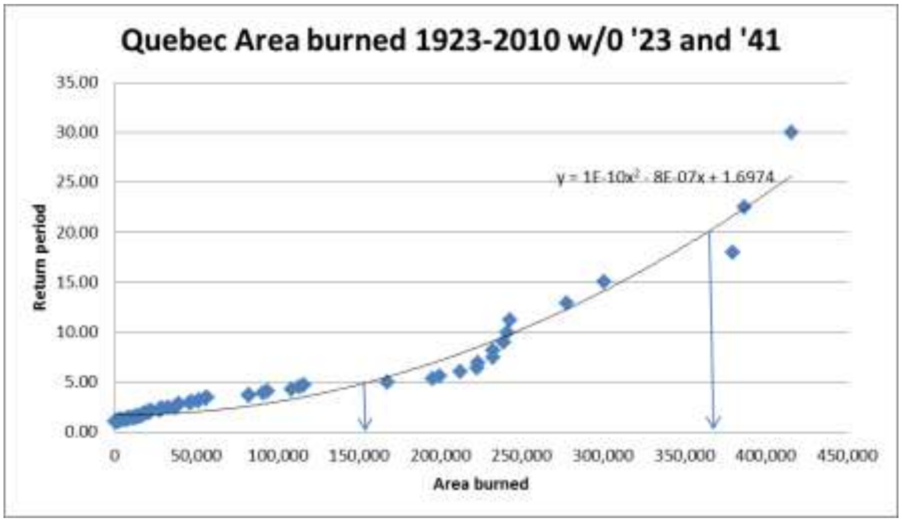
Note: below we give the same analysis for the largest fires, which fits most closely with methods used for flood control, which focus on individual events, not annual runoff.

Figure 5.



It might be argued that past extreme fire seasons arose under very different conditions of forests, harvesting practices, regulations, and control capabilities and thus should be ignored for present planning. Adopting this view for the moment, we could drop the 2 largest fire years from the record. This yields a second return period chart (Fig. 6).

Figure 6.

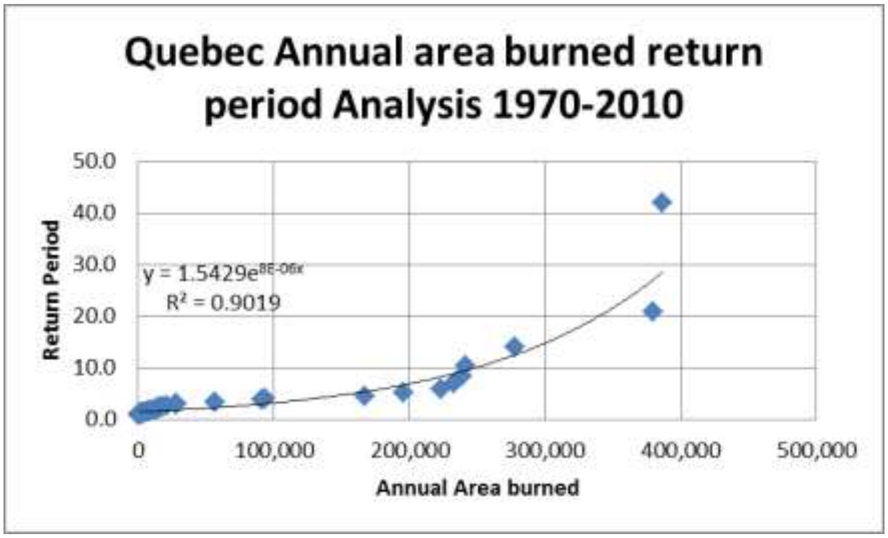


This chart illustrates the risks in using longterm averages as planning guides when there is so much variability and skewness in the data. It suggests that if we wish to provide fire control resources capable of controlling the 5 year return period fire season, we should plan for just above 150,000 hectares; the ten year figure would be about 250,000 Ha. But the total period longterm average area burned was only 88,346 Ha; dropping 1923 and 1941, the average would be about 69,000 ha. The large number of low burn years misleads the eye about the real risks. Further, as we shall see, it is the years of very large fires that burn the largest cumulative area.

Another approach would be to remove the oldest years from the analysis period on grounds of changes in forest conditions and protection capabilities. Since the early 70';s fire detection and suppression capabilities had reached roughly the current level of maturity. If we prepare the same chart for the period 1970 to the present, we see the following result (Fig 7). The relationship is significantly more ragged. Further, changing the data period does not really change the difficulty of deciding how to handle extreme events. The predicted annual burn for a 20 year interval is only slightly reduced compared to the above chart. In this chart we illustrate an exponential curve, but given the high variability in the larger fire years, it is impossible to be confident about picking one functional form.

This one may be tentatively useful --- though it anticipates the next discussion of the more recent period. The average annual area burned for this period was about 69,000 acres/yr. Based on this return period analysis, a ten year return period would mean we could expect a burn year, on average, of 240,000 Ha once in a decade, or 340,000 Ha once in twenty years.

Figure 7.

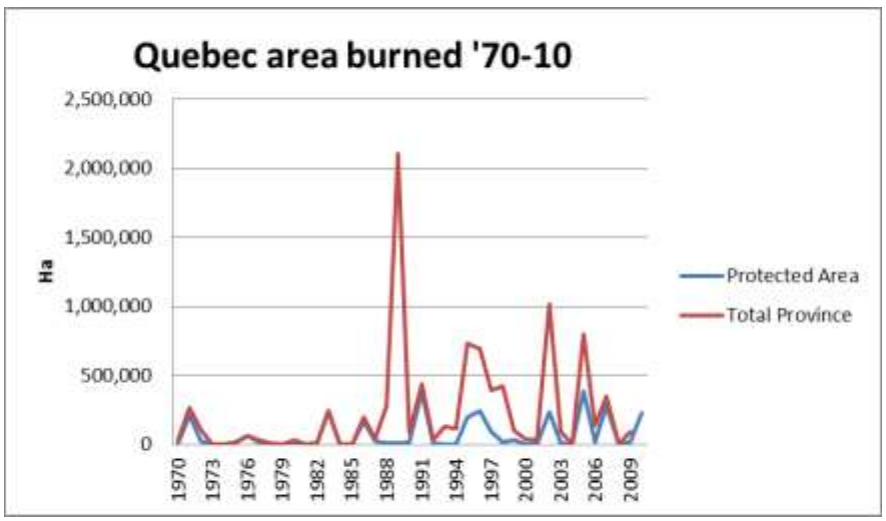


2. Recent Fire History 1970-2010

A closer focus on years 1970 to present seems useful for 2 reasons, to protect against biasing the analysis by including past periods where conditions and control capabilities differed markedly from the present, and to see whether similar general relationships prevail in this more recent period. In any case, most people would consider more recent data to be relevant for current assessment.

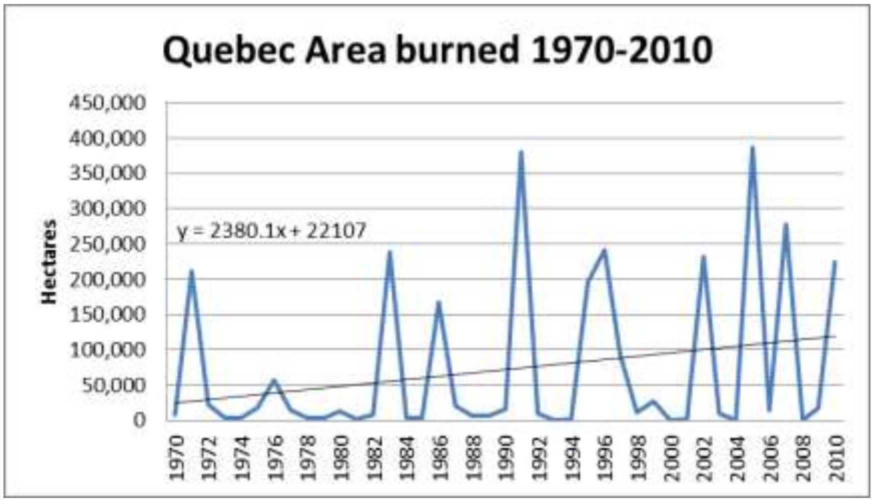
In these years, fire history for the province as a whole was quite different form the protected zone (Fig. 8). Here, we analyze only the protected zone as that is the area that gives rise to fire protection policy issues.

Figure 8.



First, since 1970, area burned has followed a highly irregular path but on a generally rising trend (Fig. 9). This occurred despite falling fire numbers (Fig 10), so that the higher area burned must reflect fires that were larger on average (Fig 11) (see also the analysis below of individual fires)

Figure 9.



This time seems to fall into two roughly equal subperiods: area burned averaged 34,752 Ha/yr from 1970-89, and then stepped up to a new average of 102,000 Ha/yr. This may be a more useful way of looking at this than the trendline over the entire period. The fire numbers do not display any clear break, however. But for the record the averages were: for 1970-1989, 1068 fires, and for 1990-2010, 754.

Figure 10

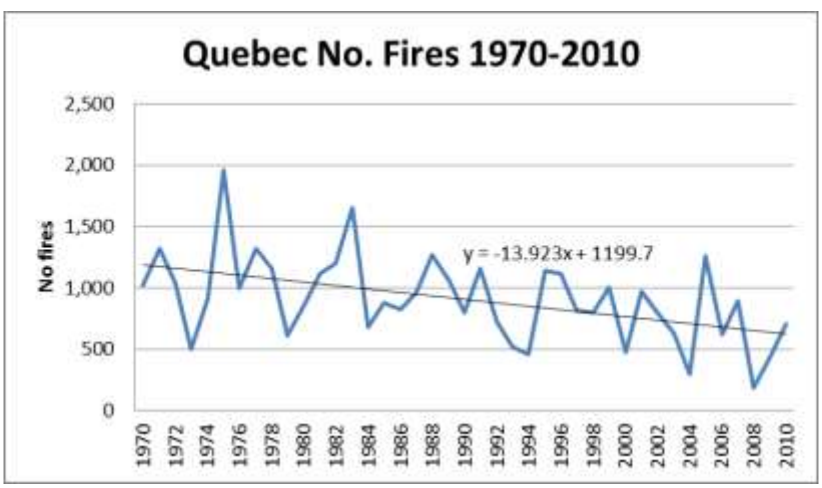
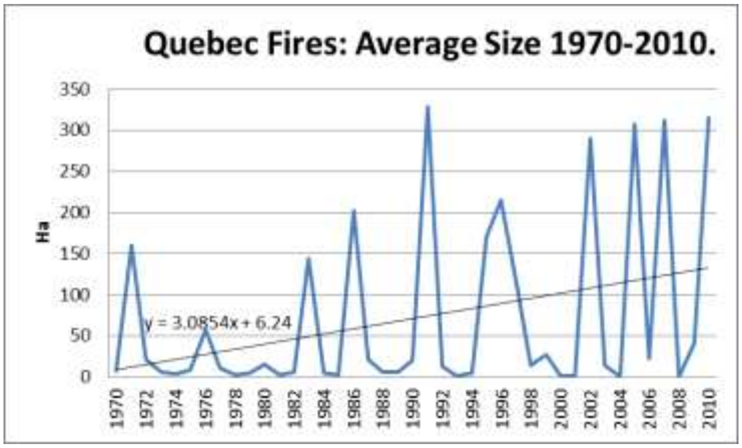


Figure 11.



