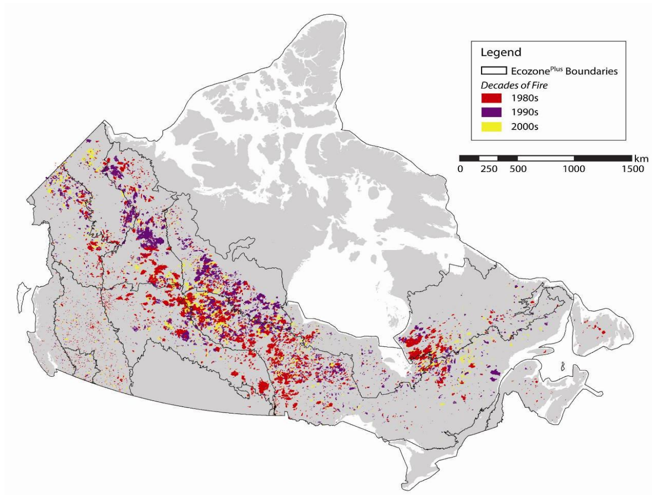

Evaluating Past, Current and Future Forest Fire Load Trends in Canada

B.J. Stocks Wildfire Investigations Ltd

128 Chambers Avenue

Sault Ste. Marie, ON P6A 4V4

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Executive Summary

Although Canadian wildland fire management agencies have developed sophisticated programs over the past century that have been quite effective in controlling unwanted fire activity, there has been a growing concern in recent years that fire management capacity is declining at a time when fire impacts are rising. These concerns prompted the development of the Canadian Wildland Fire Management Strategy (CWFS) in 2005, which identified a number of emerging issues with a growing influence on Canadian wildland fire management programs. An expanding wildland-urban interface (WUI), growing forest health issues, projected climate change impacts, increasing public expectations, expanding economic development in wildland areas, and declining fire management capacity were all identified as new challenges in Canadian fire management. At the same time, fire agencies intuitively felt that fire load was increasing in many regions of Canada, and that this trend could increase significantly through the 21st century.

This evaluation, under the auspices of the Wildland Fire Management Working Group (WFMWG) of the Canadian Council of Forest Ministers (CCFM) was undertaken to address these rising fire load concerns, and involved a thorough analysis of recent and current fire statistics, a review of the scientific literature on climate change effects on projected future fire activity and impacts, and a survey of Canadian fire management agencies to solicit opinions on the factors that may influence both current and future fire activity.

A thorough compilation and analysis of fire statistics, focused on the post-1970 period, revealed that, while the number of fires and are burned showed a general increase across Canada during the 1970-2000 period, data post-1995 shows a general decline in fire occurrence, particularly in human-caused (H-C) fires, in most jurisdictions. No distinct trend in area burned is evident, likely due to high interannual variability and the short length of the fire record. Agencies have attributed some of these declines to prevention program effectiveness, along with the increasing sophistication and effectiveness of suppression actions. Further analysis of large fires (>200 hectares) and fires separated by Full Response Zones (FRZs) and Modiified Response Zones (MRZs) also showed no trends.

Fire management expenditures for the post-1970 period for all Canadian agencies were examined and, at least for those agencies with the largest programs, are increasing steadily in constant dollars. Agencies have attributed this to several factors: the rate of inflation for key fire management components – fuel, aircraft, and to some extent personnel costs – is greater than that reflected in the Consumer Price Index (CPI); increasing costs related to greater resource sharing – although in total resource-sharing related expenditures are consistently less than 5% of total national fire expenditures; and, most significantly, that fires in wildland-urban interface areas, and in areas with other human and non-timber values at risk, are increasing in frequency and generate proportionally greater expenditures than fires that are primarily threatening only forest resources. This is occurring even as some agencies are reducing suppression intensity on fires that are less threatening to safety or resource values.

Although not directly part of this study, other studies sponsored by the WFMWG have documented agency concerns with declining resource capacity in some areas: base budget reductions in some agencies have led to reduced base fire management resources; there has been some decline in certain resource types (e.g. numbers of skimmer airtankers) though basic firefighter capacity has been maintained for the most part; all agencies are concerned about the loss of experienced career fire managers through retirement, and the challenges of recruiting and retaining key fire management personnel given demographic challenges and competition from other economic sectors.

Projections of climate change across Canada using the latest General Circulation Models (GCMs) indicate significantly worsening fire load conditions as the 21st century progresses. The result will be greater climatic variability, more severe fire weather events, increases in both lightning and H-C fire occurrences, greater area burned, and larger, more intense fires. However, at this point in time we do not have the data to validate these projected trends, although we may be

experiencing evidence of greater seasonal variability, such as longer fire seasons. Trends in fire numbers and area burned over the past 20 years do not reflect worsening fire conditions on a national scale.

Finally, while the more severe fire conditions forecast by many climate change projections have not yet been consistently observed, there has been no significant change in the long-term forecasts of increasing fire impacts being made for North America by the most credible GCMs. This would suggest that agencies can expect to see continued issues with climatic variability, increasing severe weather events, and the strong potential for a more severe fire environment. The observed increase in fire management expenditures may be the best indicator of more challenging fire management conditions, and indicate that the Canadian fire management community needs to continue its efforts to maintain its resource capacity, anticipate changing fire load, and maintain its resource sharing capacity and effectiveness.

Introduction

Although organized forest fire protection and management only began in Canada early in the last century, forest fires have been a dominant disturbance regime in Canadian forests since the end of the last Ice Age around 10,000 years ago. Lightning fire is natural and essential across much of Canada's forested landscape, and along with insects, disease, wind, and natural regeneration, helped to shape the character, and fire-adapted nature of Canadian forests long before the country was settled.

During the late 1800s and early 1900s Canadian settlers moved westward, and communities were established at a rapid rate, most often with little or no protection from wildfires. Frequent uncontrollable and disastrous wildfires, often associated with forest operations and the conversion of forests to croplands, were common during this period, resulting in extensive loss of life and property. Growing public and political awareness of this emerging problem forced governments to begin thinking about community protection, along with the protection of an expanding forest industry that was critical to the economic well-being of Canada. These impacts, which contributed significantly to the economic well-being of Canada, prompted the development of fire control organizations across the country, with a policy aimed at total fire exclusion.

Since the advent of organized fire management in the early 20th Century, the use of Canadian forests for a variety of industrial and recreational purposes has increased dramatically. This increased access and utilization has been accompanied by a concurrent increase in forest fire incidence and the fire suppression capability developed and mobilized to address this issue. By the mid-1900s all Canadian provinces, along with the Yukon and Northwest Territories (and Parks Canada) had implemented strong fire protection programs. Canadian fire management agencies are now among the most modern in the world. In 1982 the Canadian Interagency Forest Fire Centre (CIFFC) was formed to facilitate resource-sharing (personnel, aircraft and equipment) among Canadian agencies, a practice that has grown rapidly over the past few decades, and now involves partnerships with fire management agencies in the United States. While fire management in Canada has continued to evolve to meet changing demands, significant wildfire events are still common, most recently evidenced by the 2003 fires in British Columbia and the 2011 Slave Lake Fire in Alberta, which combined resulted in insured losses exceeding $1 billion and the destruction of approximately 800 homes and businesses. Over the past decade Canada has averaged approximately 8000 fires and 2 million hectares burned annually, with national fire management costs approaching $800 million annually. Canada also has large areas of remote northern forest in which fire is effectively permitted to perform its natural role in ecosystem structure and maintenance. These natural fires, which generally only receive suppression action if they threaten values, typically account for about 50% of the total area burned nationally.

The Canadian Wildland Fire Strategy (CWFS) was developed in 2005, under the auspices of the Canadian Council of Forest Ministers (CCFM), due to a rising concern that a number of emerging issues were starting to combine to reduce the effectiveness of Canada's fire management programs, and compromise abilities to deliver future programs as effectively as in the past (CCFM 2005). The CWFS, approved by all provincial and territorial governments, noted that, despite close to a century of relative success in managing fire in a manner that permitted some natural fire while vigorously protecting human life and property, fire management in Canada was approaching a crossroads. Climate change-driven forest fire and forest health issues were projected to combine with an expanding wildland urban interface (WUI) and a declining, more costly wildland fire suppression capability, to create unprecedented fire impacts across Canada in the near future. The CWFS recognized that, given these factors, maintaining recent levels of fire protection success would be economically and physically impossible, and called for a new accommodation with wildland fire with an emphasis on adaptation and new approaches, and a realization that fire would likely assume its natural role across more of the Canadian landscape in future years.

Since the release of the CWFS in 2005, the belief among fire managers that fires are becoming more unpredictable and severe has grown, leading to a request from the Wildland Fire Management Working Group (WFMWG) of CCFM to evaluate current fire load in Canada and explore, based on scientific studies and the intuitive experience and knowledge of fire managers, the most likely changes in future fire load across Canada. The sense that wildland fire load is increasing in Canada is buttressed by the fact that fire expenditures, which could be viewed as an overall integrator of fire load, are increasing nationally. In addition, between 1980 and 2007 547 communities were evacuated across Canada (209, 121 people) due to forest fire threats (Beverly and Bothwell 2010). Although evacuation costs are largely unknown, as multiple agencies are involved, this trend toward more frequent evacuations is growing.

Fire load is defined as "the number and magnitude (i.e., fire size class and frontal fire intensity) of all fires requiring suppression action during a given period within a specified area." (Merrill and Alexander 1987), and is a concept used by fire managers to integrate the complex nature of forest fire incidence and fire behavior by considering three factors: the number of fires, their size, and their intensity. Fire load indexes can be developed and used as a measure of the cumulative fire load over a particular period of time, usually a fire season, providing a measure of fire season severity that can be used in budgeting and resourcing exercises. For the purposes of this report, we will also include considerations about the demand that wildfires place on the fire management organization, including resource capacity and expenditures, as part of our fire load evaluation.

Canadian wildland fire management agencies are also concerned about the potential interaction between changing fire load and changing resource capacity. There is concern that a potentially more challenging fire environment would be exacerbated by declining resource capacity, as a result of declining government funding for fire management and other social, economic and demographic factors that could reduce fire fighting capacity. Although not directly part of this present study, the WFMWG has commissioned other reports on resource capacity (McBay, 2012) and wildland fire management agency demographics (Gordon, 2014) in response to these concerns.

These studies have indicated that, while equipment and on-the-ground firefighter numbers have been relative stable on a national basis, agencies are concerned about some declines in helicopter availability (competition from other economic sectors), declines in the number of skimmer airtankers (retirement of aging aircraft, though potentially offset by increased capacity in newer aircraft), and a significant loss in experienced management staff as career fire managers retire and agencies experience challenges in recruiting, training and retaining next-generation staff. These resource capacity issues are of significant concern; agencies need to consider how these impacts could be ameliorated in the context of the changes in fire load they are experiencing.

This evaluation of trends in forest fire load begins with a detailed analysis of fire statistics across Canada, followed by a review of recent literature on projected climate change impacts on forest fire activity and impacts across Canada, and concludes with a survey of Canadian fire managers to solicit their intuitive feelings about the current fire load and how it may be changing.

Measuring Recent and Current Fire Load in Canada

An evaluation of possible changes in fire load in Canada requires an analysis of recent trends in fire activity across the country. Trends in a number of traditional and potential indicators of fire load were evaluated using the most relevant statistics available. Trends were analyzed at both a national and provincial/territorial scale where possible. Fire load indicators analyzed included fire expenditures, overall annual numbers of fires and areas burned, fire activity in both Full Response Zones (FRZs) and Modified Response Zones (MRZs), large fire activity, lightning and human-caused fire occurrence levels, and national resource-sharing trends. Other factors affecting fire load, such as resource-sharing and the expansion of the wildland-urban interface (WUI) were also investigated to the extent possible.

Detailed forest fire statistics are available for all Canadian fire management agencies, and have been summarized nationally for a number of decades in a variety of federal reports produced by the Canadian Forestry Service (CFS), the Subcommittee on Forest Fire Protection (under the National Research Council), and CIFFC. Currently these statistics are available, updated annually, in the National Forestry Database Program (NFDP) (www.nfdp.ccfm.org), a clearing house for national forestry statistics organized under CCFM. Statistics from all of these sources were used in the following analyses, and additional information was obtained directly from various Canadian agencies to fill data gaps as required. Any 2013 statistics used were obtained from the CIFFC website and are unofficial.

Wildland Fire Management Expenditures in Canada

The sense that fire load is increasing across Canada is strengthened by the fact that fire management expenditures are rising. Fire costs are calculated annually by Provincial, Territorial, and Parks Canada forest fire management agencies in Canada and these data have been summarized nationally in recent decades. Initial summaries were undertaken by the Canadian Forest Service (CFS) and published in a series of reports covering the 1979-1990 period (Ramsey and Higgins 1982, 1985, 1991; Higgins and Ramsey 1992)). With the establishment of the NFDP under CCFM in 1990 fire expenditure data was included along with many forestry expenditures, and summarized on the NFDP website. Forest fire expenditure data for the 1990-1999 period were collected from Canadian agencies, added to earlier data from the Ramsey/Higgins reports, and housed within the NFDP, both on the website and in published reports. While other forestry and fire data were collected by the NFDP post-1999, the collection of fire costs was halted due to difficulties reconciling the various means by which fire management agencies calculate fire costs.

In order to evaluate a growing consensus that fire expenditures were rising post-2000, but were not being summarized nationally, all agencies were surveyed by a contractor (B.J. Stocks Wildfire Investigations Ltd.) and provided annual data up to 2009. The addition of these years resulted in a 40-year dataset (1970-2009) that could be analyzed to investigate trends in fire management costs over a realistic length of time. Costs in these analyses are expressed in 2009 $, with actual annual costs being converted using the annual Consumer Price Index (CPI).

Fire management agencies traditionally break down annual fire expenditures in terms of fixed and variable costs, often referred to as budgeted and firefighting costs respectively. Although the terms used may vary between agencies, fixed costs are those associated with maintaining the fire management program (e.g. infrastructure, permanent staff salaries etc.), and are somewhat constant. Variable costs vary with the nature of the fire season, and reflect the cost of additional non-permanent resources such as fire fighters, helicopters and fixed-wing aircraft.

Fixed, variable and total annual wildland fire costs are summarized nationally in **Figure 1** for the 1970-2009 period. As would be expected, variable costs fluctuate much more on an interannual basis than fixed costs. Overall costs have been rising steadily since 1970, but have increased dramatically since the mid-1990s. In addition, variability between years has also increased markedly during this period. Overall fire management expenditures (in 2009$) have risen from approximately $200 million in the early 1970s to an average of more than $800 million in the post-2000 period.