The increase in fire sizes is just a mathematical identity so too much should not be made of it, especially given the skewness of the fire size distribution.

Coincidence of Peak Years with Other Jurisdictions

Since the early 70's, Quebec's peak fire years have not matched those elsewhere in the Compact. Its area burned is the principal source of variability of demand on firefighting resources in Eastern Canada and the Compact as a whole.(Fig 12A). In 2010, with its immense fires, it accounted for virtually all of it. And since 1980, Quebec has reached or exceeded 15% of Canada's area burned 6 times (Fig 12B). The other major province for area burned is Newfoundland. Despite similarities with adjacent portions of Quebec, their fire experience has been quite dissimilar (Fig. 13). Since 1970, Quebec exceeded 200,00 Ha of area burned 7 times, but only once did Newfoundland exceed its period average in those years. Newfoundland's worst fire years coincided with a serious fire year in Quebec only twice, in 1991 and 1996.

Fig. 12 A.

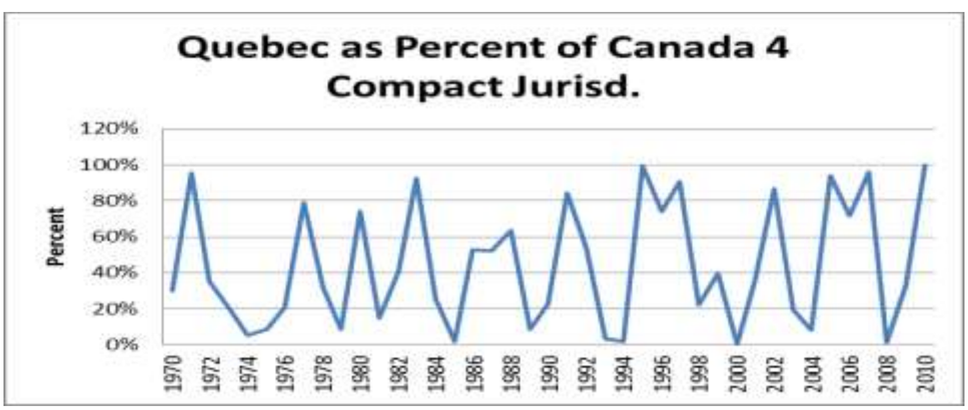


Fig 12 B Quebec as percent of all Canada

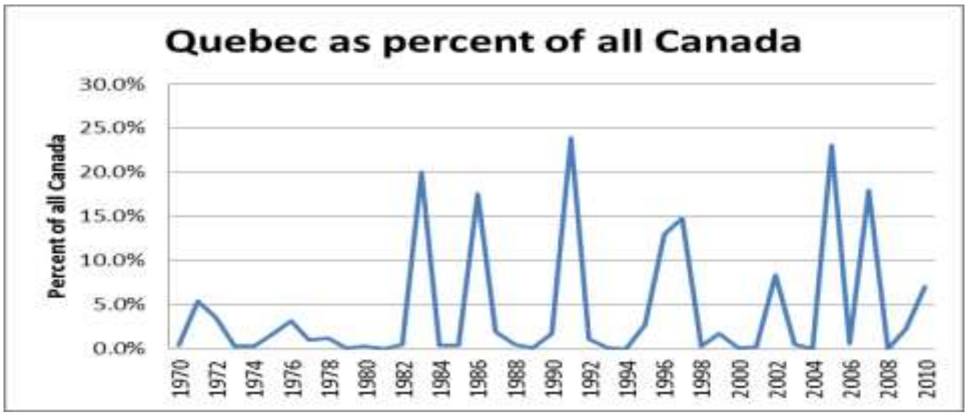
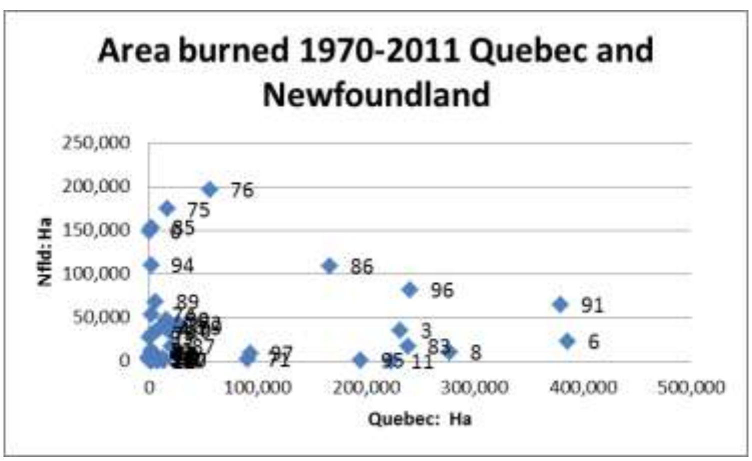
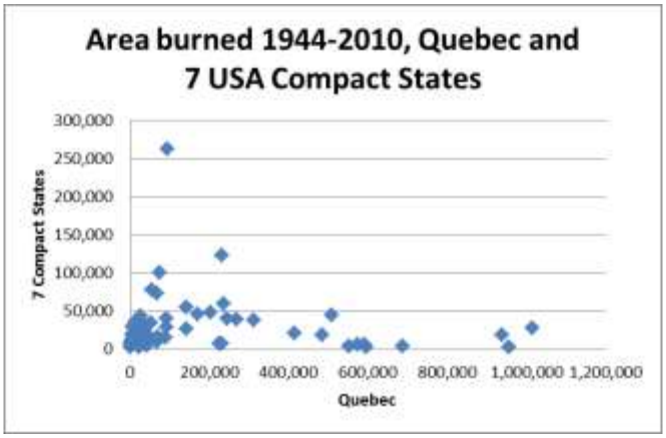


Fig 13



Comparing Quebec experience to the USA Compact members, the first point is that the scale of Quebec's area and extent of its natural fire is far larger than the USA, even adding all 7 states together. Adding the 7 states together, the worst ten years in USA all occurred before 1965 and 6 before 1950. The only one in the entire period to match a bad Quebec year was 1950, and that was the tenth ranking year. On the other side, Quebec experienced 9 years exceeding half a million acres burned from 1950-2010. Eight occurred after 1967, and all of those were in years that were mild in the US Compact states (Fig 14).

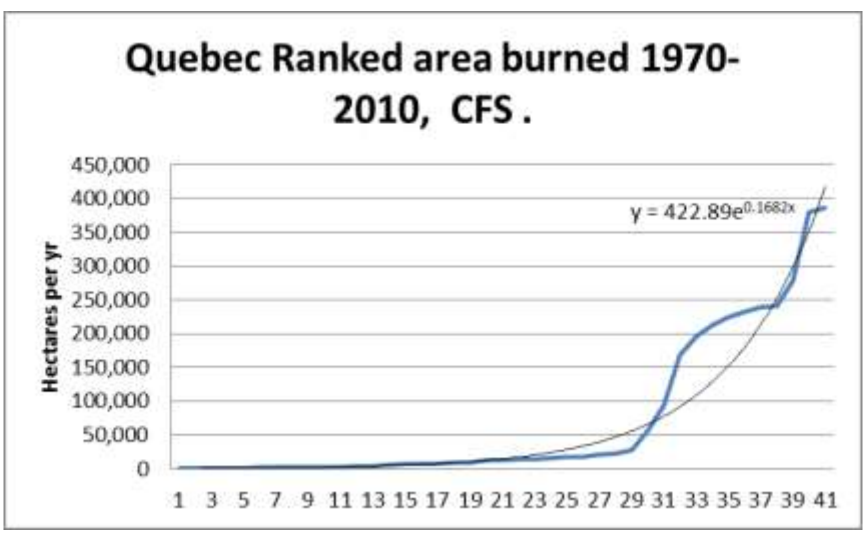
Fig. 14



Ranked Data 1970-2010

The ranked distribution of fire years (Fig. 15) shows the same pattern seen elsewhere: numerous years of modest area burned, with a small number of extremely high ones. This suggests we are dealing with a fat-tailed distribution with extreme events (Taleb, 2011).

Figure 15



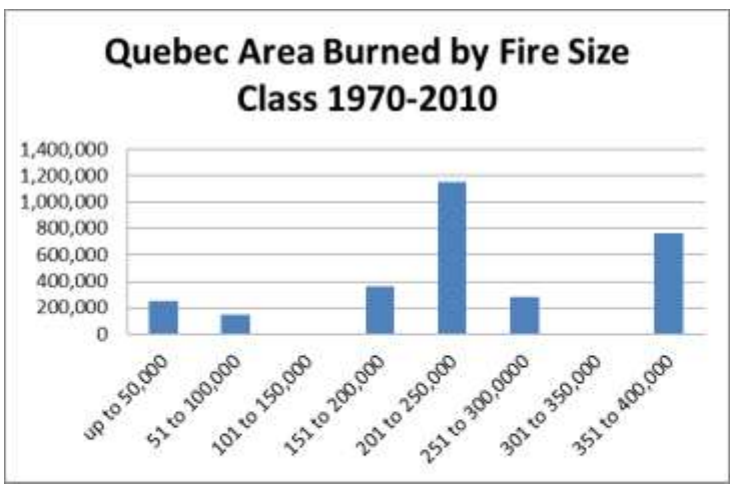
From 1970 to 2010, 35% of the cumulative area burned was burned in only 3 years (Table 3). The very largest fire, 107,000 acres, burned roughly half the entire area burned in 2010. Total area of recorded fires in this period was just under 3 million ha or 7.3 million acres. Note the discontinuous distribution when using this set of bin cut points. This shows vividly that just because no year larger than 400,000 hectares has occurred recently, this is not evidence that no larger fire year could ever occur. Not only could such a fire year occur, but there is no reason it could not burn far more than 400,000 Ha.

Table 3.

Quebec: Cumulative Area Burned by Annual area				
up to 50,000		249,221	8.4%	
51 to 100,000		150,699	5.1%	
101 to 150,000		0	0.0%	
151 to 200,000		363,126	12.3%	
201 to 250,000		1,147,979	38.8%	
251 to 300,0000		278,033	9.4%	
301 to 350,000		0	0.0%	
351 to 400,000		766,563	25.9%	

The small fires burn very little – which is why we want to keep them from becoming big ones. This chart (Fig. 16) conveys the data in the above table:

Figure 16.



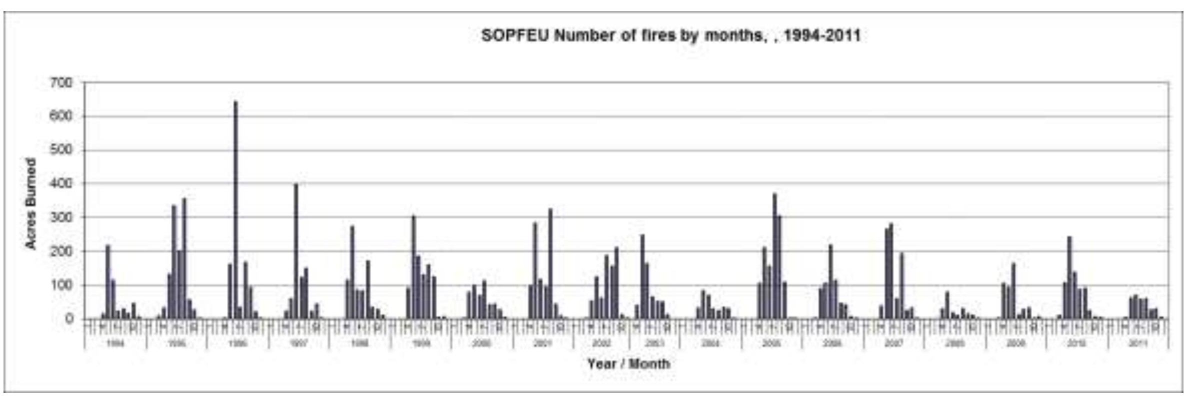
3. Analysis of Individual Fires Dataset 1994-2010

Sopfeu provided us with a detailed daily dataset on individual fires from 1994 to 2010. This gives us an unusual ability to "drill down" into fire occurrence history. The total area of fires 1994-2010, in the protected zone, based on this data was 1.7 million ha.

Fires by Month

This dataset certainly supports the notion that "there are no bad years, only bad months". Quebec, unlike some other Compact jurisdictions, typically has a unimodal fire season, with one very sharp peak month (Fig. 17, 18). This month moves around from year to year, however. Usually, "shoulder months" are also important. But the fire system must be primed to manage the peaks. In six of these years, the peak month for fire numbers was May. June was second most common peak month. The record month in this period was June 1996, when 642 fires burned. July and August each accounted for 2 peak months (Table 4). The month of June '96 alone exceeded the entire annual total number of fires in 9 of these years.

Figure 17



Comparing average monthly distributions for beginning and ending 5 year periods suggests a slight shift in occurrence from June to May, but this is partly the result of the huge June '96 fire siege (Fig. 18).

Figure 18

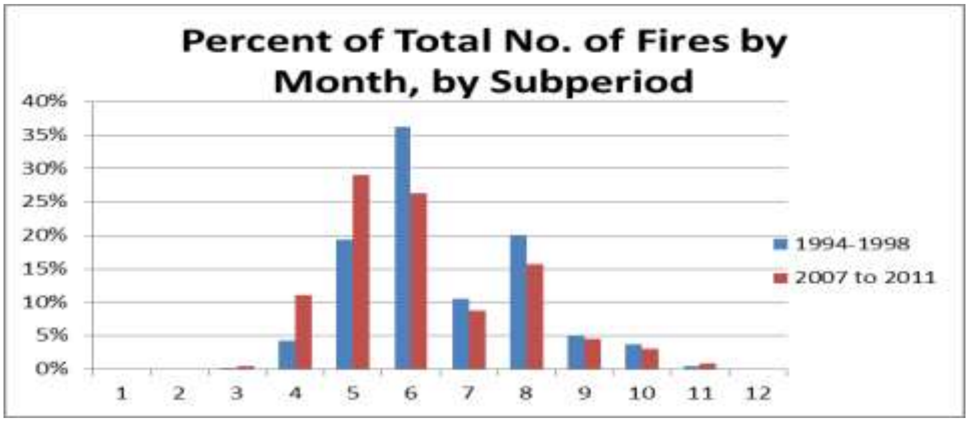


Table 4. Peak month each year, number of fires

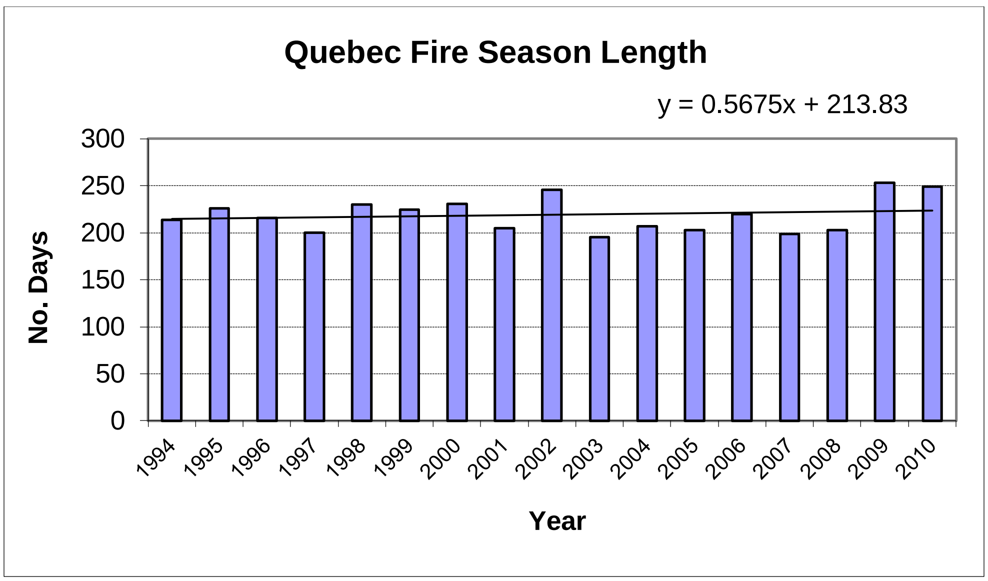
Year	No. of Fires	Month
1994	216	5
1995	356	8
1996	642	6
1997	399	6
1998	273	5
1999	305	5
2000	113	7
2001	325	8
2002	210	9
2003	248	5
2004	82	5
2005	370	7
2006	218	6
2007	281	6
2008	78	5
2009	164	6
2010	242	5
2011	69	6

Length of Fire Season

This database enables us to get a glimpse at the important question of whether the "fire season" is changing. This forces a clear definition; we decided to use the following: *Fire season is the number of days from the first reported fire to the suppression of the last fire in a given year.*

By this definition the season shows a slight upward trend (Fig. 19), but one so irregular that we cannot draw firm conclusions. Total season length by this definition can vary by four weeks from year to year.

Figure 19



If the data could be recovered over a long enough time period, other definitions of fire season should be explored, such as using fires only above one hectare.

Fire Size Distribution

More than half the fires in this period were one half ha or smaller (Table 5). But there were a total of 77 fires 10,000 ha and larger. The largest fire was 107,000 ha (in 2010); interestingly it did not occur in a heavy fire year.

Table 5. Quebec Individual Fire Size Distribution 1994-2010 (ha).

Size class: upper limit	*Frequency*	*Cumulative %*
0.5	7240	57.31%
1	2737	78.97%
5	1462	90.54%
25	603	95.31%
50	138	96.41%
100	100	97.20%
1000	181	98.63%
5000	96	99.39%
10000	30	99.63%
25000	35	99.91%
50000	6	99.95%
75000	3	99.98%
100000	2	99.99%
125000	1	100.00%

In much of the literature on this subject, the focus is on average “fire cycles” and on fire sizes. But for our purposes, we need to consider the cumulative area burned as well. As has often been noted, the very large fires do most of the damage, affect the most land, and generate most of the total cost and commitment of resources. For 1994-2010, fires above 10,000 ha accounted for less than 1% of fire numbers, but 69.6% of the area burned (Table 6). There were twelve fires exceeding 50,000 Ha in size.

Table 6. Quebec area burned by fire size classes

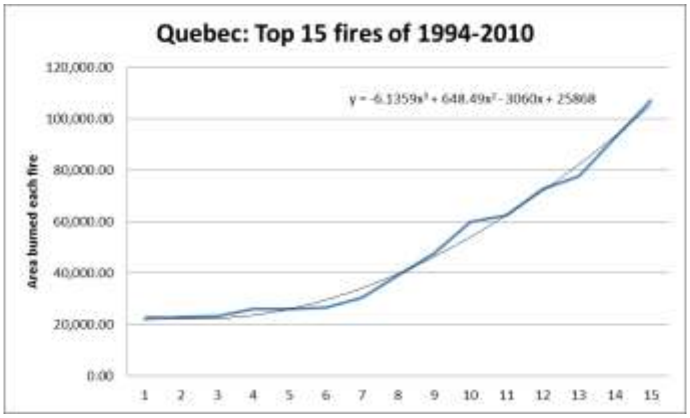
Area Burned by Size of Fires:		
Upper limit of size class	**Area burned**	**Percent**
1	1,344	0.1%
5	3,543	0.2%
25	6,469	0.4%
50	4,992	0.3%
100	7,124	0.4%
1000	69,666	4.0%
5000	227,342	13.1%
10000	208,145	12.0%
25000	544,538	31.3%
50000	195,896	11.3%
75000	194,822	11.2%
100000	170,239	9.8%
125000	107,004	6.1%
Total	**1,741,123**	1.0

In ranked data, we look only at the fires above 1000 Ha. This again displays the pattern of extreme sizes of a very few large fires (Fig. 20). To this chart we could not even fit a plausible equation. This illustrates again the principle that *the very largest fires operate in a different universe of conditions than all the rest.*

Fig20.