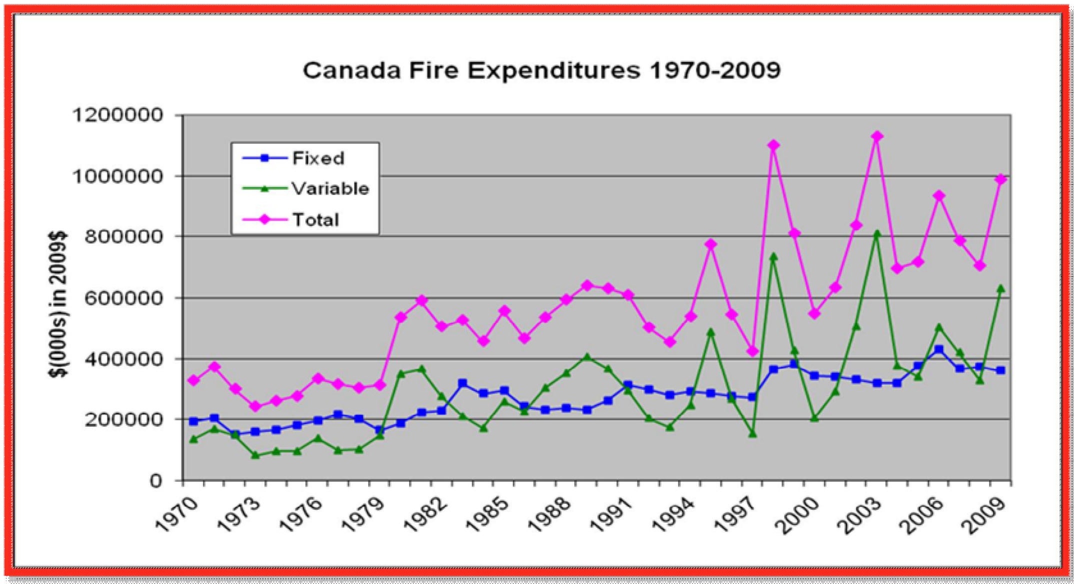


Figure 1 – Trend in Canadian fire management costs (fixed, variable, total) 1970 – 2009

The wide range in fire expenditures between agencies is illustrated in **Figure 2**, with Alberta (AB) and British Columbia (BC) spending much more than other agencies, followed by Ontario (ON), Quebec (QC), Saskatchewan (SK), and Manitoba (MB) in that order. These agencies all experienced a rise in costs in the most recent decade (particularly BC and AB) in comparison to the 1970-2009 period. Average fire expenditures in the remaining seven jurisdictions - Newfoundland (NL), Nova Scotia (NS), New Brunswick (NB), Prince Edward Island (PE), the Yukon Territory (NT), the Northwest Territories (NT), and National Parks (NP) - are generally an order of magnitude lower than the average combined costs of BC, AB, SK, MB, ON and QC.

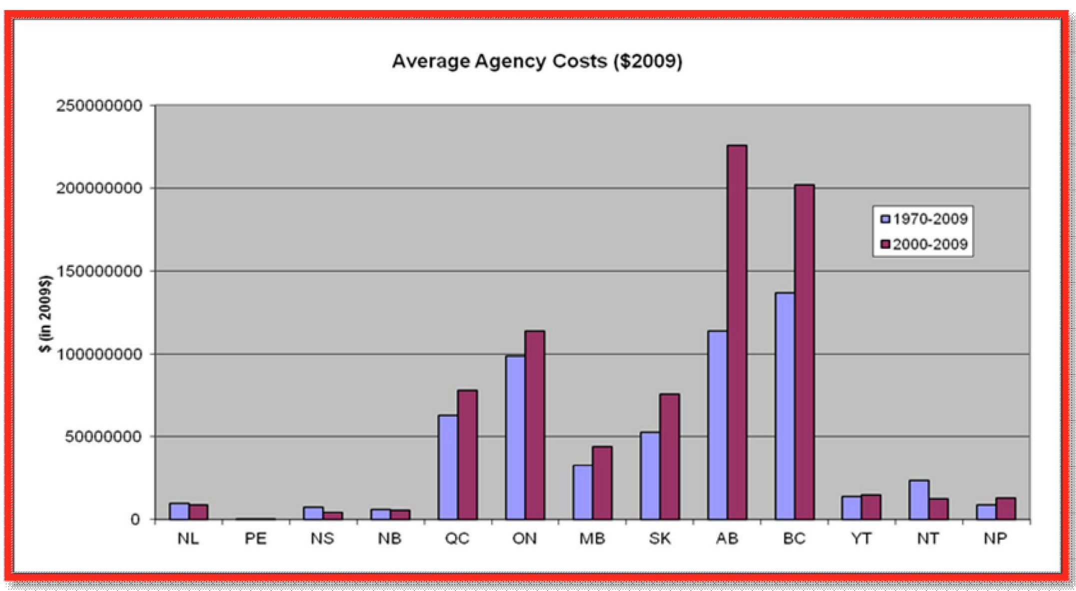


Figure 2 – Average annual fire management costs by jurisdictions (1970 – 2009 and 2000 – 2009)

Fire expenditures for all Canadian fire management agencies are shown in **Appendix A**. Note that the scale of the Y-axis (expenditures) varies significantly between agencies, with large fire programs (e.g. BC, AB, ON) routinely spending 20 to 30 times as much as individual Maritime Provinces. As expected, fixed costs rise more slowly and show much less interannual-annual variability than variable costs, and this fact is common to all agencies. From **Appendix A** it is evident that BC and AB have recorded the highest and most variable fire costs in recent years, raising the question whether rising costs in these two jurisdictions are driving the national trend upward. However, costs have also risen steadily in SK, MB, ON and QC over the past four decades. As these six agencies spend by far the most, it seems likely that these jurisdictions are most responsible for the rising trend in national expenditures.

Fire expenditures for the Maritime Provinces, NT, YT and NP are also shown in **Appendix A**. Fire costs in NT and YT are generally much lower than the six largest agencies, but do approach MB expenditure levels. Fire costs are much lower again in the Maritime Provinces. As might be expected, fire costs for PE are particularly low, even in comparison to NS and NB. In general fire expenditures for these smaller fire agencies seem to be decreasing in recent years, although interannual variability is evident as it is with larger agencies.

The following figures compare total fire expenditures between agencies, with the higher-spending agencies in **Figure 3a** and the lower-spending agencies in **Figure 3b**. The large differences in expenditures between agencies are evident both when comparing the graphs, and when comparing individual agency costs within graphs. All agencies in **Figure 3a** exhibit a rising trend in expenditures over the period of record, with quite significant increases in BC and AB, and moderate increases in ON, QC, SK and MB. Conversely, the agencies with lower-spending fire programs (**Figure 3b**), show no significant changes (some modest increases in YT, NL, NB and NP, with declines in NS and NT) in expenditures over the same period.

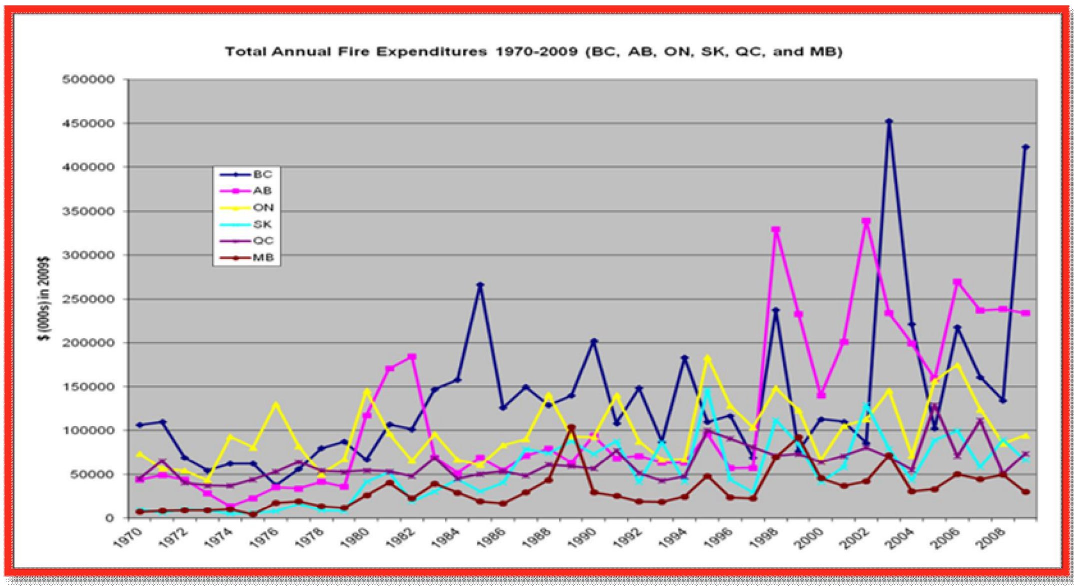


Figure 3a – Annual fire expenditures for the 1970 – 2009 period (BC, AB, SK, MB, ON, and QC)

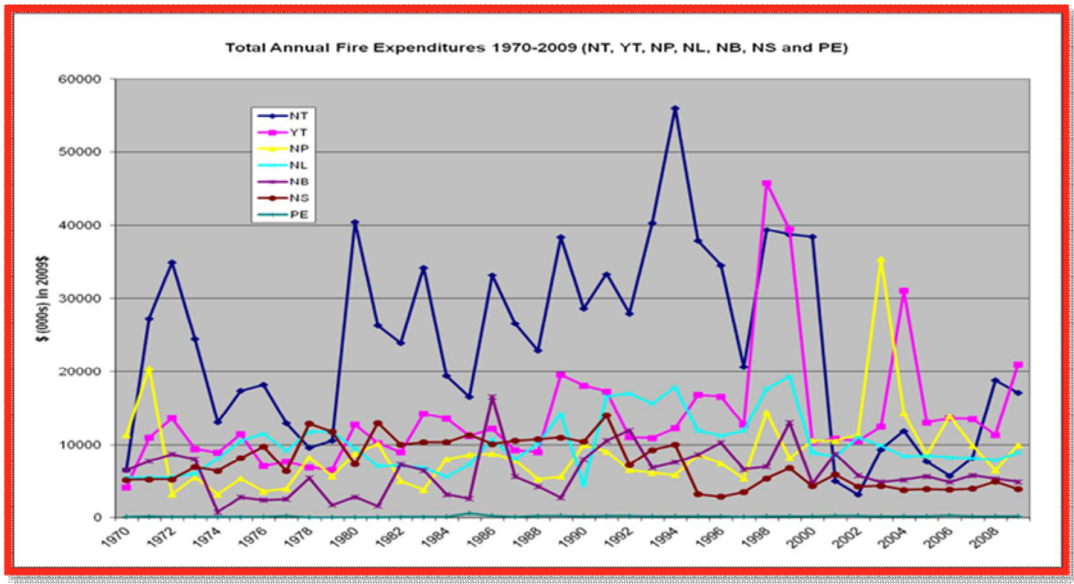


Figure 3b – Annual fire expenditures for the 1970 – 2009 period (NT, YT, NL, NS, NB, and PE)

Area Burned and Number of Fires Nationally

In evaluating potential causes for rising costs and increasing fire load in Canada, reviewing the number of fires and area burned over time is a logical place to begin. The annual number of fires and area burned in Canada for the post-1920 period are shown in **Figure 4a**, along with trend lines for this 94-year period. A striking feature of this graph is the huge interannual variability in area burned, which can vary from less than 300,000 hectares to more than 7,500,000 hectares in any given year. Fire occurrence is less variable between years, but ranges approximately from 3,000 to 11,000 fires annually. Large interannual variation in fire activity and impacts presents both budgeting and resourcing problems for fire management agencies, as peak fire loads often outstrip available resources.

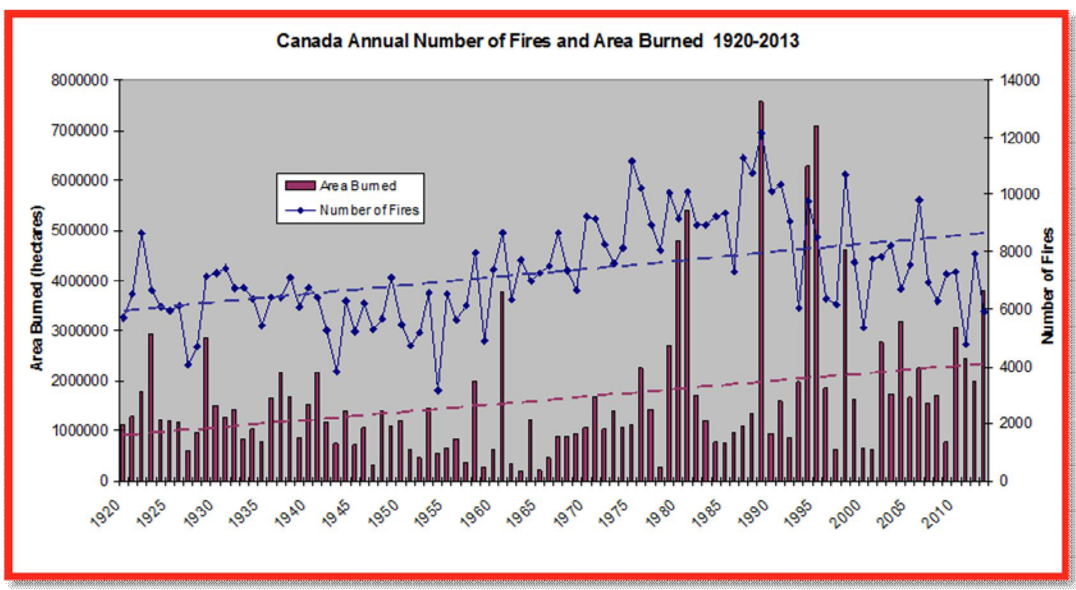


Figure 4a – Annual number of fires and area burned in Canada (1920 – 2013)

From **Figure 4a** trends in both fire activity and area burned appear to rise steadily, from averaging slightly more than 6000 fires and less than 1 million hectares burned in the early 1920s, to averaging more than 8000 fires and 2 million hectares burned in recent years. These trends are strongly influenced by significant decades in the 1980s and 1990s, and by the fact that, prior to the 1970s, many fires were not detected or recorded, with the result that fire activity during this period is under-represented in the national fire records. This weakness cannot be corrected, but can be assumed to be less significant with passing decades, as fire detection and monitoring programs expanded. Continuously evolving fire management programs across Canada undoubtedly influence just how much can be gleaned from long-term statistics and trends. Decadal averages for the 1920-2013 period (**Figure 4b**) also show a gradual decline for the 1920s-1960s period, followed by rapid increases in fire activity and impacts for the 1970s, 1980s, and 1990s. However, the period post-2000 shows a modest decline in fire numbers and area burned nationally.

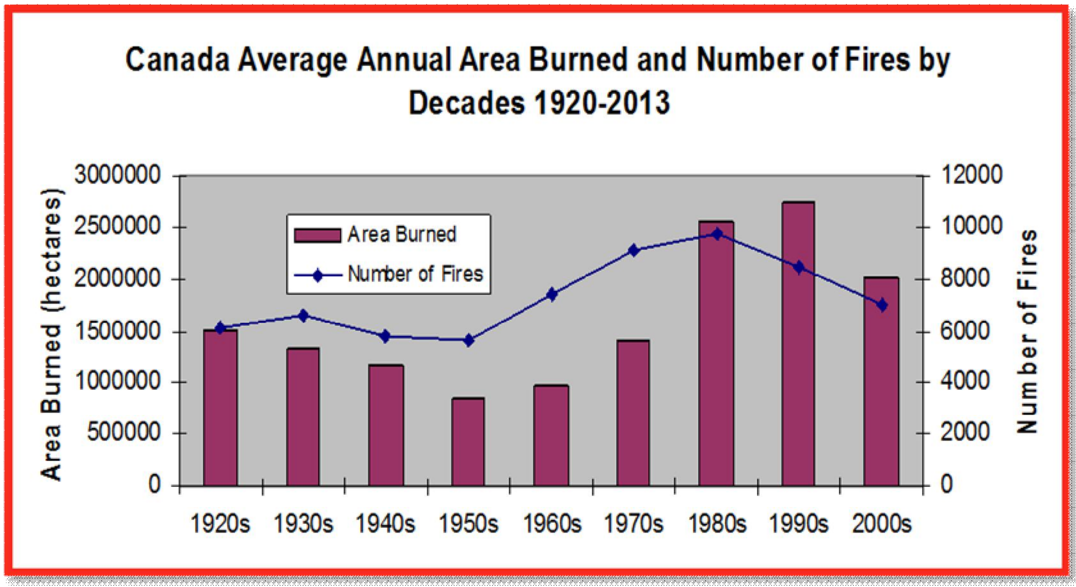


Figure 4b –Decadal averages of annual area burned and fire numbers in Canada (1920 – 2013)

National fire data records are considered to be much more reliable following the advent of extensive satellite coverage in the early 1970s. When data is limited to the post-1970 period (**Figure 4c**) trend lines change significantly. Fire numbers actually show a substantial downward trend while area burned increases slightly, both due to the stronger influence of declining fire activity post-2000.