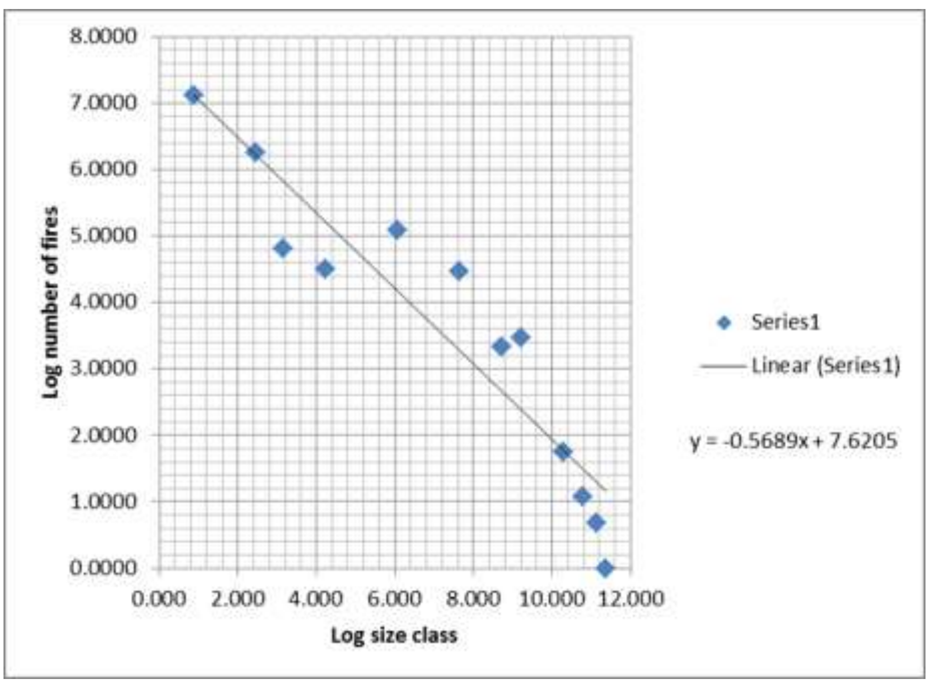
Judging roughly by eye, the shape of this distribution shifts dramatically at about the top 15 fires. So, we "truncate" the distribution and study only these fires, which after all pose most of the risk, damage, and cost. The ranked size distribution of these fires is roughly described by a cubic function (Fig. 21).

Fig. 21



The Quebec fire size distribution for this period (Fig. 22) roughly follows a Power Law distribution, as is true for wildland fires in other regions (Cuj and Perera, esp. p. 236; also Lin and Rinaldi, 2009). Notably, at the largest size classes, the fit is somewhat more loose. Analysts speak of "truncated" distributions, recognizing that the largest fires often do not follow trend.

Figure 22 Power Law Distribution all fires larger than 1 Ha 1994-2010.



The “Fire Triangle”, 1994-2010

This portion of the intensive protection zone to the north and west contains not only fire adapted and vulnerable forest types but its weather regime is suited to large fires. Perhaps this is not a coincidence. Snowpacks are not heavy there, and often have melted away fairly early in the spring. Because of the importance of this region as a spawning ground of megafires, we analyse the data separately[3]. This region accounts for 688,00 Ha of fires in this period, about 40% of cumulative area burned in the entire province. This area has been exceedingly volatile in its annual fire behavior (Fig 23). Its burning is concentrated strongly in May and June (Fig 24). The largest fires in that region have been huge, though the record breaking fires of 1991 and 2010 did not occur there. The region has equaled or exceeded 50,000 ha of annual burning 5 times since 1994. This region experienced just over 1,000 fires 0.1 Ha and larger.

Figure 23

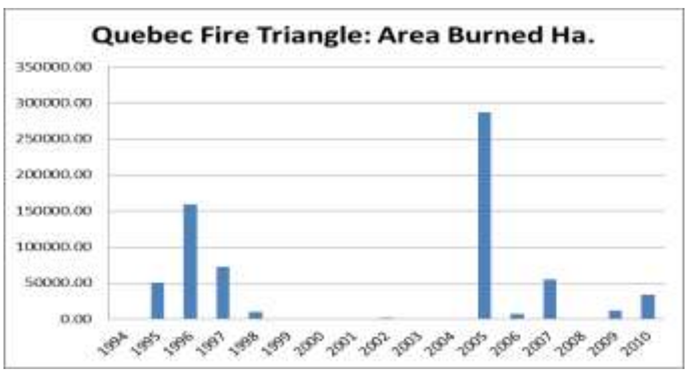
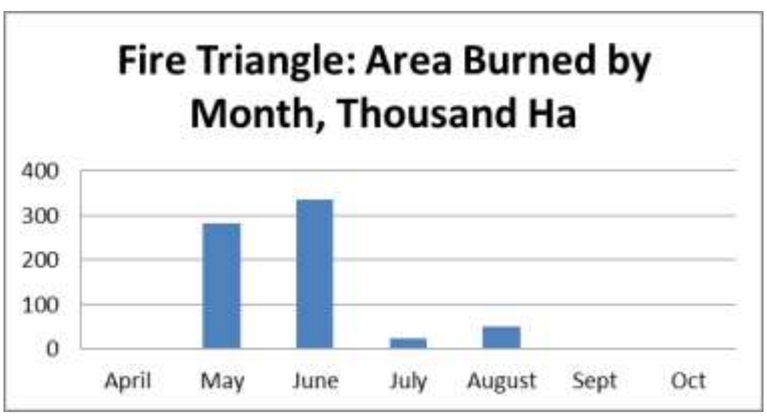


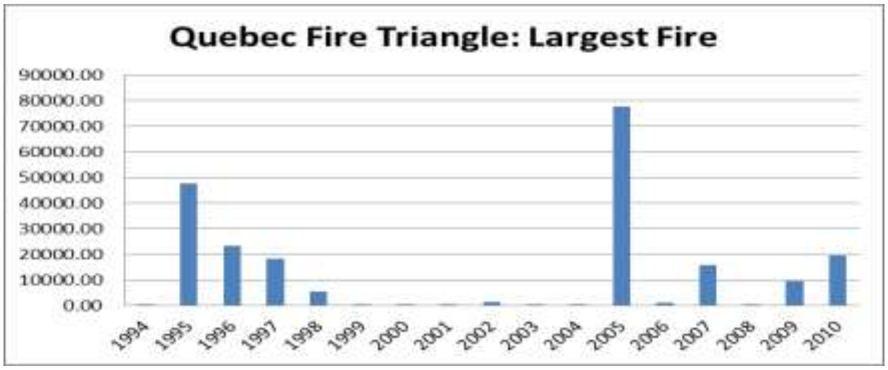
Figure 24



[3] This analysis uses zones 1,4, and 5 in the Sopfeu database; these map codes do not match the maps reproduced here.

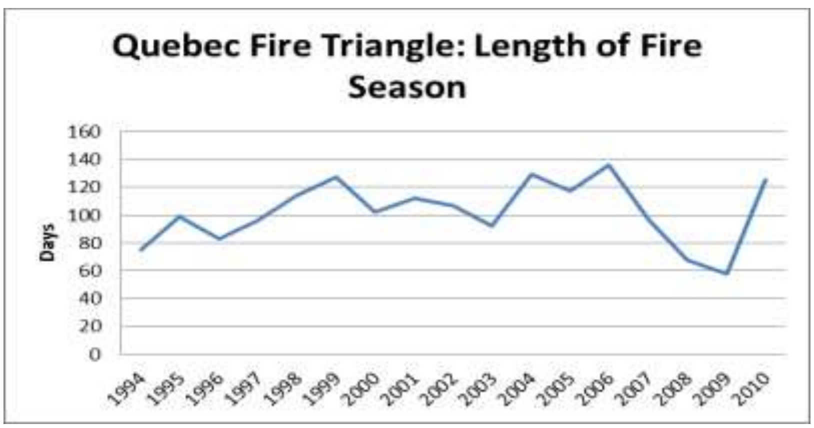
Massive fires clump together: of the top 20 fires in this region and period, 9 occurred in 2005 alone. In these years, 3 fires exceeded 20,000 Ha.

Figure 25



For a region so far north, the season is fairly long, with many years well over 100 days since 1994 (Fig 26)

Figure 26



For this region we also present some of the familiar extremes analysis. The Fire Triangle presents some of the most extreme behavior of any area in the Compact (Figs 27, 28). The excess plot provides one perspective. It is simply a plot of the amount by which each successive large fire exceeds the previous one. Such plots are commonly used in analysis of extreme events.

Figure 27

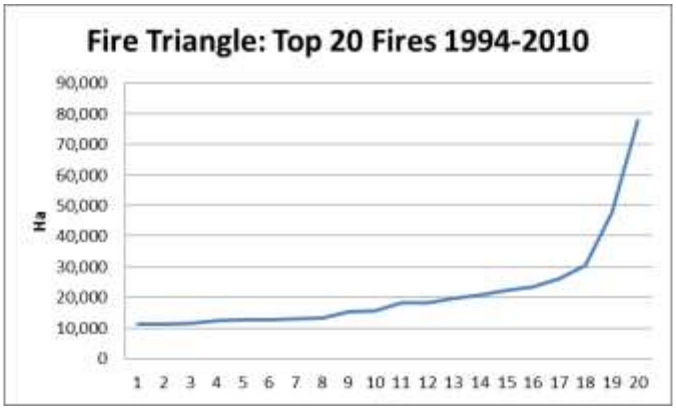
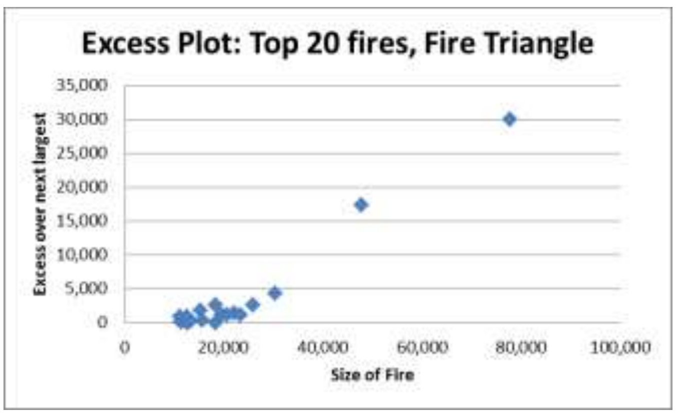


Figure 28

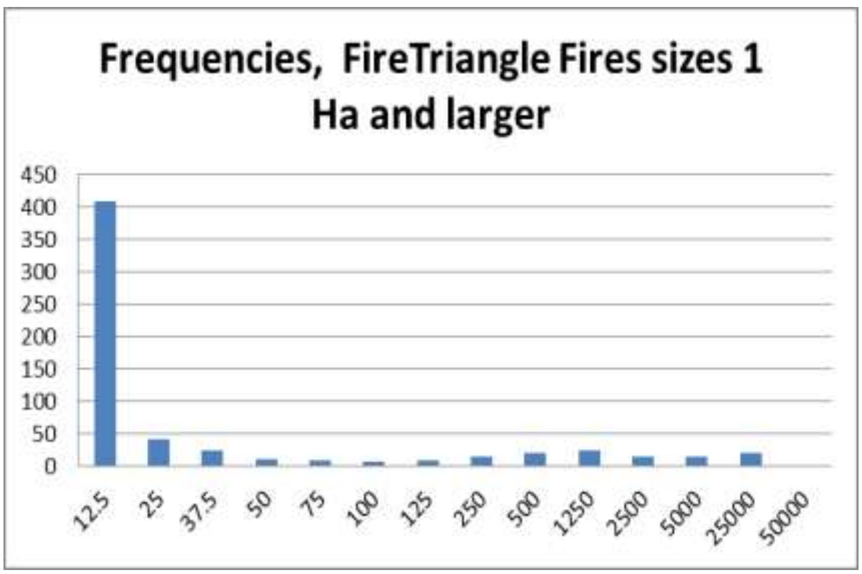


The fire size distribution in this zone of Quebec is exceedingly ill-behaved from a statistical standpoint (Table 7 and Figure). Here we only tabulate fires 1 Ha and larger. Experimenting with various bin sizes, including uniform deciles, has not yielded a straightforward way of statistically depicting this size distribution. What we see instead is a trimodal distribution in the way the bins are identified here. About 2/3 of the fires are smaller than 25 Ha. Fires are few in the 150-250 size range, then a secondary peak occurs in the 1000 to 2500 range, and then a peak in the 100,000 to 500,000 range.

Table 7. Frequency summary by size class -- Fire Triangle

Upper limit of size class	*Frequency*
25	409
50	43
75	25
100	11
150	9
200	7
250	9
500	15
1000	21
2500	24
5000	15
10000	16
50000	20
100000	1

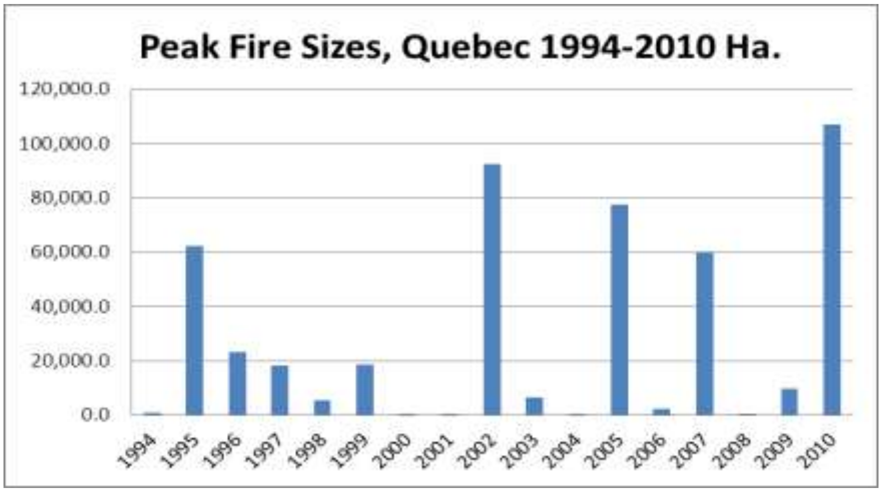
Figure 29.



Return periods of largest annual fires

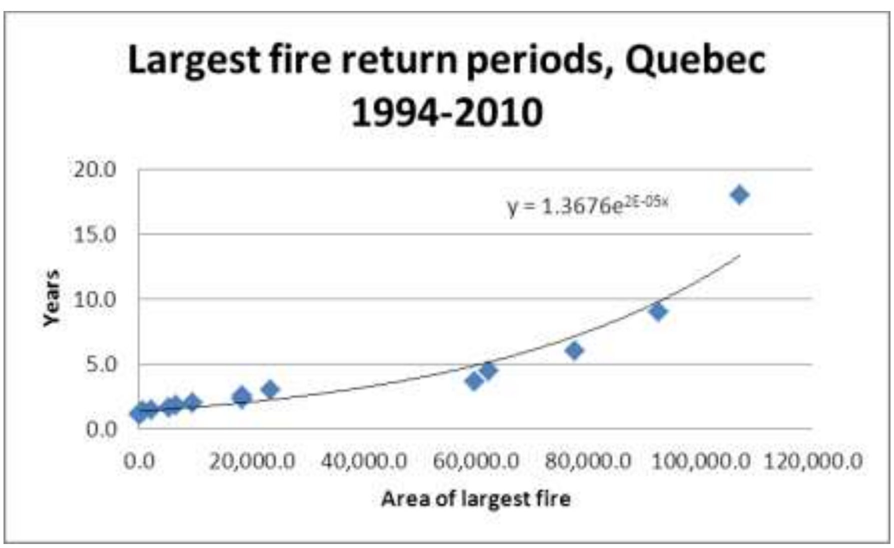
We now return to province-wide analysis. The largest fires in each year since 1994 are shown in Fig. 30. The striking feature is the high variability in size of each year's largest fire. Over this period, five fires exceeded 60,000 Ha.

Figure 30.



The largest annual fires can be subjected to the same return period analysis as was done above for fire years. Based on this analysis, it would be reasonable to expect a fire of 90,000 ha or larger to occur on average once in ten years (Fig. 31). With this small set of data this analysis cannot be definitive, but only makes a very general point. Whether to include earlier years which had fewer large fires would be a policy decision and would need to be based on much more detailed analysis. In particular, extrapolating to longer return periods than the run of data in this chart would be speculative.

Figure 31.



A recent report provides a synoptic history of recent large fire activity across Canada, from the 1960s to the 00s (Krezek-Hanes et al 2011; partially updated in Federal, Provincial and Territorial Governments, 2011, p. 96-97). It was based on mapped datasets of fires larger than 2 square kilometers. This assessment found nationally that area burned by large fires rose dramatically from the 60's to the 80s, remained the same in the 90's, then declined I the 00s. This analysis found that fire risk had increased in Northeast Quebec, but fallen in western Quebec, along the North Shore, and in the Atlantic Provinces. Over the 1959-2007 period, annual area burned in Quebec's Boreal Shield was 0.49 % of the forest area; this ecozone accounted for 37% of national area burned, and the fire season was 143 days.

Fires by Forest Type

Reflecting the geography of fire in Quebec, the boreal types account for most of the fires. From 1994-2010, the breakdown of fire numbers by type was:

Boreal spruce	29%
Leafless aspen	22
Boreal mixedwood - green	16
Boreal mixedwood – leafless	12
Mature jackpine	6

Together these accounted for 85% of the fires.

Daily Fire Activity

The Sopfeu dataset enables us to dissect a fire season's activity in a number of different dimensions that are highly relevant for understanding impact of fires on resources. The total number of fires active on a given day is a useful indicator of stress on firefighting resources. Over the period 1994 to 2011, Quebec experienced 27 days with 200 or more fires burning at once. On 96% of the days, 50 or fewer fires were burning (Table 8).

Table 8.

Size class Fires per day	No fires burning
50	3977
100	114
150	24
200	15
250	2
300	3
350	3
More	4
Total	**4142**
Source: Sopfeu, Jan 2012.	

In future research, it would be valuable to tabulate the extent to which runs of consecutive days exceed various levels of fires/day

While 80% of the fires burned 1 or 2 days, and some were out by the time they were reached, from 1994-2010, 826 fires burned 10 days or longer (Table 9). It only takes a few such fires to consume even a large organization's surge capacity. Even once contained, a fire may require continued monitoring and may represent a contingent claim on resources should it revive again.

Table 9 . Quebec: Number of fires by number of Days they Burned, 1994-2010.

Bin	*Frequency*	*Cumulative %*
2	3559	28.17%
1	3262	53.99%
4	3103	78.55%
6	1066	86.99%
8	433	90.41%
0	386	93.47%
10	184	94.93%
12	166	96.24%
14	98	97.02%
16	90	97.73%
18	55	98.16%
More	45	98.52%
24	32	98.77%
20	31	99.02%
22	29	99.25%
26	29	99.48%
34	16	99.60%
28	15	99.72%
36	15	99.84%
32	13	99.94%
30	7	100.00%

Largest Fires over the Period

It is of interest to look at the largest fires not only in aggregate statistical bundles but as they actually occurred over time[4]. Arbitrarily we choose 1000 ha as a large fire. Plainly, what is considered “large” would vary by resource conditions, fire hazard levels, and proximity to settlements. This analysis highlights the extraordinary variability in Quebec’s fire experience. From 1994-2010, in five years there were no fires larger than 1000 hectares (Fig. 32, Table 10). For very large fires of 10,000 ha or more, in 2005 there were 14, and in 1996 there were 9. The largest during this period occurred in 2010— it burned 107,000 ha. The highly variable occurrence of these largest fires creates the bulk of the uncertainty in pre-season planning for resources, as well as

[4] Alexander (2010) lists catastrophic fires across Canada, including one in Quebec, near Lac St Jean in the 19th century

within–season decisions allocating resources. It also creates the major challenges for the various compacts and arrangements for providing reinforcements when needed.