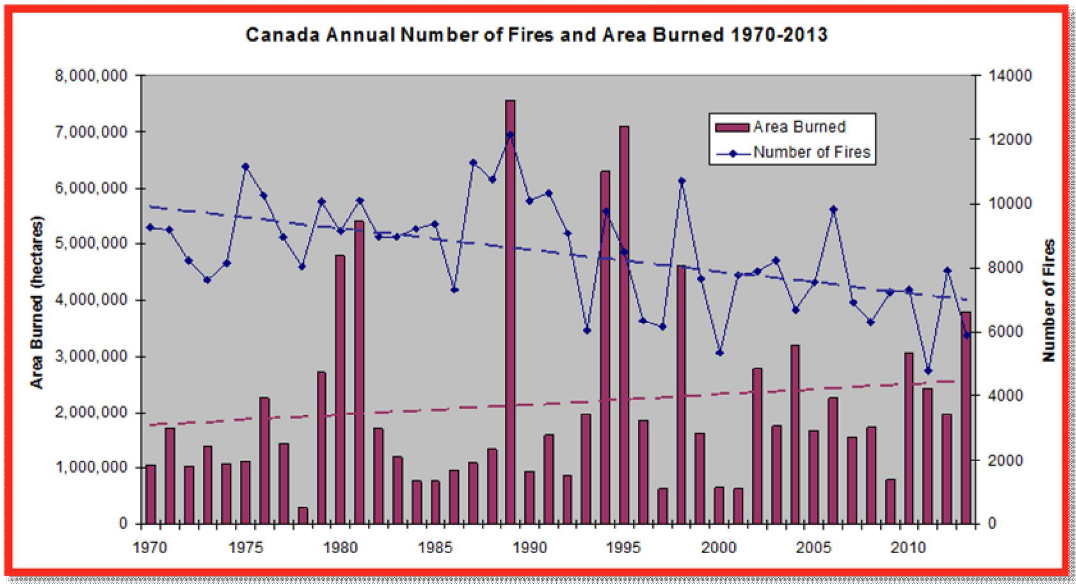


Figure 4c – Annual number of fires and area burned in Canada (1970 – 2013)

Analyzing trends in Canadian fire activity is problematic due primarily to the highly episodic nature of the dataset. Large interannual variability is the norm, particularly in the yearly area burned by wildland fire, which can vary by much more than an order of magnitude (from less than 300,000 hectares to more than 7,500,000 hectares) annually. This raises the question whether a 44-year dataset is long enough to overcome such variability and facilitate a reasonably accurate trend analysis. Fire numbers are much less variable interannually than area burned and may yield better trend analyses.

Analysis of national-scale fire statistics does not appear to shed any light on why expenditures are rising, as national fire numbers and area burned appear to have declined recently, during the period when expenditures have risen most abruptly. Statistics from individual jurisdictions were then examined to see if more regional trends were evident.

Area Burned and Fire Numbers by Individual Jurisdictions

The annual number of fires and area burned for all Canadian provincial and territorial fire management agencies were compiled for the post-1970 period from NFDP records and are shown in **Appendix B**. When visually comparing graphs for individual agencies, note that Y-axis scales differ significantly. Fire statistics for the 44-year period between 1970 and 2013 are shown individually for agencies with the highest expenditures (BC, AB, SK, MB, ON and QC) in the first part of **Appendix B**. One common feature for all agencies in this grouping is the highly episodic nature of the area burned annually.

BC statistics show a declining number of fires with large interannual variability. Annual area burned has increased over the past decade, and seems to correspond well with the concurrent increase in expenditures for BC shown in **Appendix A**.

Fire numbers in AB appear to have increased significantly in recent years, which may be partially due to a change in policy over the last decade which has resulted in the addition of smaller fires to the AB fire record. AB had many insignificant years in terms of area burned, but significant years have occurred recently and during the 1980-1981 period, events that coincide with increased expenditures in AB (**Appendix A**).

No significant trends are evident in the SK and MB records, with both provinces experiencing wide interannual-annual fluctuations in fire activity. The MB statistics are dominated by the huge areas burned in the northern region of the province in 1989.

Both ON and QC show large interannual variability in both area burned and fire numbers, but both provinces also show a steady decline in fire numbers over the 1970-2013 period. No trend in area burned is evident in ON, but QC exhibits a strong upward trend, which could be due to the fact that large fires in northern Quebec during the 1970s and early 1980s are not included in the NFDP statistics.

Fire statistics for agencies with lower expenditures (YT, NT, NP, NL, NS, NB and PE) are also presented in **Appendix B**. Despite the fact that fire activity levels in these agencies are lower than those represented in agencies with larger budgets, there are still some similarities, particularly in terms of the highly episodic nature of annual fire statistics.

The YT, NT and NP graphs show the usual high interannual variability, at least partially due to the fact that these jurisdictions allow natural fire to burn extensively. A downward trend in fire numbers is evident in NT, while YT and NP have not shown much change. Similarly, area burned totals are not exhibiting any trend, except in YT, where the trend is strongly influenced by one significant year in 2004.

The NL post-1970 fire record shows that area burned is highly episodic between years, largely a function of frequent major fires in Labrador that receive limited suppression action. Fire numbers in NL show a strong downward trend over the period of record.

In the Maritimes, the area burned in NS post-1970 is dominated by one significant fire year in 1976. Otherwise the annual area burned during this period was less than 3000 hectares. In addition, fire numbers in NS have declined steeply over the past 44 years. Similarly, the area burned in NB has declined dramatically in recent years, with the exception of major fire activity in 1986. Fire numbers have also declined steadily over the 1970-2013 period. PE statistics are relatively insignificant when compared to other agencies, but still exhibit the same interannual variability. Both fire numbers and area burned have declined significantly.

From the fire statistics presented above for individual jurisdictions it is evident that the larger agencies are dealing with the most fire activity, and are also incurring the highest costs. It would seem a strong likelihood that increasing fire load nationally would be driven by fire activity in these agencies. Fire expenditures and fire activity in the smaller agencies are not rising, and are not significant enough to affect the overall national trends. In addition, while NT, YT, NP, and NL often have large areas burned in their MRZs, it is safe to assume this is not reflected in increased expenditures by these agencies.

In the search for causes for rising expenditures it therefore seems prudent to focus on the agencies with the largest programs. For comparative purposes **Figures 5a and 5b** are included here to show both fire numbers and area burned for these larger agencies - BC, AB, SK, MB, ON and QC.

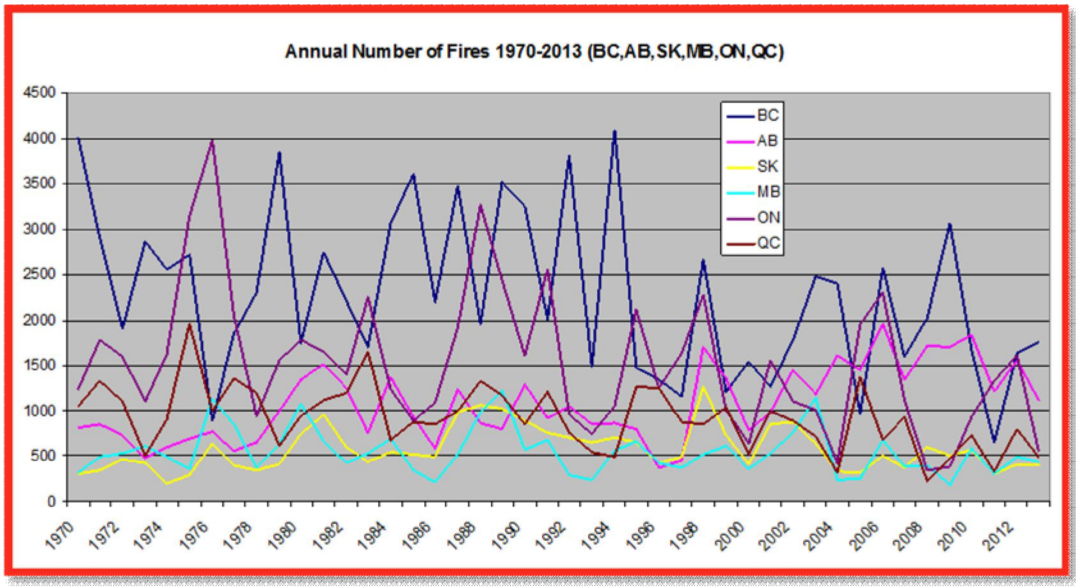


Figure 5a – Annual fire numbers for 1970 – 2013 (BC, AB, SK, MB, ON and QC)

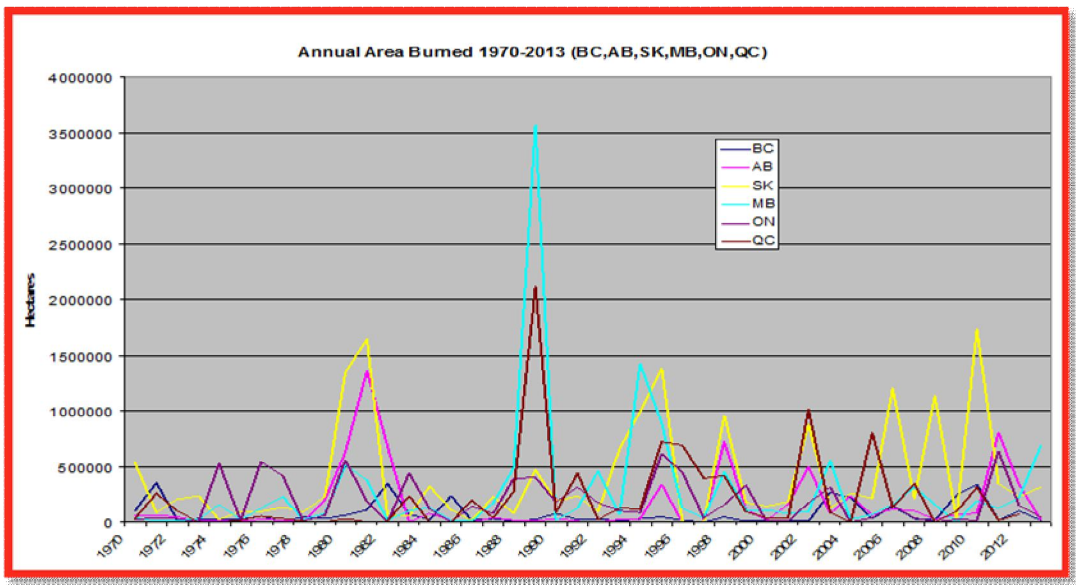


Figure 5b – Annual area burned for 1970 – 2013 (BC, AB, SK, MB, ON, and QC)

Fire Activity in Full Response Zones (FRZ) and Modified Response Zones (MRZ)

As mentioned earlier, many Canadian provinces and territories have extensive zones (MRZs) where "modified" fire suppression is practiced and most fires burn naturally. Fire activity is monitored in these zones (which cover close to 50% of the Canadian forested landscape), but suppression action is only undertaken when communities or other values are at risk, and suppression action is often limited to just protecting values. The vast majority of fires in the lightly populated MRZs are caused by lightning, and often grow large due to a lack of suppression action. Conversely, most fires in the FRZs across Canada are caused by human activity (recreational activities, industry operations, railways etc.), and are usually much smaller due to aggressive suppression action.

Figure 6 shows the geographical distribution of MRZs (white) and FRZs (grey) across Canada, with extensive MRZs in Labrador, northern QC, ON, MB and SK, as well as most of NT and YT. BC and AB, as well as the Maritime provinces (including the island of Newfoundland) consider their complete jurisdictions to be FRZs, with a policy of aggressively suppressing all fires.

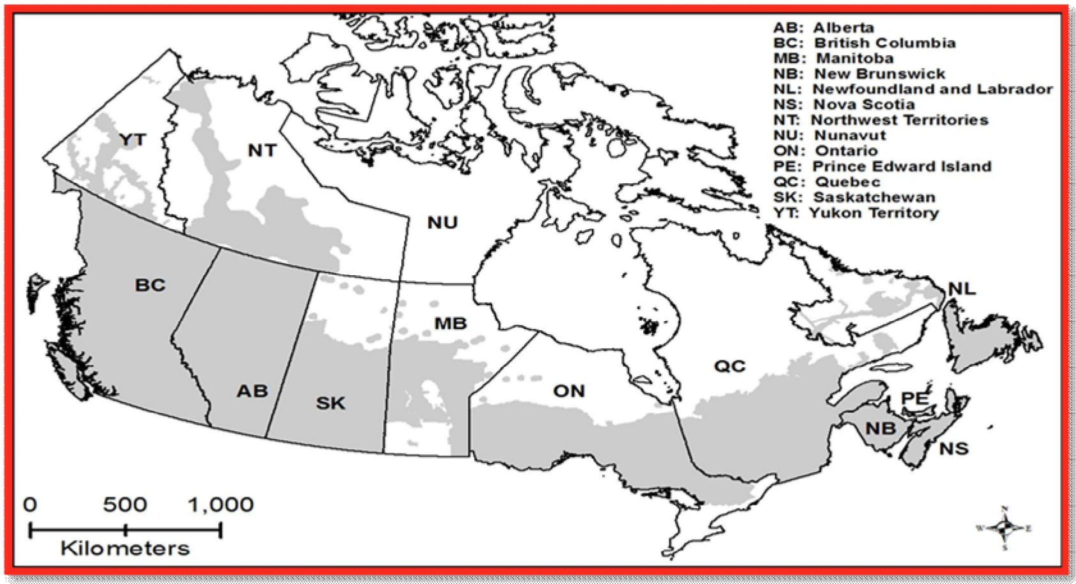


Figure 6 - Distribution of FRZs and MRZs across Canada (adapted from Magnussen and Taylor, 2012)

NFDP and CIFFC statistics have been used to determine trends in fire numbers and area burned in both the FRZ and MRZ across Canada for the 1990-2013 period, and the results are shown in **Figure 7**. Area burned in both zones does not appear to be changing significantly, and fire numbers in the MRZ have remained relatively constant over the 24-year period. However, the number of fires in the FRZ is declining, which is consistent with the earlier results from many jurisdictions across Canada. The large differences in fire sizes between zones are also evident. The MRZ, despite having only 8% of the total number of fires nationally, accounts for about 66% of the total area burned.