Figure 32.

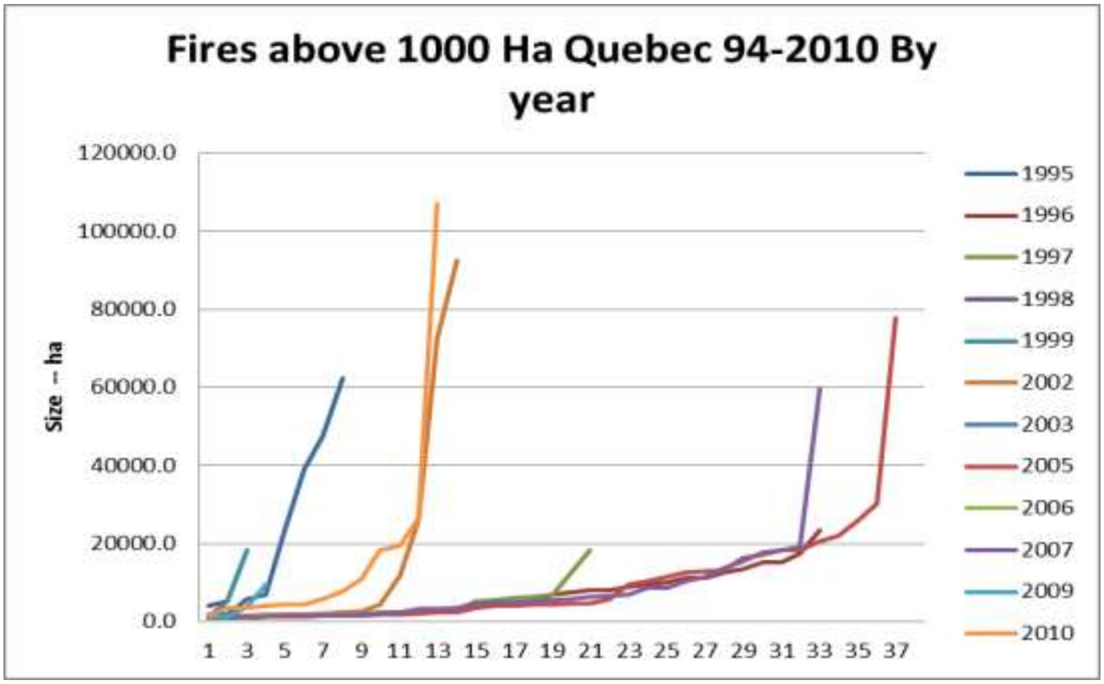


Table 10.

Quebec Top 15 Fires, 1994-2010		
Date	Area	Ratio to next largest
05-05	22,185.00	1.07
08-95	23,105.00	1.04
06-96	23,353.00	1.01
05-05	25,959.00	1.11
07-02	26,127.00	1.01
06-10	26,650.70	1.02
05-05	30,328.00	1.14
08-95	39,122.00	1.29
08-95	47,709.00	1.22
05-07	59,846.90	1.25
08-95	62,317.00	1.04
07-02	72,658.00	1.17
05-05	77,698.00	1.07
07-02	92,541.00	1.19
05-10	107,004.10	1.16

Fires by Causes

Sopfeu records of fire causes are available from the 1930's. To average out variability and make trends easier to see, we have reduced these to decadal totals. These numbers need to be read in light of the view that attribution of fires to causes is an inexact science. Still, the trends are of interest. The dramatic shift in lightning as a cause of area burned is a key trend (Table 11, Figs 33 and 34). This is likely a result of reducing human causes, and of early detection and suppression of such fires.

As we have seen above, the number of fires per year has fallen. Very broadly speaking, as land uses have changed and regulations have become institutionalized, human causes have fallen as percent of all recorded fires. Lightning fires have increased in size as those of most other causes have fallen. They now account for about 90% of all area burned, thought they are only 34% of the number of fires.

Table 11

Table	Quebec Forest fires by cause: percent distribution of numbers of fires and area burned, by decade, 1930-2010									
	PERCENT OF TOTAL NO. FIRES									
	FOUDRE	CH.FER	OP.F	OP.I	INC	RÉS	RÉC	DIV	TOT.HUM	TOTAL
1930-39	4.9%	2.5%	2.0%	0.7%	2.7%	41.6%	22.0%	23.6%	95.1%	100.0%
1940-49	9.7%	3.4%	5.3%	0.8%	1.2%	25.4%	34.5%	19.6%	90.3%	100.0%
1950-59	13.4%	3.3%	6.7%	3.4%	2.0%	15.6%	42.4%	13.1%	86.6%	100.0%
1960-69	23.0%	2.9%	8.3%	3.2%	2.8%	5.7%	39.1%	14.9%	77.0%	100.0%
1970-79	20.1%	4.2%	7.9%	10.6%	4.3%	13.7%	35.0%	4.2%	79.9%	100.0%
1980-89	17.8%	2.9%	6.5%	10.4%	5.5%	22.0%	34.1%	0.8%	82.2%	100.0%
1990-99	32.3%	1.8%	6.1%	6.8%	4.2%	21.0%	27.4%	0.4%	67.7%	100.0%
2000-10	33.6%	1.7%	6.2%	5.3%	3.7%	23.9%	24.3%	1.3%	66.4%	100.0%
	PERCENT OF TOTAL AREA BURNED									
1930-39	3.7%	0.2%	8.8%	0.0%	6.8%	41.3%	18.1%	21.1%	96.3%	100.0%
1940-49	7.9%	1.2%	13.4%	0.2%	1.2%	27.0%	22.3%	26.8%	92.1%	100.0%
1950-59	23.5%	3.6%	17.7%	13.1%	1.8%	11.9%	23.4%	5.0%	76.5%	100.0%
1960-69	24.3%	0.2%	22.6%	0.5%	2.6%	2.9%	25.8%	2.2%	57.0%	100.0%
1970-79	33.1%	2.8%	14.5%	3.3%	2.2%	2.6%	28.3%	13.2%	66.9%	100.0%
1980-89	88.0%	0.2%	1.7%	0.7%	0.4%	1.1%	6.2%	1.6%	12.0%	100.0%
1990-99	79.2%	0.0%	12.0%	4.2%	0.2%	1.1%	3.3%	0.0%	20.8%	100.0%
2000-10	89.8%	0.2%	1.0%	0.1%	0.1%	0.2%	8.7%	0.0%	10.2%	100.0%
			Source: Sopfeu.							

Figure 33

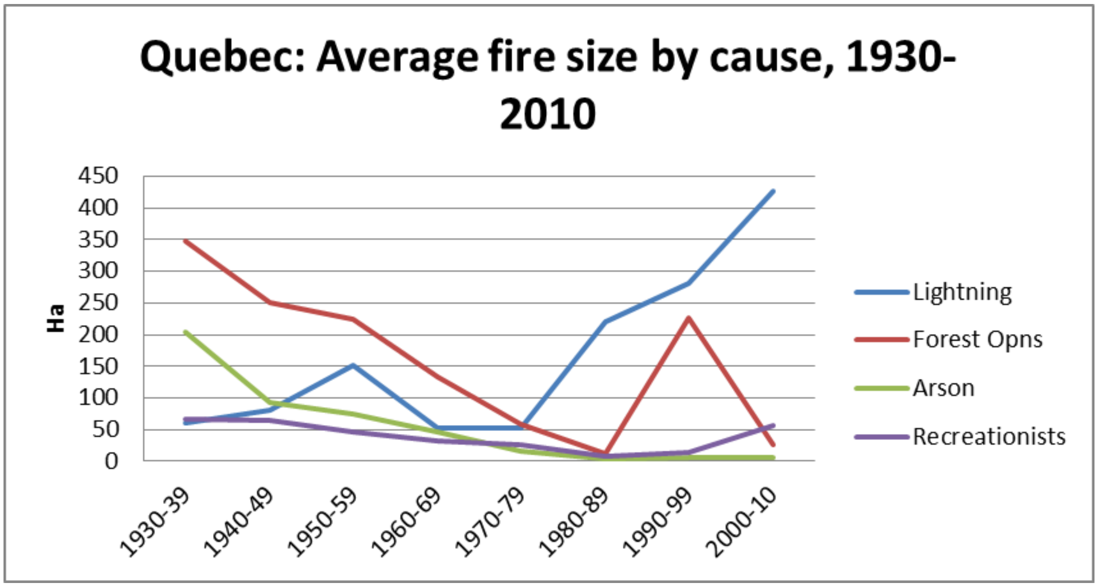
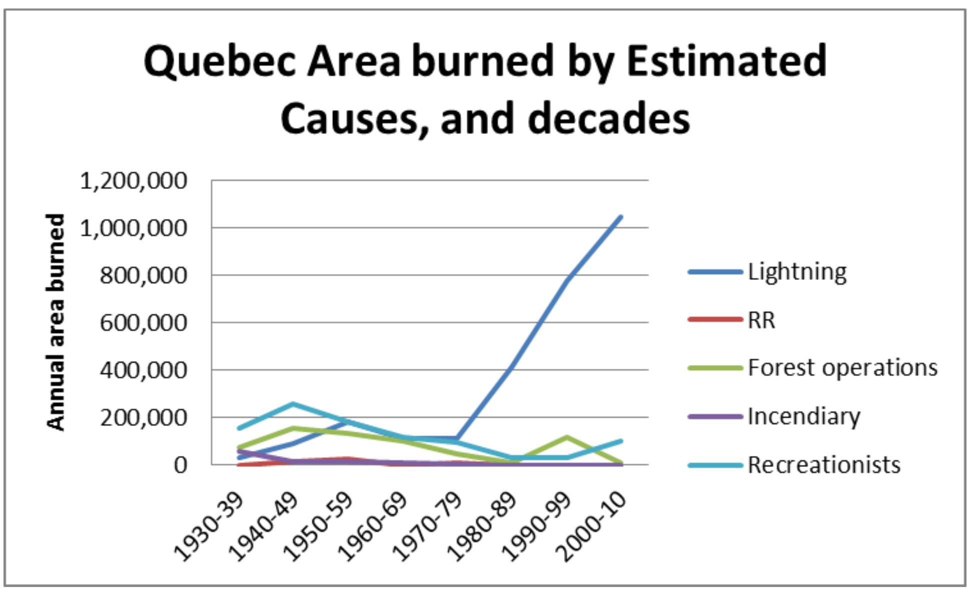


Figure 34



Source: Sopfeu

Conclusion on Extreme Fires:

In an important analysis of fire data in the southern Sierras in California, Holmes et al (2007) applied extreme value methods and reached a conclusion that is relevant to much of the Compact region:

A major conclusion of this chapter is that large wildfires are intrinsic to fire-adapted ecosystems and that memorable events such as the Yellowstone fires of 1988 (e.g., Romme and Despain 1989) and the McNally fire of 2002 in SQF cannot be simply dismissed as catastrophic outliers or anomalies. Rather, the underlying fire generation process operates in a fashion such that wildfires greatly exceeding those represented in local or regional fire histories may occur sometime in the future. Infinite variance in wildfire production, or "wild randomness", greatly complicates planning operations for large fires. For example, moving average models of acres burned in large fires likely provide poor forecasts of the size of future large fires because the first moment converges very slowly to its true value in a wildly random state. The development of decision-making strategies for resources exposed to the state of wild randomness remains a challenge for risk managers in the finance and insurance sectors as well as for wildfire managers.