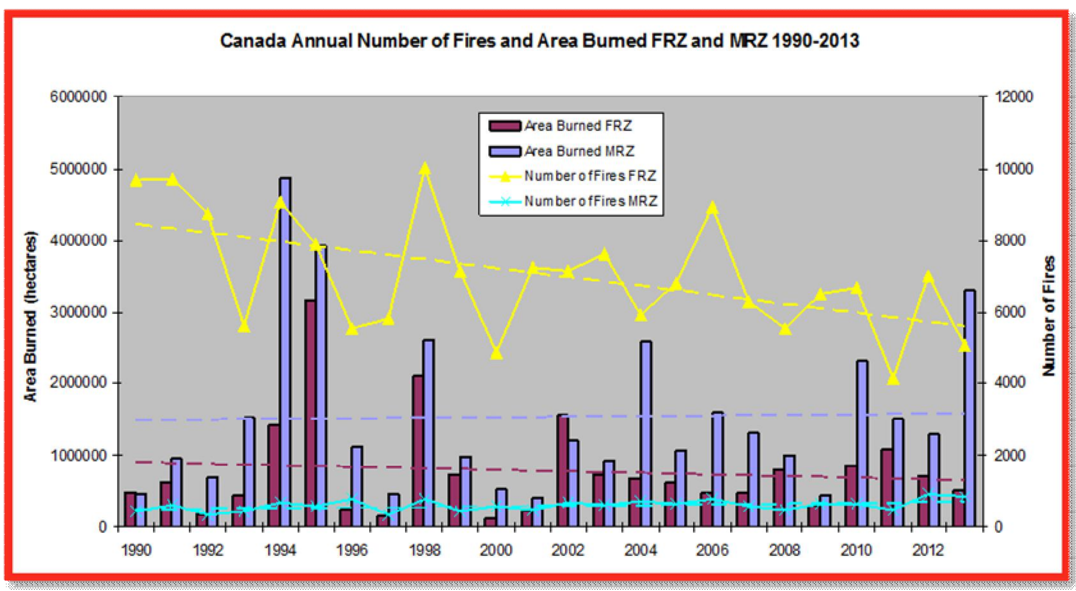


Figure 7 - Annual number of fires and area burned in Canadian FRZs and MRZs (1990 - 2013)

Large Fire Activity

Fires that escape initial attack and grow large, often referred to as "project" fires, usually require costly extended suppression action, a factor that could be related to rising expenditures. To investigate this possibility, the number of fires >200 hectares, and the area burned by these larger fires, were evaluated for the 1970-2011 period. The Canadian Large Fire Database (LFDB), which consists of all fires >200 hectares post-1959 (Stocks et al. 2003), now known as the National Fire Database (NFDB) (http://cwfis.cfs.nrcan.gc.ca/ha/nfdb) was used in this analysis, with the assumption that fires >200 hectares in size would be a reasonably proxy for "project" fires. The analysis was limited to the six largest fire management agencies, with the assumption that, if large fires were having an impact on Canadian fire expenditures, the impact would be most notable in these jurisdictions.

The number and area burned by large fires for BC, AB, SK, MB, ON and QC for the 1970-2011 period are shown in **Figures 8a and 8b** respectively. In both graphs large interannual-annual variability in both numbers and area burned by large fires is evident, as was the case when fires of all sizes were considered earlier. However, no trends over time are evident in either graph, with the exception of area burned in SK, which shows an increasing trend in recent years.

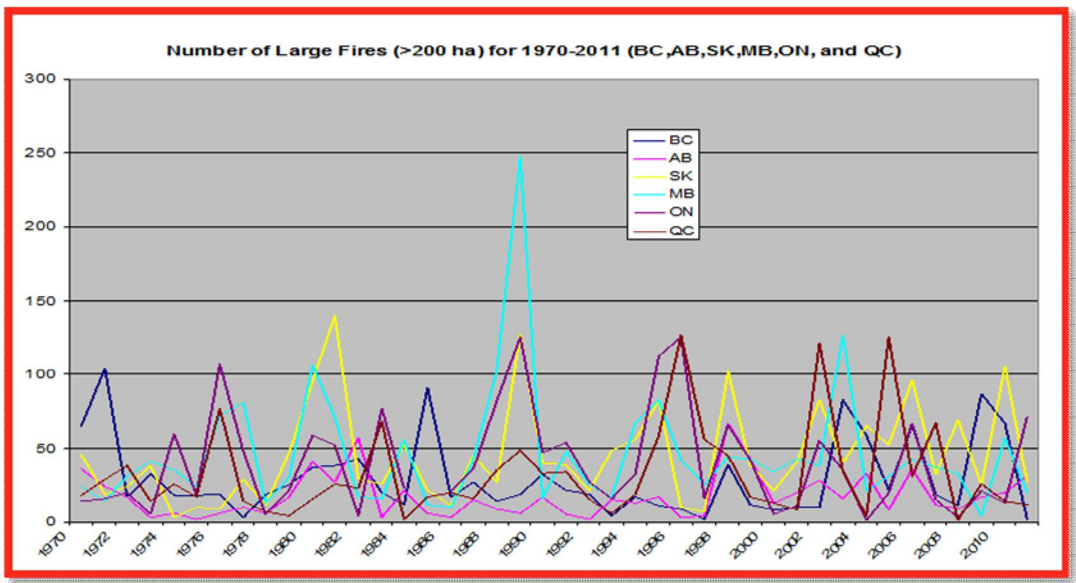


Figure 8a – Large fire numbers (1970 – 2011 for BC, AB, SK, MB, ON and QC)

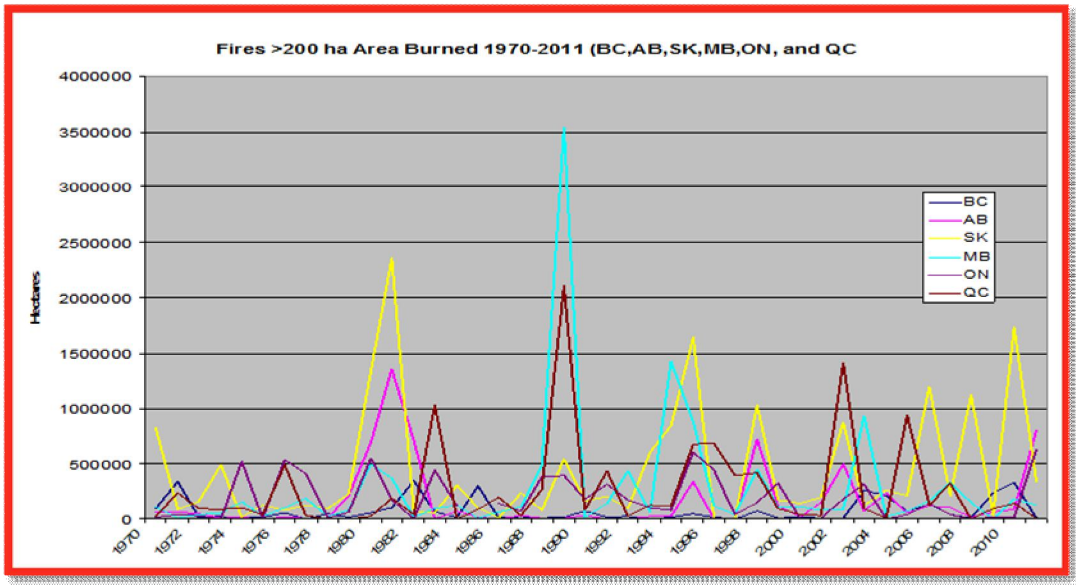


Figure 8b – Area burned by large fires (1970 – 2011 for BC, AB, SK, MB, ON, QC)

Human – Caused and Lightning Fire Activity

After investigating trends in fire activity and area burned for all fires by agencies, a further analysis of fire trends for both lightning and human-caused (H-C) fires was undertaken. Data for this analysis came from the Ramsey and Higgins papers for the 1978-1990 period, and from the NFDP post-1990. Minor holes in the dataset were filled through contact with individual agencies where warranted.

Figures 9a and 9b illustrate both the number and the area burned by H-C and lightning fires by jurisdictions across Canada. With the exception of the Maritimes, the number of lightning and H-C fires is roughly similar within each jurisdiction. However, the proportion of the area burned by lightning fires is much higher in NT, YT, NP, SK and NP. This is likely due to the effect of MRZs in many jurisdictions, where lightning fires predominate and most frequently burn naturally. In addition, lightning fires often occur simultaneously in generally less accessible areas, delaying suppression response times and resulting in more fires growing larger. Lightning fires do not appear to be a major issue in the Maritimes.

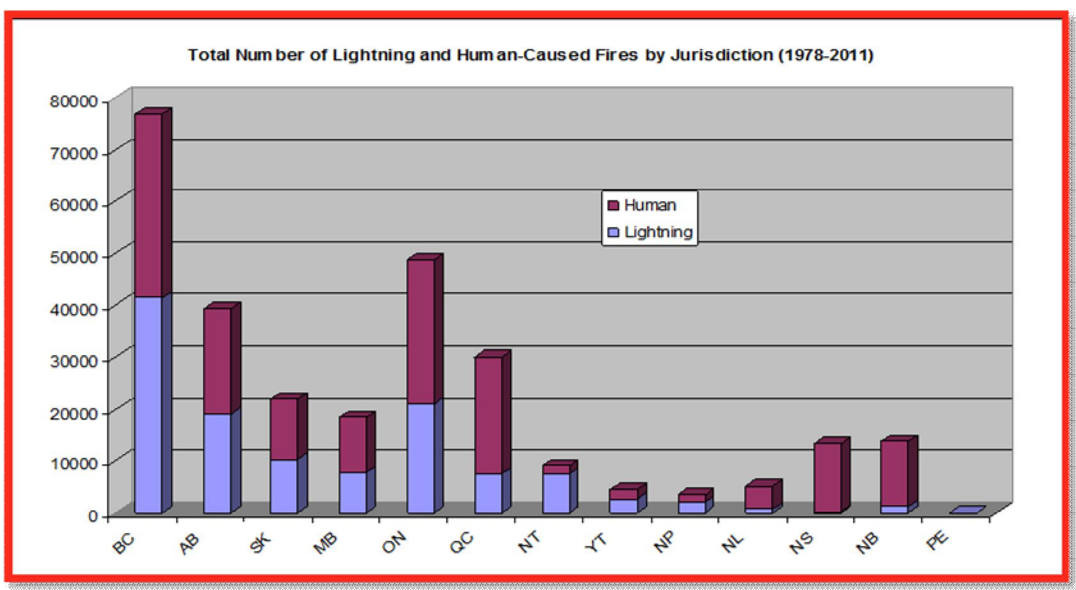


Figure 9a - Total numbers of lightning and H-C fires by jurisdiction (1978-2011)

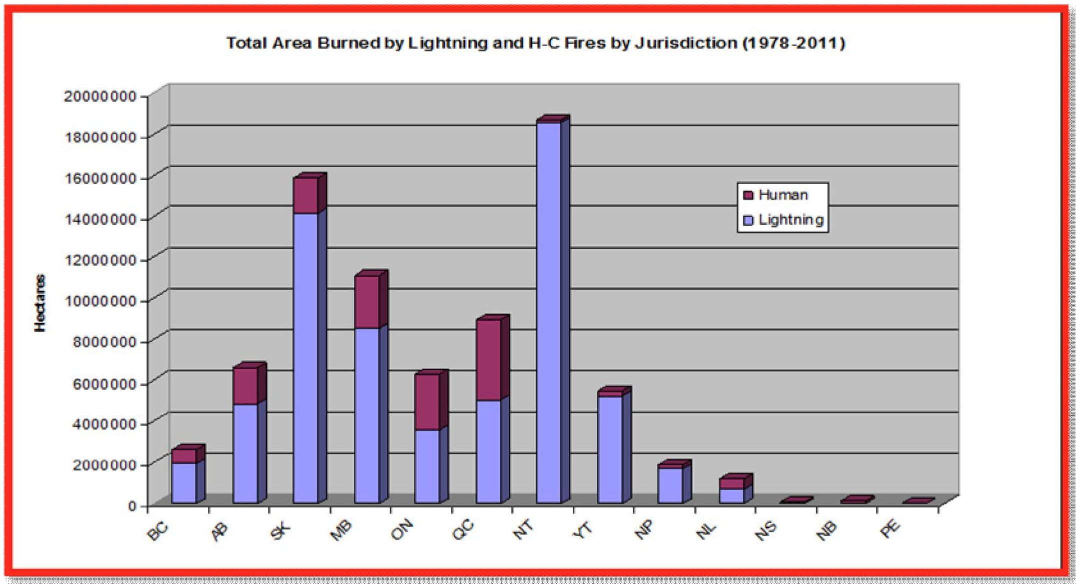


Figure 9b- Total area burned by lightning and H-C fires by jurisdiction (1978-2011)

The annual trends in both fire occurrence and area burned for both lightning and H-C fires are shown in **Figures 10a and 10b** respectively. As usual these trends are difficult to interpret due to large interannual variability, particularly in area burned. Nationally, the trend in fire numbers for both fire causes is downward, but the downward trend in H-C fire numbers is much more significant, particularly in recent years. Overall trends in area burned appear to be slightly downward for lightning fires and slightly upward for H-C fires.

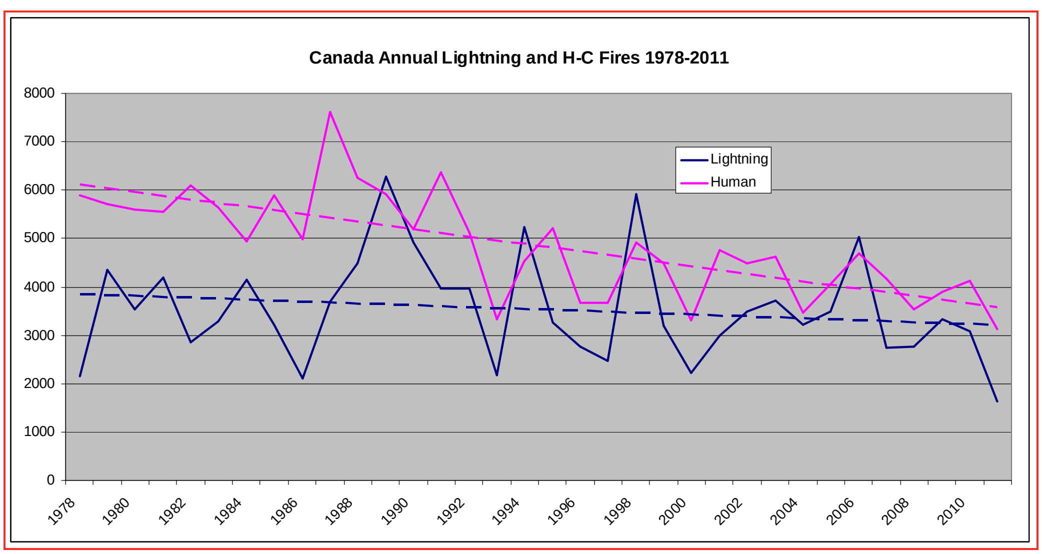
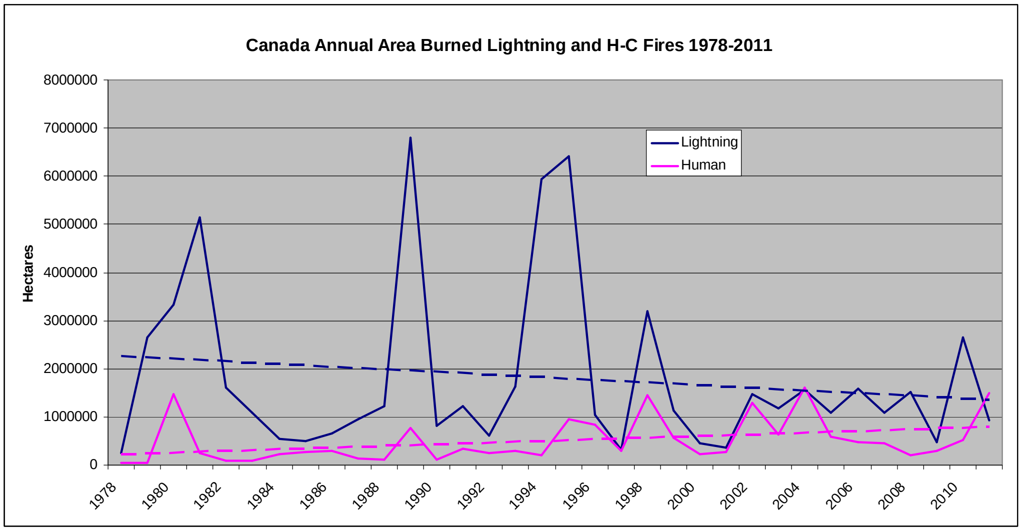


Figure 10a - National lightning and H-C fire annual trend 1978-2011



Fire 10b - National lightning and H-C fire area burned trend 1978-2011

Trends for all agencies were plotted, but only trends for those agencies with the highest fire activity and fire management costs (AB, BC, SK, MB, ON, and QC) are shown in the following figures, as these agencies would be the most likely to exhibit any correlation between rising expenditures and fire activity.

Separating lightning and H-C fires by agency is only possible over the complete geographical extent of the jurisdiction, and no separation by cause within the MRZ and FRZ (where applicable) was possible due to missing data at this level of resolution. However, in the case of BC and AB all fires can be considered to be a FRZ, even though a small number of fires in BC have received a form of modified suppression is recent years.

Trends in H-C fires for the six major jurisdictions are shown in **Figure 11a**. Strong downward trends in human-caused fire numbers are evident in BC, SK, ON and QC during this period, while a strong upward trend can be observed in AB in recent years. As mentioned earlier, this trend may be influenced by the addition of smaller fires to the AB database in recent years. No trend is evident in MB.

Separate L and H-C graphs of numbers and area burned for each jurisdiction are in **Appendix C.**

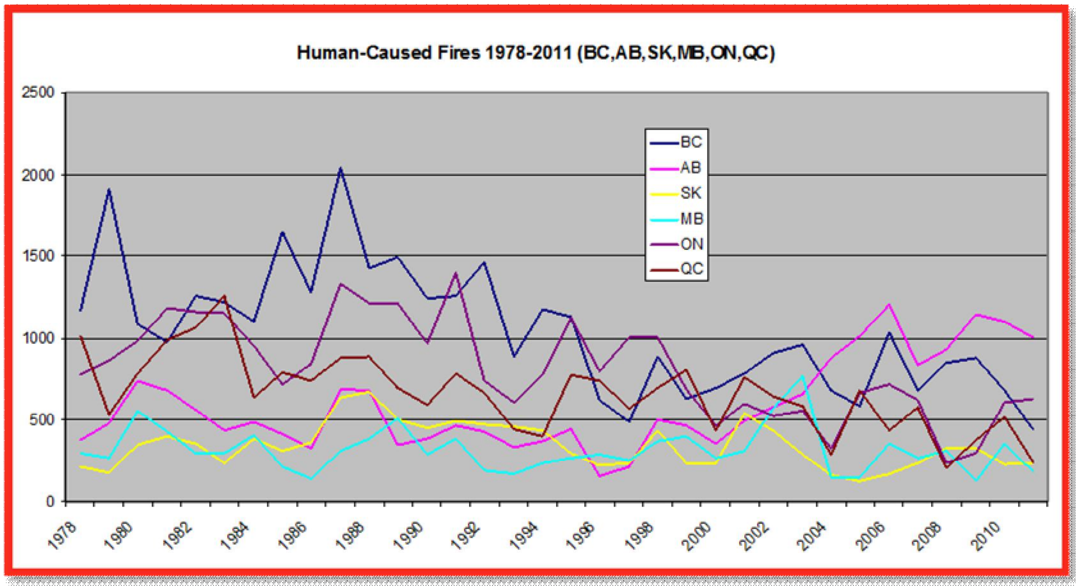


Figure 11a – Human caused fire numbers (1978 – 2011 for BC, AB, SK, MB, ON, QC)

Lightning fire trends are shown in **Figure 11b**. No significant trends in lightning fire occurrence are obvious over this period, with all agencies recording relatively consistent numbers over time. Lightning fire occurrence appears highly episodic, particularly in BC and ON, in comparison to H-C fire activity.

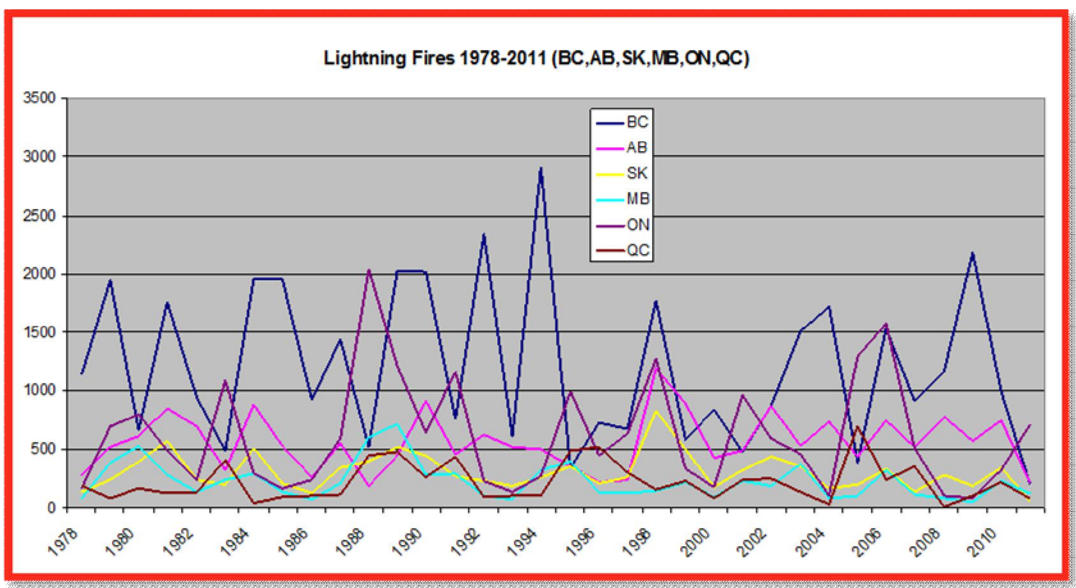


Figure 11b – Lightning fire numbers (1978 – 2011 for BC, AB, SK, MB, ON, QC)

Trends in area burned for both H-C and lightning fires are shown in **Figures 12a and 12b** respectively. For reasons mentioned earlier H-C fires generally burn less area than lightning fires, but H-C fire area burned shows significant interannual-annual variability. The area burned by lightning fires also vary widely between years, with SK and MB showing the largest areas burned, a reflection of large MRZs in these jurisdictions.

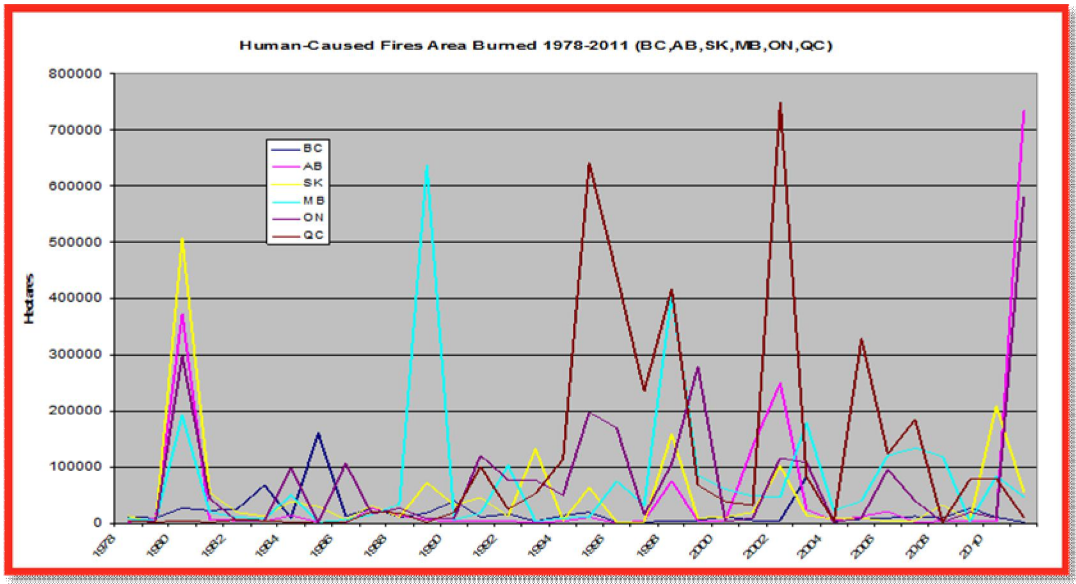


Figure 12a – Human-caused fires area burned (1978 – 2011 for BC, AB, SK, MB, ON and QC)

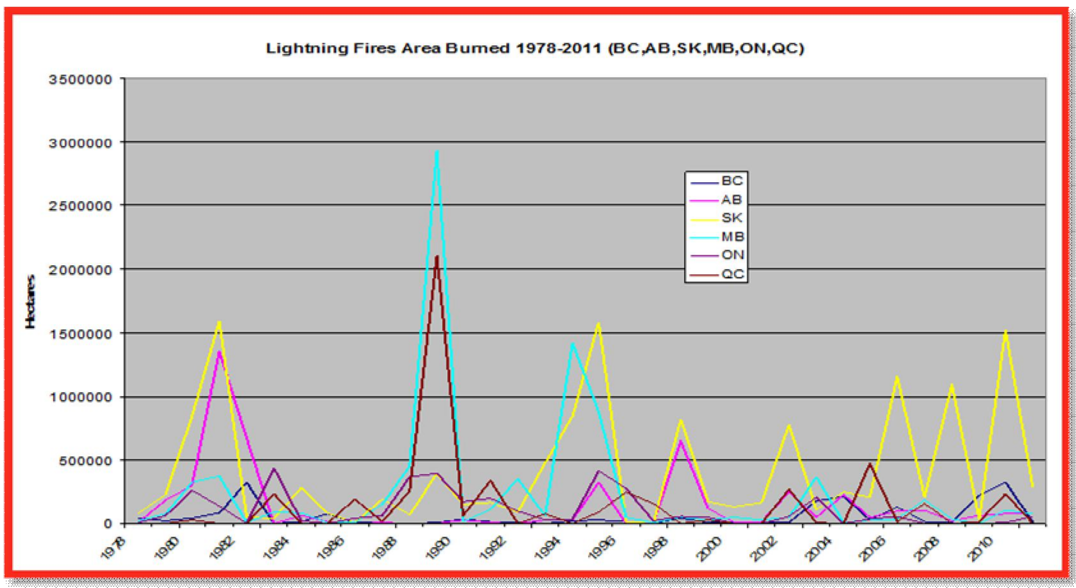


Figure 12b – Lightning fires area burned (1978 – 2011 for BC, AB, SK, MB, ON and QC)

Resource Sharing Trends

With the establishment of CIFFC in 1982, Canadian fire management agencies committed to sharing resources in a much larger and more organized fashion. **Figure 13** shows just how much sharing has taken place since that time, with levels increasing almost annually, particularly after the mid-1990s when the introduction of common training standards made personnel exchanges much easier.

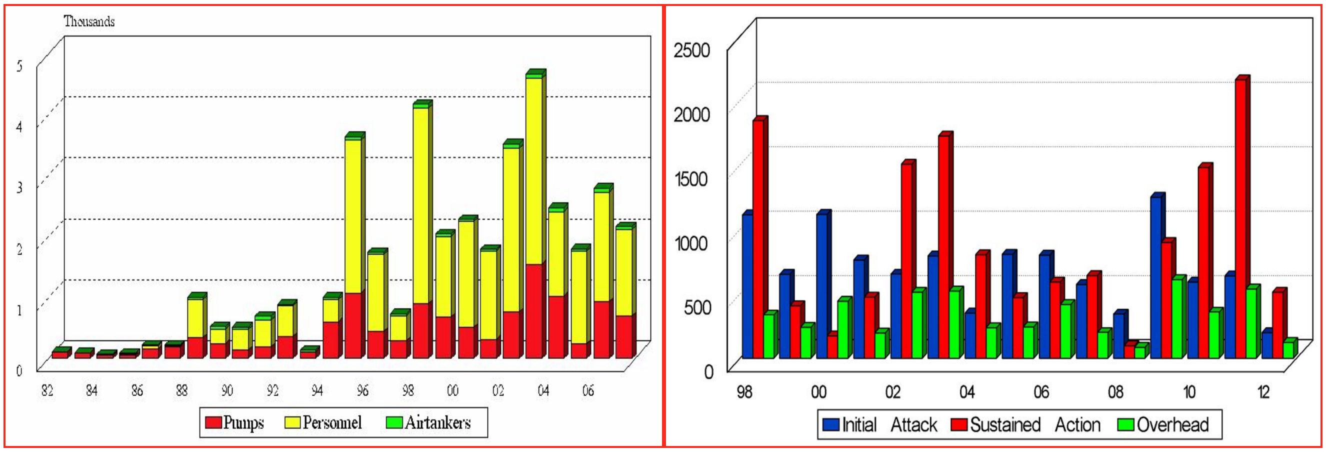


Figure 13 – Resource units shared 1982-2007 (left) and personnel mobilized 1998-2012 (right) through CIFFC

In order to determine the cost of resource sharing among agencies, and the contribution these costs might make to overall fire management expenditures nationally, CIFFC invoices were examined for the past 8 years (2006-2013). Annual resource exchange costs are presented in **Appendix D**, and ranged from a low of \$6.55 million in 2008 to a high of \$31.46 million in 2009, averaging \$16.2 million annually (note scale differences between years). Total resource exchange costs for the 8-year period amounted to \$140.69 million. BC, AB and ON are the agencies most heavily involved in sharing resources in almost all years, but other agencies, particularly QC, are also beginning to share more frequently. In fact, in recent years 10-12 agencies have been involved in the resource exchange program each year, a strong indication of how much agencies have come to rely on their partners. **Figure 14** summarizes total resource sharing costs by agencies (both paid and received) for the 2006-2013 period, and illustrates how heavily BC, AB, ON and QC have relied on resource sharing during this period.