Fire Occurrence History: Connections to Weather

We have found that weather data to carry out the same types of analyses that we did in the US states are not readily available. But for Eastern Canada, in contrast to the northeast US, there is an abundance of published scientific literature on the topic.

A quick review of recent publications on this topic leads to a number of results, summarized very briefly here:

1. Teleconnections with conditions in the Gulf of Alaska, and Pacific, and North Atlantic appear to influence drought and hence fire occurrence.
2. Temperature, through its role in drying fuels, is a key variable and has been generally increasing in our region.

3. Growing season and ice free seasons are rising and hence, very likely length of fire seasons.
4. Growing season rainfall has been rising slightly, but the frequency of rainfall within the year is more important for fire incidence than the total amount.
5. Low snow winters and early springs can accelerate fire seasons by opening growing seasons with low soil moisture reserves.
6. Considerable work has been done on regional weather systems in their influences on fire. An excellent review, still understandable through the technical meteorology jargon, is Fauria and Johnson, 2008.

Drought history in eastern Canada has been intensively studied. Work by Girardin and collaborators have developed multi-century reconstructions (Fig. 35). The Canadian Drought Code (CDC) is a drought index, measuring soil moisture conditions. The chart shows drought code and temperature for two study regions, the eastern Abitibi Plains APe), and the Southern Laurentians (SL), both in Quebec. The results show that drought peaks occur roughly once every ten to 20 years, but they are not nearly as intense as in the Plains. But fire history shows, they do not need to be. Correlations between annual drought indices and are burned are modest, as we would expect (Girardin, 2004, p. 117 Girardin, 2006, p. 284), but clearly drought plays a role.

Figure 35 :

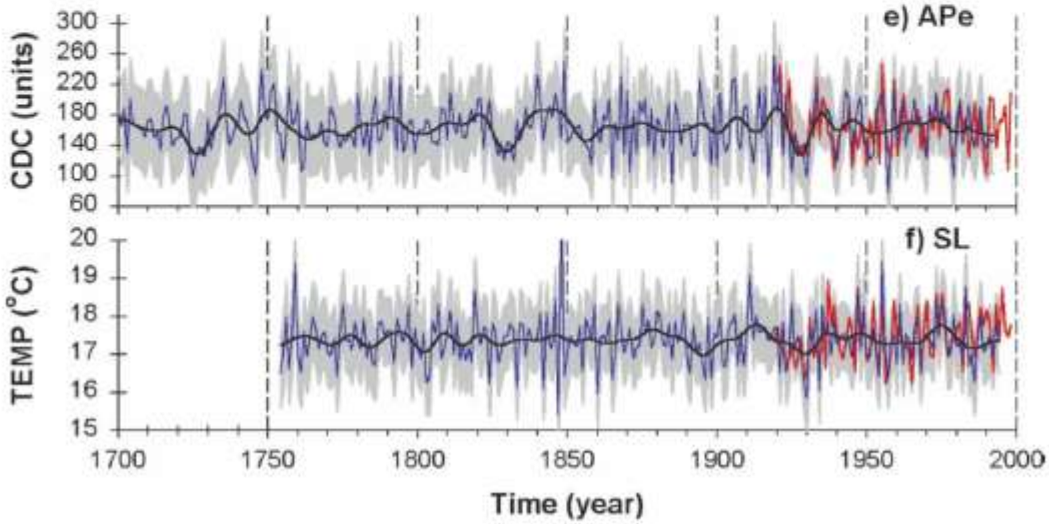


FIG. 4. Reconstructions of the mean July CDC (units) for the (a) BP, (b) LS, (c) LN, (d) APe, and (e) APw regions. The CDC scale ranges from soil saturation (zero) to extreme drought (>300). (f) Reconstruction of the SL mean July–August temperature (°C). Shaded area: error bars plotted against the time period for which a given calibration model was used. Red lines show instrumental 1913–98 records. Variance in the instrumental records was adjusted to correspond to reconstructions. Smoothed curves (black lines) were obtained from a polynomial fitting (order 6) across a moving 10-yr window within the data. These curves accounted for (a) 22.0%, (b) 22.8%, (c) 24.9%, (d) 35.1%, (e) 19.2%, and (f) 8.1% of the variance in the reconstructions.

Source: Girardin et al 2006, p. 1932

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Appendix Table

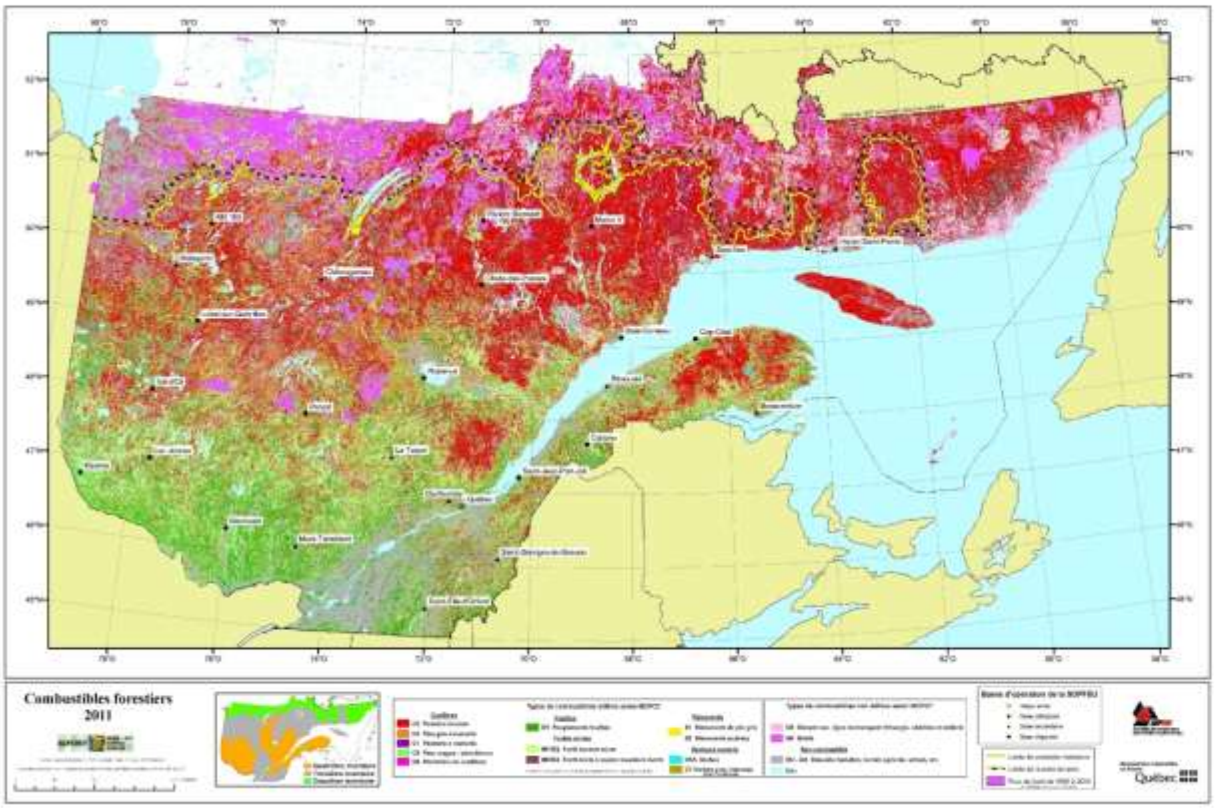
Quebec Fire History 1922-2010

Source: MRN, winter 2012

Year	Area Burned (Ha)	Area Burned (acres)	No. Fires	Year	Area Burned (Ha)	Area Burned (acres)	No. Fires	Year	Area Burned (Ha)	Area Burned (acres)	No. Fires
1922	300,909	743,245	1,608	**1951**	108,324	267,560	852	**1981**	2,481	6,129	1114
1923	1,230,133	3,038,429	997	**1952**	27,516	67,966	604	**1982**	7,970	19,686	1202
1924	20,727	51,197	205	**1953**	205,651	507,958	2272	**1983**	238,903	590,090	1653
1925	7,770	19,193	323	**1954**	4,755	11,745	380	**1984**	3,082	7,613	683
1926	8,156	20,145	210	**1955**	126,498	312,451	1266	**1985**	2,697	6,661	880
1927	14,048	34,699	265	**1956**	8,377	20,691	400	**1986**	167,550	413,849	830
1928	1,639	4,048	104	**1957**	30,190	74,569	883	**1987**	20,934	51,708	959
1929	4,138	10,220	220	**1958**	2,836	7,005	384	**1988**	7,143	17,643	1266
1930	15,632	38,612	413	**1959**	36,668	90,570	693	**1989**	6,497	16,048	1064
1931	14,597	36,055	763	**1960**	20,613	50,914	883	**1990**	16,065	39,679	798
1932	438,621	1,083,395	1214	**1961**	26,959	66,589	861	**1991**	379,892	938,334	1156
1933	40,034	98,884	1200	**1962**	99,191	245,003	1252	**1992**	9,439	23,314	723
1934	84,158	207,871	891	**1963**	37,030	91,464	1202	**1993**	984	2,430	518
1935	113,409	280,121	1125	**1964**	68,332	168,781	1168	**1994**	2,179	5,383	463
1936	11,392	28,138	371	**1965**	10,777	26,620	763	**1995**	195,577	483,074	1145
1937	45,754	113,011	867	**1966**	7,362	18,184	751	**1996**	241,225	595,826	1120
1938	56,315	139,099	1136	**1967**	36,269	89,585	905	**1997**	93,753	231,571	819
1939	32,000	79,040	856	**1968**	410,823	1,014,733	1134	**1998**	11,845	29,258	797
1940	16,690	41,225	875	**1969**	1,247	3,079	613	**1999**	27,807	68,683	1005
1941	1,032	2,549	499	**1970**	4,824	11,915	1017	**2000**	794	1,961	475
1942	253	625	168	**1971**	91,090	224,993	1275	**2001**	1,358	3,354	970
1943	2,089	5,160	172	**1972**	27,694	68,405	1084	**2002**	232,443	574,134	803
1944	93,524	231,005	974	**1973**	3,021	7,461	508	**2003**	9,048	22,348	627
1945	20,964	51,780	988	**1974**	3,018	7,455	911	**2004**	258	638	300
1946	21,622	53,407	993	**1975**	17,058	42,133	1963	**2005**	386,671	955,078	1258
1947	37,725	93,181	1110	**1976**	56,903	140,551	996	**2006**	13,768	34,007	623
1948	95,302	235,395	1275	**1977**	14,140	34,927	1321	**2007**	278,033	686,742	892
1949	57,546	142,138	1445	**1978**	3,641	8,993	1160	**2008**	133	328	189
1950	82,059	202,686	1311	**1979**	3,200	7,905	615	**2009**	17,948	44,332	441
				1980	13,186	32,570	861	**2010**	223,358	551,694	707
								2011	2,528	6,244	311

Appendix : Maps of Fireprone Regimes

Turn this to Landscape ----



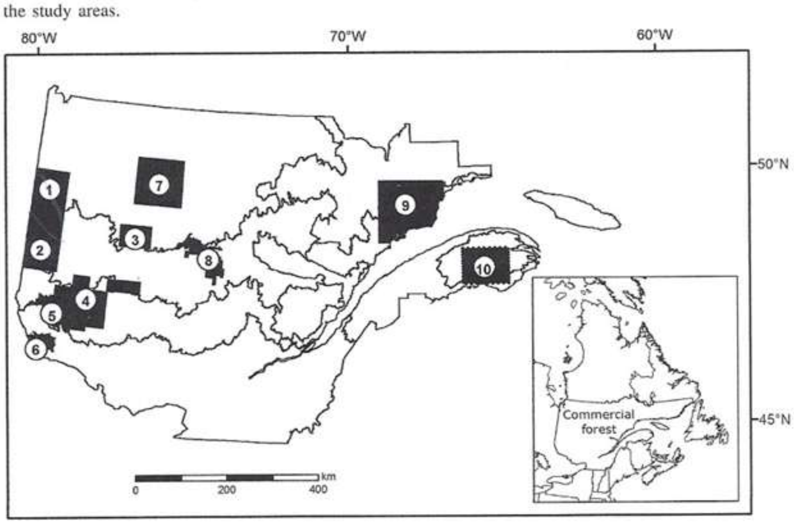
Source: Sopfeu

Table 1. Geographic coordinates and other details for each of the study areas.

Site No.	Study area	Bioclimatic subdomain	Reference	Latitude (°N)	Longitude (°W)	Area (km^2)
1	Abitibi northwest	Western black spruce – moss	Bergeron et al. 2004	49.50	79.00	7 942
2	Abitibi southwest	Western fir – white birch	Bergeron et al. 2004	48.50	79.00	7 777
3	Abitibi east	Western black spruce – moss	Kafka et al. 2001	48.88	76.29	3 294
4	Abitibi southeast	Western fir – yellow birch	Lesieur et al.*	48.55	77.28	13 156
5	Temiscamingue north	Western fir – yellow birch	Grenier et al. 2005	47.19	78.52	2 850
6	Temiscamingue south	Western sugar maple – yellow birch	Drever et al. 2006	46.37	78.45	1 793
7	Waswanipi	Western black spruce – moss	Le Goff et al.†	49.99	75.73	10 950
8	Central Quebec	Western fir – white birch	Lesieur et al. 2002	48.55	74.31	3 844
9	North shore	Eastern black spruce – moss	Cyr et al.‡	49.63	68.00	14 135
10	Gaspésia	Eastern fir – white birch	Lauzon 2004	48.52	65.79	6 480

Note: Study area locations are shown in Fig. 1.
*Lesieur, D., Gauthier, S., and Bergeron, Y. Unpublished data.
†Le Goff, H., Bergeron, Y., Flannigan, M., and Girardin, M. Historical fire regime shifts related to climate teleconnections in the Waswanipi area, central Quebec, Canada. Submitted for publication.
‡Cyr, D., Gauthier, S., and Bergeron, Y. Manuscript in preparation.

Fig. 1. Location of the study areas throughout the bioclimatic regions of Quebec's commercial forests. See Table 1 for names and other details of the study areas.



7= fir

Source: Bergeron et al 2006. P. 2739.

Appendix

Several Megafires.

Note to readers: we would welcome any additions to this short set of vignettes.

Baie Comeau Fire, summer 1991.

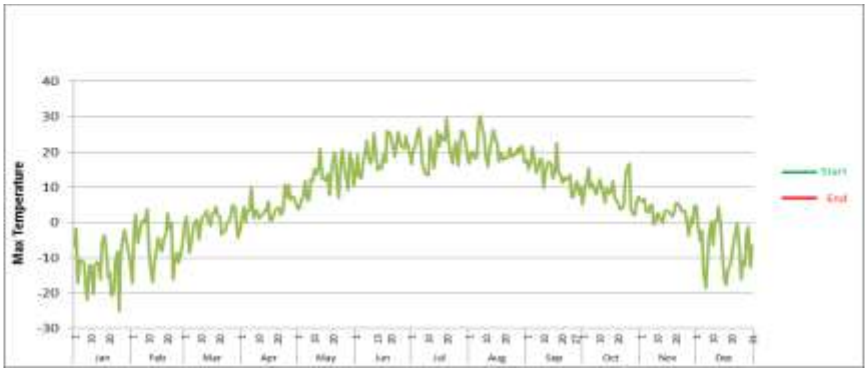
This fire burned 201,000 ha of wildland, accounting by itself for 53% of the Province's total area burned in that year. This fire alone exceeded the annual total for 13 of the succeeding years. As described by Sopfeu meteorologist Olivier Lundquist (pers comm):

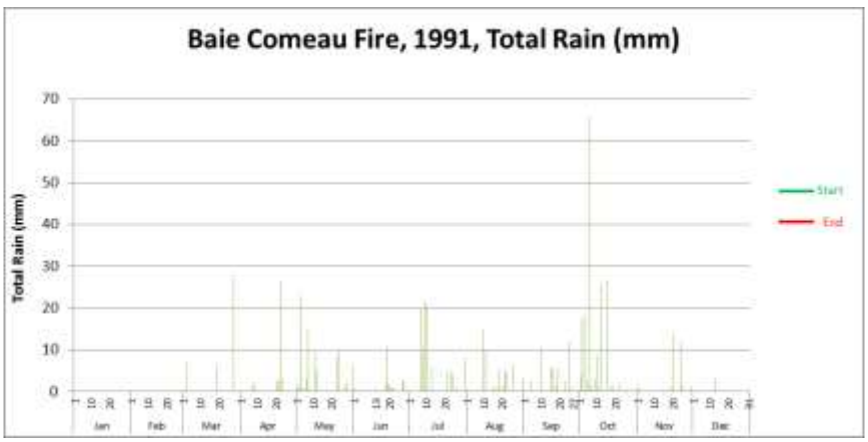
"….while it wasn't particularly hot leading up to the 13th of June, it was particularly dry during the 12 days prior, with only 1.8 mm of rain. At 12:32 pm on the 13th of June, the fire was started by some forestry equipment, and history tells the rest. The fire was officially pronounced extinct on the 27th of September after burning 201,000 ha (496682 acres) of wildland.

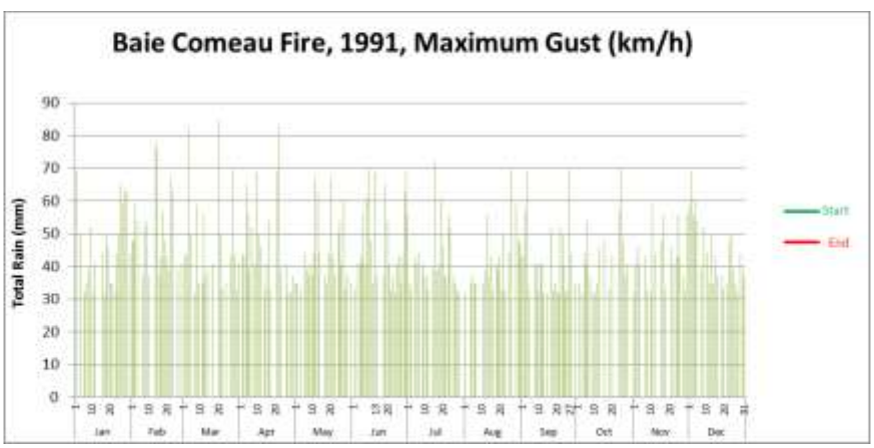
The weather data does not seem all that unusual. Certainly, the dry conditions during the 12 days prior to ignition are not to be expected every year, but I'm quite convinced that this happens every once in a while. To be sure on a return period, one would have to analyze the weather data in some detail.

With weather data sent by Mr Lundquist, we have constructed the charts:

(lines to mark start/end refused to copy: dates were June 13 to Sept 27.)







Smoky Lake Fire 2010

This fire grew together from a number of individual starts. It burned 107,000 ha, accounting for about half the entire area burned that year. It burned for 105 days, the longest duration of any fire from 1994-2010.