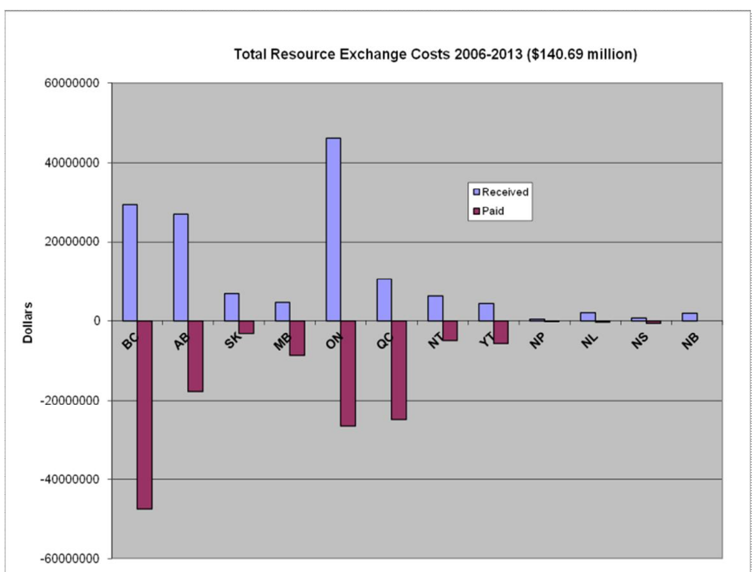


Figure 14 – Total resource sharing costs by agencies for 2006 – 2013 period

However, despite the rising use of resource sharing, and the considerable cost involved, it does not appear that increasing sharing is contributing significantly to rising national fire expenditures. In 2009, a year when BC experienced significant fire activity, \$31.5 million was spent on resource sharing nationally, with BC accounting for \$26 million of this total. During that year national variable costs were approximately \$628 million, while variable costs in BC alone totaled \$382 million (variable costs are assumed to include resource sharing costs in agency budgets). In 2008, a relatively light year in terms of resource sharing, total Canadian variable costs were \$330 million and resource sharing costs amounted to \$6.6 million. Thus resource sharing appears to represent less than 5% of total fire expenditures annually.

Climate Change and Future Fire Load in Canada

Background

Large variability in the Earth's climate has been documented over the past hundreds of thousands of years through analysis of data from ice cores, tree rings, pollen, glaciers, ocean sediments, and the Earth's orbit, which can be considered indirect measures of climate. This historical record reveals that the Earth's climate has exhibited a natural variability over time due to natural causes (e.g. volcanoes, changes in solar energy and greenhouse gas (GHG) concentrations).

Since the Industrial Revolution began in the late 1700s/early 1800s, humans have been using fossil fuels at a rate that has accelerated since that time as industrialization spread globally. GHG emissions to the atmosphere have risen steadily since measurements of carbon dioxide (CO2) concentrations began in Hawaii in 1958, and this trend has been attributed largely to fossil fuel consumption and land-use change globally. The Earth's atmosphere today contains 42% more CO2 than it did prior to the Industrial Revolution, and the levels of other atmospheric GHGs (including methane, ozone, carbon monoxide and nitrous oxide) are also rising steadily. This has resulted in a warming atmosphere and a more unstable, warming, and changing climate. Since 1900 the global average temperature has risen by 0.7 degrees Celsius and the northern hemisphere is much warmer than at any time in the past 1000 years.

Growing scientific and political awareness of the potential threat of climate change led to the establishment of the Intergovernmental Panel on Climate Change (IPCC) by the World Meteorological Organization in 1988. The IPCC was created to provide a forum for scientists to cooperate in the assessment of scientific evidence of climate change, with the goal of providing policymakers with a scientific consensus at regular intervals. Between the First IPCC Assessment Report in 1990 (IPCC 1990) and the Fifth Report in 2013 (IPCC 2013), a series of reports to which thousands of scientists have contributed, the IPCC has incrementally and more strongly endorsed the view that climate change is a human-caused reality. The following quote from the Fifth Assessment Report summarizes the scientific consensus at this point in time:

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased" (IPCC 2013).

These findings have led to increased public and political awareness of potential climate change impacts around the world, and a general commitment to develop strategies to mitigate and adapt to the effects of climate change. Under the auspices of the United Nations, countries have been meeting since the 1990s to negotiate commitments to reduce emissions of greenhouse gases. Both the 1997 Kyoto Protocol (http://unfccc.int/kyoto_protocoal/items/2830.php) and the 2009 Copenhagen Accord (http://unfccc.int/home/items/5262.php) have committed signatory countries to reduce emissions of important GHGs.

Climate change science has expanded greatly since the formation of the IPCC, and is currently a major research focus in most developed countries. General Circulation Models (GCMs) and higher-resolution Regional Climate Models (RCMs) that include three-dimensional representations of the atmosphere, oceans and terrestrial biosphere, have been developed and constantly refined to provide projections of future climates. These models have been used to develop future climate scenarios, and researchers have been using these scenarios to further investigate the future impacts of a changing climate in many disciplines. In addition to extensive research on atmospheric and oceanic impacts, there has been a strong focus on the potential effects of climate change on the terrestrial biosphere.

With climate change scenarios predicting the most significant warming at northern latitudes and over land, there was a strong scientific consensus that impacts in this region of the globe would be both early and significant. The world's extensive boreal zone became the focus of a large amount of climate change-related research, given the huge amount of terrestrial carbon stored in this region, and its increasing vulnerability to natural disturbances driven by a warming climate. In Canada research has focused on forest carbon stocks, forest health, species migration, and natural disturbances (fire, insects, and wind damage).

Climate Change and Wildland Fire

Canadian fire researchers became involved in assessing and predicting the likely impacts of climate change on Canadian wildland fire activity in the late 1980s and early 1990s, and have shown global leadership in this area since that time. Extensive cross-disciplinary collaboration between federal, provincial and academic scientists has been common in Canada over the past 2-3 decades, as research into fire and climate change has matured. Canadian researchers have also worked closely within international teams investigating the common potential threats from climate change on future fire regimes across the circumboreal zone, particularly focusing on Russia, Alaska and northern Canada. There was an early intuitive sense that wildland fire could be expected to be influenced quickly and significantly by a trend towards climate warming, and that fire would be likely to interact synergistically with other natural disturbance such as insects and wind damage under these conditions.

The Canadian approach focuses on the use of the most current GCM outputs, along with recent fire activity and fire weather/danger relationships, to forecast future wildland fire regimes under a changing climate. Confidence in these projections is increased using emerging GCMs that continue to improve in content and resolution. Early Canadian research focused on projecting climate change-related changes in fire danger, while more recent studies have used these results to project changes in wildland fire occurrence and area burned, along with implications for fire management and the carbon budget of Canadian forests. Each of these areas of research is explored more deeply in the following sections, with the most pertinent scientific references.

Future Fire Weather and Fire Danger / Behavior Conditions

Canadian climate change/fire research began in the late 1980s with a focus on developing future fire danger scenarios. Fire weather from recent decades was augmented with GCM-derived monthly temperature and precipitation data for a $2xCO_2$ scenario, resulting in predictions that fire seasons would be longer and more severe in Ontario (Street 1989) and that fire danger levels would increase by nearly 50% across Canada (Flannigan and Van Wagner 1991). Stocks et al. (1998) used a similar approach, with four GCMs, to evaluate the relative occurrence of extreme fire danger conditions in Canada and Russia, and in Canada and Alaska (Stocks et al. 2000). In both cases, they found both an earlier start to the fire season and large increases in the geographical extent of extreme fire danger conditions under a $2xCO_2$ climate (**see Figure 15**). Earlier spring fire season starts, and an increase in future fire season length across Canada by 30 days were also predicted in a Wotton and Flannigan (1993) study. In a very recent study, Flannigan et al. (2013) examined the potential influence of climate change on fire season severity and length globally using 3 modern GCMs. Their results suggest that fire seasons will be three times more severe and fire season lengths will increase by 20 days in the Northern Hemisphere (particularly at high latitudes) by the end of this century.

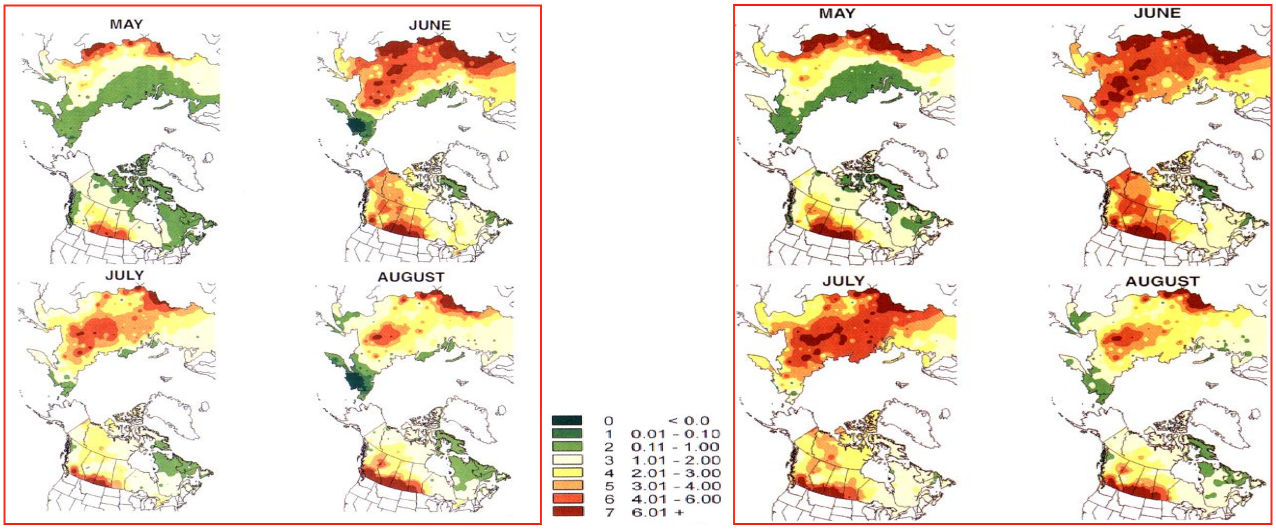


Figure 15 - Average Monthly Severity Rating (MSR) across Canada and Russia for 1980-1989 period (left) and for a 2xCO_2 climate (from Stocks et al. 1998)

The intensity and severity of boreal fires in Canada can be expected to increase under a warming climate as the amount of fuel available to burn will increase as a result of drier conditions as well as stand degradation associated with vegetation shifting and declining forest health (de Groot et al. 2003, 2009). Fire is expected to be a major driver of vegetation shifting in response to climate change, often in synergy with other natural disturbances, exacerbating the direct effects of global warming on species distribution and migration (Stocks 1993; Weber and Flannigan 1997).

Area Burned

Flannigan et al. (2005), produced the first estimates of area burned in Canada under a changing climate, using relationships between weather, fire danger and area burned by large fires between 1959 and 1997 (Stocks et al. 2003), along with outputs from two GCMs, they determined future area burned under a 3xCO_2[1] climate. As illustrated in **Figure 16** large increases in area burned are forecast in many Canadian ecozones, with the most significant increases occurring in the boreal and taiga regions of the country. The projections of area burned in this study suggest a 75-120% increase in area burned by the end of this century.

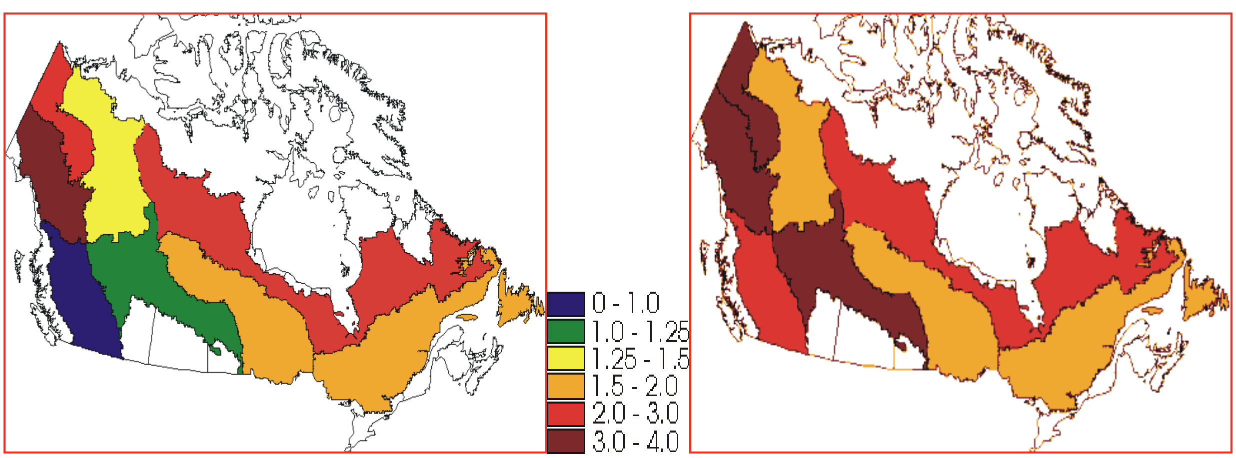


Figure 16 – Ratio of 3xCO_2/1xCO_2 area burned by Canadian ecozones for Canadian (left) and United Kingdom (right) GCMs (from Flannigan et al. 2005)

Other studies have also projected increases in area burned in many regions of Canada over the next century (Bergeron et al. 2004: Amiro et al. 2009; Flannigan et al. 2009). In a similar United States study, Balshi et al. (2008), using air temperature and fuel moisture data, predicted that area burned in western North America would increase by 100% by 2050 and 350-500% by 2100[1].

Temperature appears to be a very important variable affecting fire activity, with warmer temperatures resulting in increased fire activity (Gillett et al. 2004; Flannigan et al. 2005; Parisien et al. 2011). Warmer temperatures would increase evapotranspiration (resulting in decreasing forest fuel moisture contents), lead to increased lightning activity and ignitions (Price and Rind 1994), and result in a lengthening of the fire season (Wotton and Flannigan 1993).

The strength and persistence of blocking high pressure systems in the upper atmosphere has been shown to be strongly correlated with the development of large forest fires (Skinner et al. 1999, 2002). The persistence of blocking ridges is expected to increase in a $2xCO_2$ climate, a factor that could contribute to more large fires (Lupo et al.1997).

Fire Occurrence

The approach to predicting future changes in fire occurrence involves the development of relationships between lightning and human-caused fires and current fire weather and fire danger conditions, followed by the application of these relationships with GCM climate data to forecast future fire occurrence. Using this approach, Wotton et al. (2003) predicted a 50% increase in human-caused fires in Ontario by 2100 AD. Projections of future lightning fire occurrence levels are based solely on the effects of a warming climate on fuel dryness, and do not take into consideration the projected increases in lightning activity in a warmer atmosphere, as described by Price and Rind (1994). Lightning fires were investigated by Krawchuk et al. (2009) who, using a $3xCO_2$ climate scenario, predicted that lightning fires in northern Alberta would increase by 80% by the end of this century. In the most thorough fire occurrence study to date Wotton et al. (2010) investigated future fire activity across Canada under a $3xCO_2$ scenario. From **Figure 17**, which shows fire occurrence percentage change by 2090 AD for both lightning and human-caused fires, it is evident that, although activity is forecast to increase across all forested regions of Canada, the relative increase varies regionally. The most significant increases are forecast for the boreal and taiga ecozones, particularly in west-central Canada. Lightning fire occurrence is also forecast to increase more than human-caused fire activity.

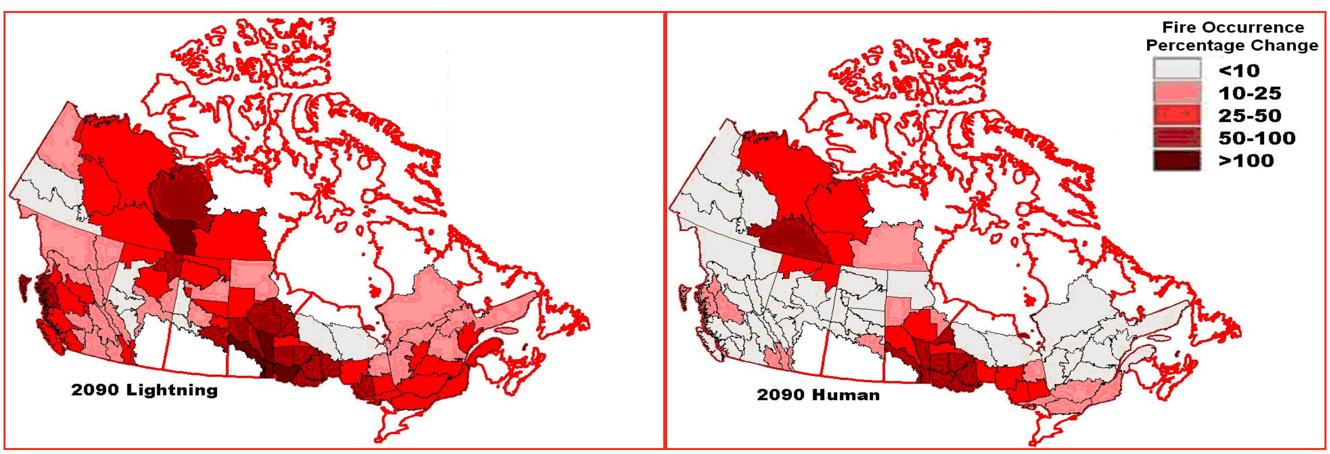


Figure 17 – Relative change (percentage increase) in fire activity between current (baseline) and future ($3xCO_2$) climate scenarios (from Wotton et al. 2010)

[1] A *$2xCO_2$ scenario represents a doubling of atmospheric CO_2 levels from the pre-industrial level, which is expected to occur by 2050AD. A $3xCO_2$ scenario represents a tripling of atmospheric CO2 levels, and is expected by 2100 AD.*

Fire Management Implications

The forecast impacts of climate change-driven future fire activity outlined in previous sections raises the question whether current Canadian fire management programs will have the capability to both mitigate and adapt to future fire regimes. Fire management agencies generally operate (and are budgeted) with a narrow margin between success and failure, and a trend towards more fire activity under a changing climate could mean more fires escaping initial attack and growing larger (Stocks 1993). The resulting increase in area burned could be much greater than that expected when considering the corresponding increase in fire weather severity alone. There is also a likelihood that, given competing fiscal demands, governments would be challenged to provide Canadian fire management agencies with the budget increases required to maintain their current levels of effectiveness (Stocks 1993).

In Ontario, simulation studies using the Ontario initial attack system (McAlpine and Hirsch 1998) showed that reducing the number of escaped fires from current levels would require a very large investment in additional resources, and that incremental increases in fire suppression resources result in diminishing gains in initial attack success. More recently, Wotton and Stocks (2006) used Ontario's initial attack simulation system in combination with scenarios of expected fire occurrence and fire weather to show that a doubling of current resource levels would be required to meet a modest increase of 15% in fire load (which is based on number of fires and difficulty to control). Further, Podur and Wotton (2010) used GCM outputs along with fire growth and suppression simulation models to project a doubling of area burned by 2020 AD and an eightfold increase by 2100AD. These changes were driven by increases in fires escaping initial attack, with escaped fire frequency increasing by 34% by 2040 and 92% by the end of the 21st century.

Finally, during early climate change negotiations around the Kyoto Protocol, there was discussion of using the carbon stored in Canada's vast forests to offset GHG emissions. However, subsequent studies showed clearly that increasing natural disturbance rates (and synergies between fire, insects and blowdown) under a changing climate could overwhelm attempts to influence the forest carbon balance through forest management (Kurz et al. 1995, 2008a, 2008b).

Operational Fire Management Perspectives on Changing Fire Load in Canada

There has been a growing sense among many Canadian wildland fire managers that fire conditions, at least in some regions of the country, are becoming more volatile, resulting in fires that are more difficult to control effectively. This has resulted in a perceived increase in fire load to date, and growing concerns over a future in which fire activity is forecast to increase significantly.

In order to further evaluate this issue, a survey of all Canadian fire management agencies was undertaken in which senior fire managers were asked for their opinions on current and future fire load trends. They were provided with fire statistics (expenditures, fire occurrence and area burned data) for the past four decades for both their jurisdiction and Canada, and asked to provide their thoughts on the following subjects:

1) Causation of trends in numbers of fires and area burned (both within your agency, and nationally).

2) Changes in protection policies or responsibilities that may have affected the numbers of fires tracked by your agency over time.

3) Causation of trends in fire management expenditures (both within your agency, and nationally).

4) Other trends in changing fire load and resource capacity within your jurisdiction.

5) What actions your agency has taken in response to changing trends – including changes to policy, response guidelines, resource capacity, or other actions.

Perspectives varied between agencies, based not only on the wide range in values they protect, but the size and budget of their organization (and thus their expenditures). Larger agencies have moved to more dedicated fire management programs with more training and standards. Jurisdictions with large MRZs all accommodate natural fire, and this has a very large effect on their fire statistics.

1) Fire Activity Trends:

Almost all agencies reported a decline in H-C fire numbers and area burned in recent years. This was attributed to a variety of factors, including:

- more successful fire prevention and public education programs
- the frequent use of restricted fire zones
- new or improved forest industry guidelines
- a reduction in railway lines (in Maritimes)
- a rural exodus from farmlands to urban centres
- lower fire danger conditions (in some cases).

However, some agencies anticipate an increase in H-C fires in the near future due to expanding natural resource-based industries, particularly the oil/gas and mining sectors, and the continued expansion of communities into flammable wildlands.

Most agencies reported that lightning fire numbers and area burned have remained variable but have not changed in the recent past. Some agencies (with MRZs) reported an increase in lightning fire numbers and area burned due to increased use of satellite detection and mapping. Others believe improved suppression technology is placing downward pressure on area burned on both lightning and H-C fires within FRZs. At the same time, some agencies are allowing (and encouraging) more natural fire where possible, and anticipate that this will increase area burned in MRZs.

2) Changes in Protection Policies

- A number of agencies reported expanding protection responsibilities associated with growing industrial development (mining, oil and gas etc.), particularly in more remote regions.
- Some agencies have established agreements that result in local or municipal governments assuming responsibility for fires in and near communities.
- All agencies report increased sharing of resources through CIFFC, and this has become a key component in fire program planning.

3) Fire Expenditure Trends:

Most fire management agencies across Canada, including all agencies with large programs, indicated that the costs of providing fire management services within their jurisdiction were rising. Many of the suggested reasons for this trend were common among agencies. These included:

- Increasing numbers of fires near high-value resources in or near the wildland-urban interface which require large commitments of costly resources. Public expectations in these areas are also growing, putting further pressure on fire management agencies.
- The increasing costs of suppression resources (aircraft, helicopters, retardant, fuel etc.) which seem to be rising faster than the Consumer Price Index.
- The expanding use of resource-sharing. With agencies down-sizing in the mid-1990s, the resource shortfall is made up through extensive sharing, and these costs are added directly to fire budgets. This culture of free-flowing resources across Canada can results in significant and rapid expenditures.
- Variable costs increasing while fixed costs reduced through government fiscal policies.
- Increased professionalism, including training of fire crews and overhead teams.
- Expansion of programs to keep up with increasing development of remote areas for natural resource extraction.

4) Other Trends in Fire Load and Resource Capacity:

- Climate change impacts on fire danger, insect damage.
- Expanding resource development and WUI.
- Changing demographics - decline in experienced staff, succession planning hindered by constraints.
- Permanent staff capacity declining, but filled with more non-permanent internal and external resources, which is costly.
- Less access to resources, competing demands from expanding industries.

5) Actions Taken in Response to Changing Trends:

- Increased strategic planning to improve effectiveness and efficiency- community protection, workforce demographics, preparedness review plans.
- Developing more flexibility in managing fires, suppressing larger risk fires quickly, allowing more lower risk fires to burn naturally.
- More involvement in resource exchange through CIFFC and Compacts with the US.
- Some agencies report no changes.

Summary

Canadian wildland fire management expenditures have been rising steadily over the past four decades, and have risen most quickly, and with increasing variability, since the mid-1990s. This has been particularly evident in BC and AB, but other agencies with large fire management programs have also experienced rising expenditures, particularly ON and QC. On the other hand, some agencies, most notably NS, NB and NT, have seen costs decline in recent years. In addition, there has been an intuitive sense among fire managers that fire load has been increasing as well, and this was a major reason for the development of the CWFS in 2005. The foregoing analyses of recent fire statistics, projected future changes in fire load under a changing climate, and a survey soliciting the opinions of experienced Canadian fire managers was aimed at determining possible reasons for increasing expenditures and fire load.

A review of national fire statistics post-1970, a four-decade period in which coverage of all fires across Canada has been consistent and reliable, does not show a trend towards increasing fire activity at a national scale. The high degree of interannual variability, which is common with wildland fire statistics, makes discerning trends difficult. Based on recent studies (e.g. Metsaranta 2010) it is likely that a 44-year record, in which annual area burned varied by more than an order of magnitude, is an insufficient length of time to discern a statistically significant trend. This would be true at both the national and provincial/territorial scale in Canada.

While annual area burned trends are difficult to discern, post-1970 national fire numbers show a declining trend, most significantly since the early 1990s. This recent trend is also evident in individual jurisdictions across the country, with the exception of AB, where fire occurrence is rising - partly, but not wholly due to changes in the fire accounting system in 2004.

Given the large differences in response to fires in FRZs and MRZs across the country, it was felt that an examination of fire statistics for the FRZs may yield some trend information that might influence overall fire costs, since these zones receive more aggressive and expensive fire responses. However, even with this filter, no trends emerged. The number of fires in FRZs showed a declining trend, as might be expected given earlier jurisdictional trends, while area burned numbers showed no distinct trend. Fire numbers and area burned in the MRZs remained relatively constant.

With the assumption that large fires, which are disproportionately costly, may be contributing to rising national costs, an analysis of fires >200 hectares in size was undertaken for BC, AB, SK, MB, ON and QC. Large interannual variability in both fire numbers and area burned was evident in this dataset, just as it was when all fires were considered, and no trends over time emerged.

Next, an analysis of lightning and H-C fires within each jurisdiction was undertaken, although this data could not be separated by FRZ/MRZ. Lightning fire statistics did not exhibit any significant trends, but a strong downward trend in the number of H-C fires in BC, SK, ON and QC was evident, indicating that the overall downward trend in fire numbers has been largely driven by H-C fires.

Resource-sharing between Canadian fire management agencies has been growing steadily since the inception of CIFFC in 1982, and an analysis of annual resource-sharing costs for the 2006-2013 period was undertaken to determine the financial scale of this program. BC, AB, ON and QC were the most active agencies in terms of resource-sharing, but virtually all agencies were involved in many years. Annual costs varied from approximately $7 million to almost $32 million annually. With annual national expenditures averaging ~$800 million during this period, it would appear that resource-sharing costs do not contribute significantly to rising national expenditures.

A thorough review of the pertinent literature on climate change and future fire activity in Canada was undertaken and summarized. A continuing number of studies, beginning in the early 1990s, have used the latest GCM models in combination with recent fire data, to produce updated predictions of fire activity in Canada during the 21st Century. The results from these studies indicate:

- Large increases in the geographical extent and frequency of extreme fire danger episodes, particularly in west-central Canada.
- Increases in fire season length, with seasons beginning earlier in spring.
- Increasing frequency of more intense, higher severity fires.
- Large increases in area burned (75-120%) across the Canadian boreal zone.
- Significant increases in the frequency of both H-C and lightning fires across the boreal zone, with lightning fire numbers expected to increase more than H-C fires.
- A declining capability of Canadian fire management agencies to maintain their current levels of effectiveness if future fire projections are accurate, as models indicate current resource levels would have to be doubled to meet even a modest (e.g. 15%) increase in fire load.

Agency surveys with respect to perceived changes in fire load and policies to address this issue were undertaken. Given that an analysis of national and jurisdictional fire and area burned trends yielded no rising trends in fire activity that might link to rising costs, it was hoped that fire management agencies might have an intuitive sense of the factors at play that might answer this question, at least in part. While most associated the downward trend in fires with improved prevention and activities, most fire managers surveyed pointed to some potential causes for rising costs that would not necessarily show up in annual fire statistics. Key among these are:

- rising operational, equipment and infrastructure costs.
- the additional costs and scrutiny associated with fighting fires closer to the WUI.
- increased accountability under public and political scrutiny.
- increasing expansion of resource-extraction activities which increase H-C fire activity and put more people and values at risk.
- fire programs expanding coverage without additional baseline funding.
- fire agency's becoming more involved in all hazards(e.g. flooding)

Frequently updated and improved GCMs continue to project significant increases in fire activity and impacts across Canada, despite the fact that evidence of these impacts has yet to be conclusively identified. However, steadily rising fire management costs are a strong indication that things are changing. At this point in time it appears that the rapidly rising costs of fire equipment and operations, the increased fire costs associated with protection high-value resources in the WUI, and the expansion of fire management responsibilities both geographically and across hazard types are the factors most likely driving costs upward. However, as climate change continues, agencies will increasingly be dealing with more frequent and severe fires in a more severe fire environment. The observed increase in fire management expenditures that prompted this study may be the best indicator of more challenging fire management conditions. The Canadian fire management community needs to continue its efforts to maintain its resource capacity, anticipate changing fire load, and maintain its resource sharing capacity and effectiveness.

Acknowledgements

This work would not have been possible without the gracious assistance of a number of wildland fire colleagues. Mike Flannigan (University of Alberta), Mike Wotton (Canadian Forest Service), Steve Taylor (Canadian Forest Service) and Paul Ward (retired) contributed time and thoughts to the data analysis and conclusions in this report. John Little (Canadian Forest Service) arranged and provided data from the National Fire Data Base. Numerous fire managers around the country also provided data and insights. A special thanks to Sherra Muldoon for valuable assistance in organizing this report.

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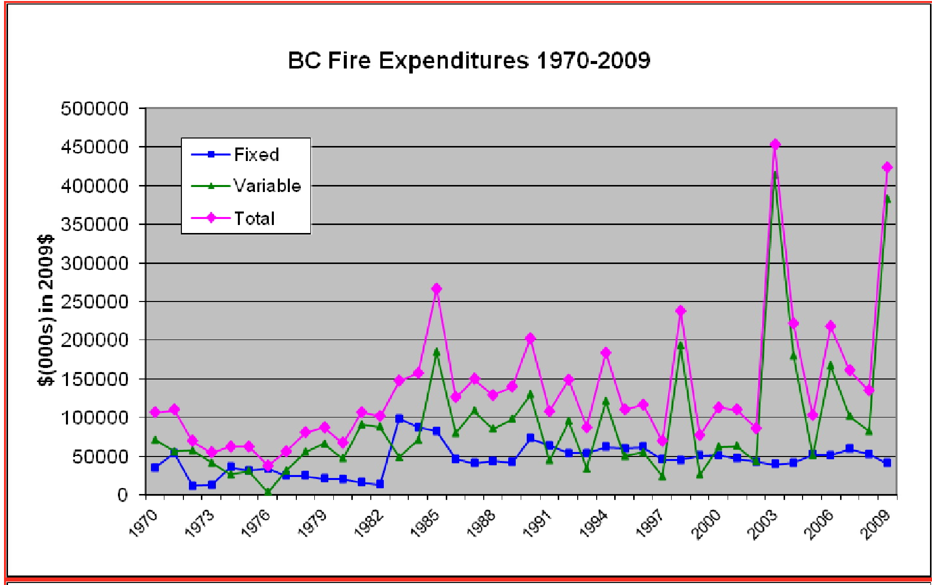
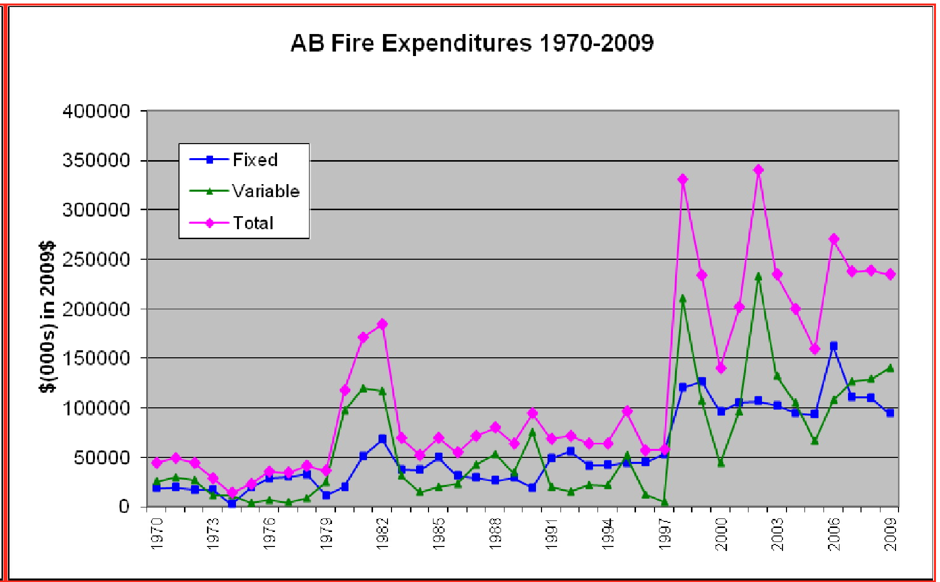
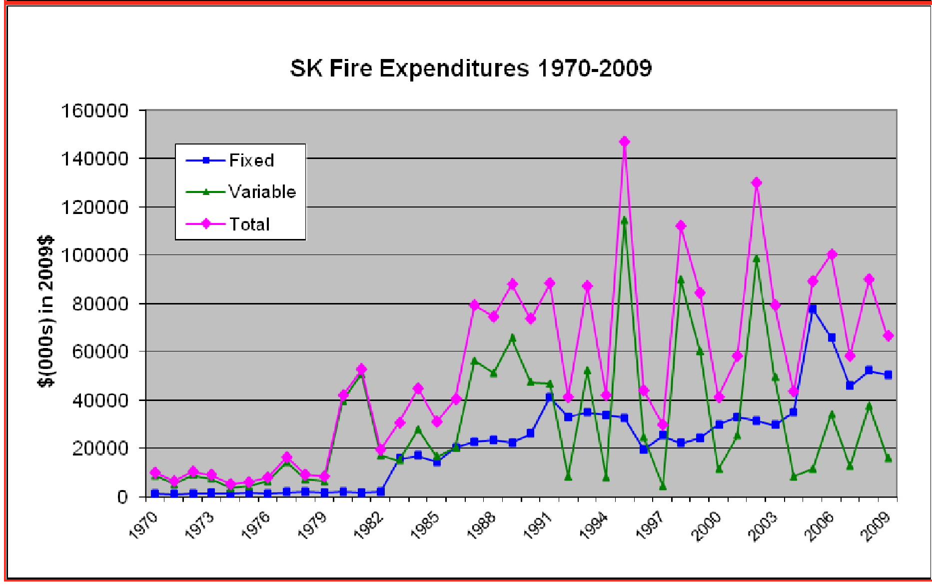
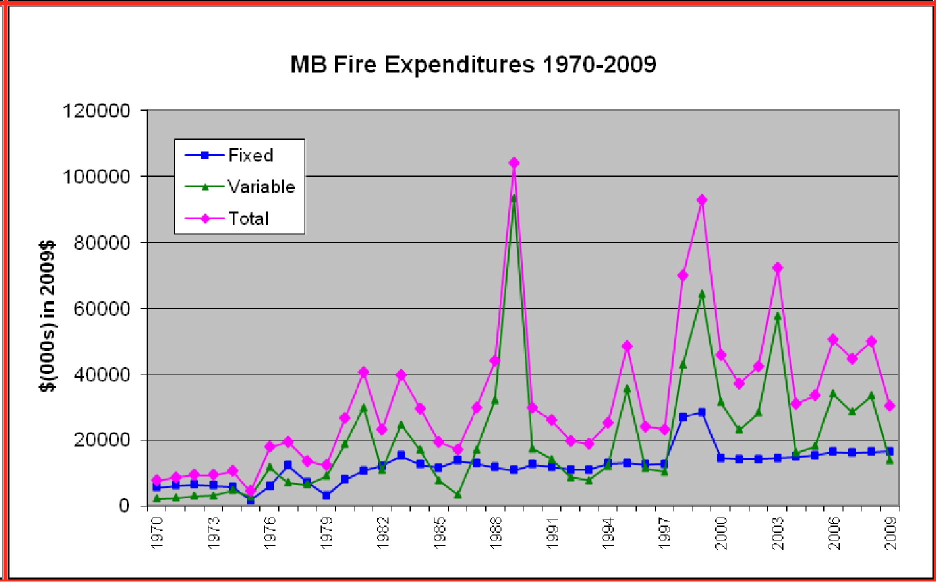
Appendix A - Wildland Fire Expenditures

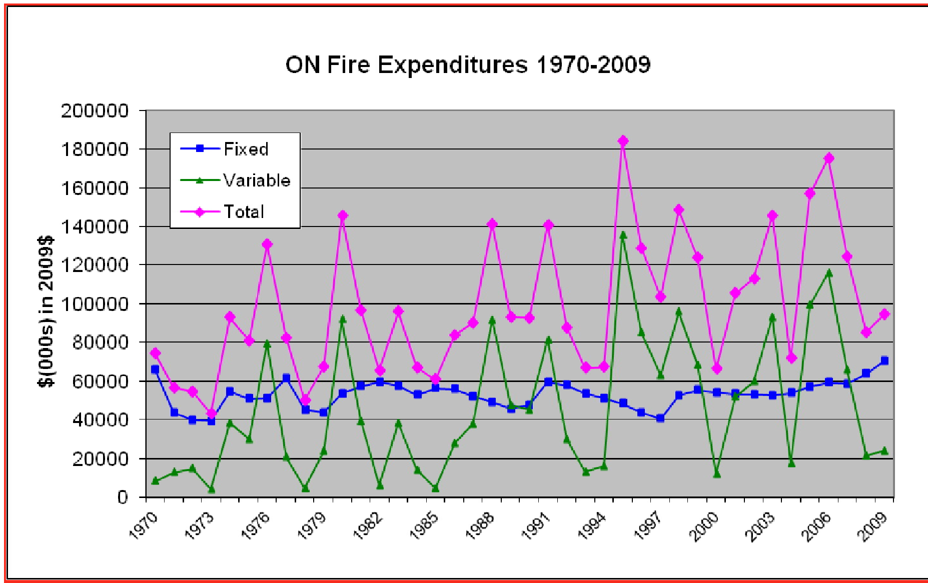
FIRE MANAGEMENT EXPENDITURES FOR INDIVIDUAL CANADIAN JURISDICTIONS 1970-2009







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Variable
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100000
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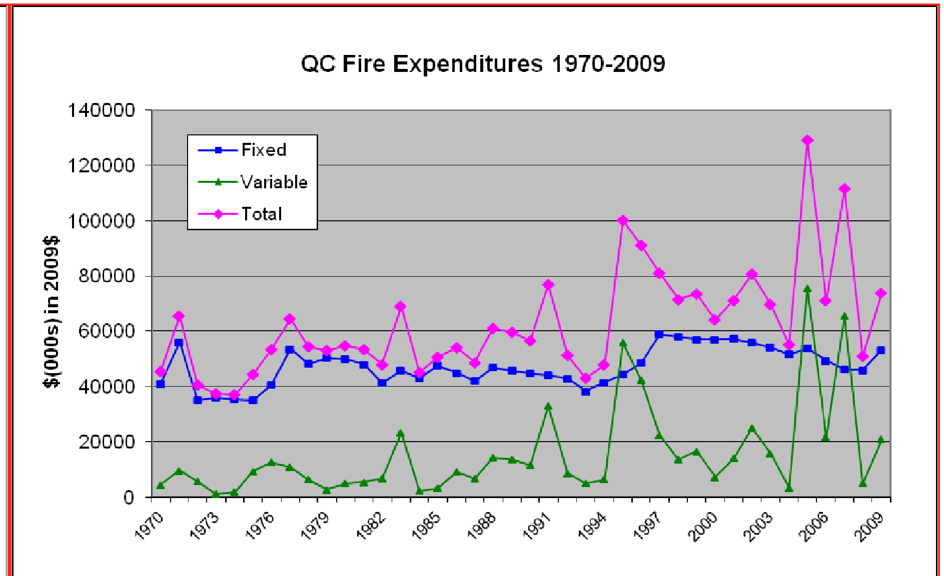
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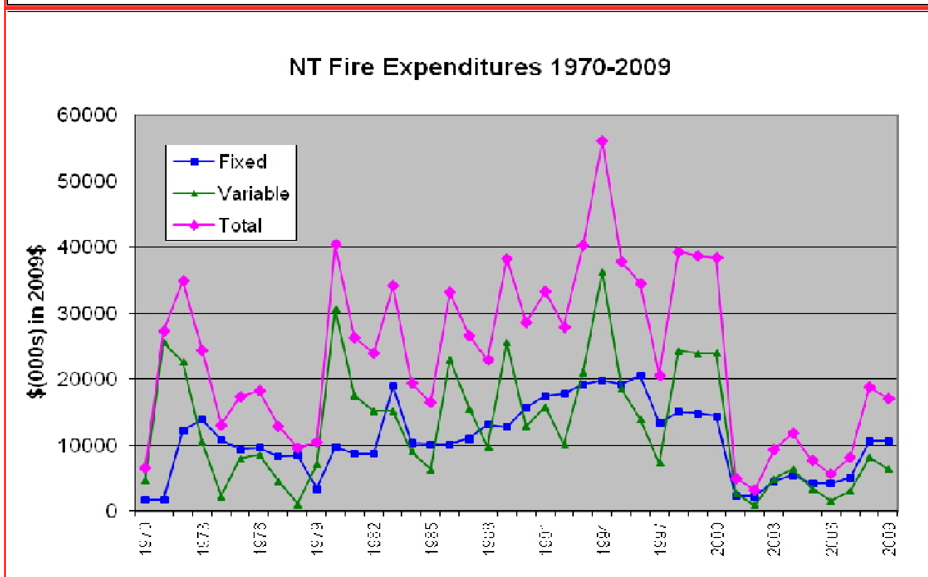
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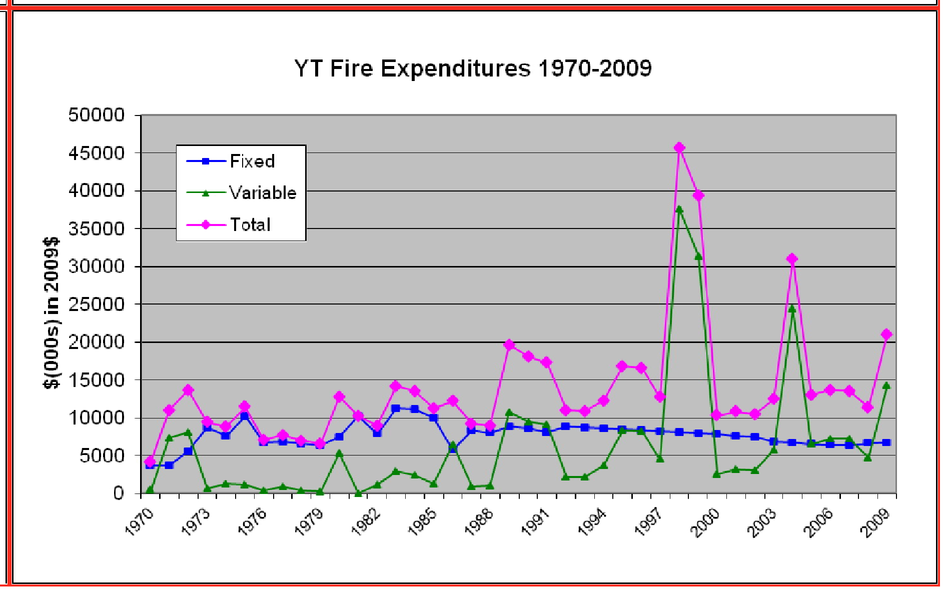
2003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25000
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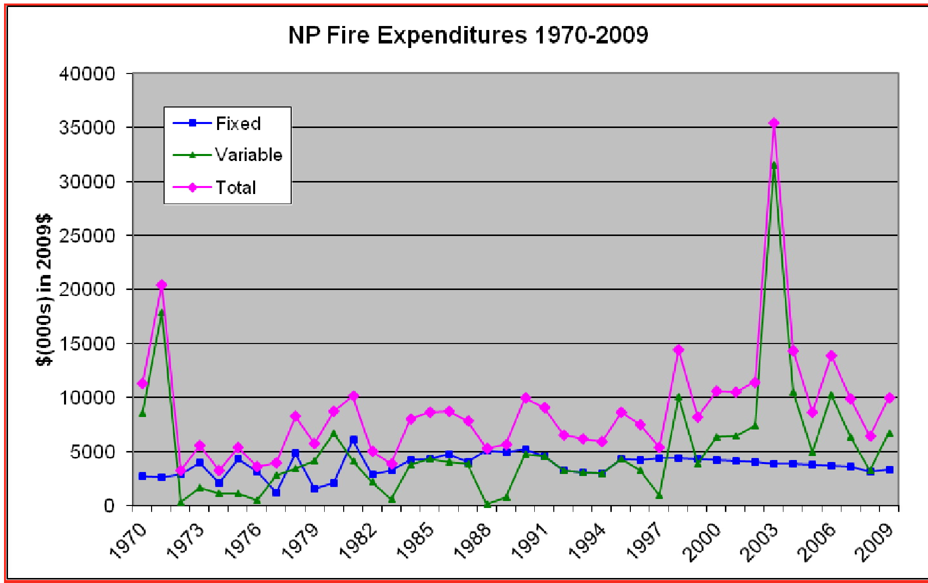
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40000
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2003
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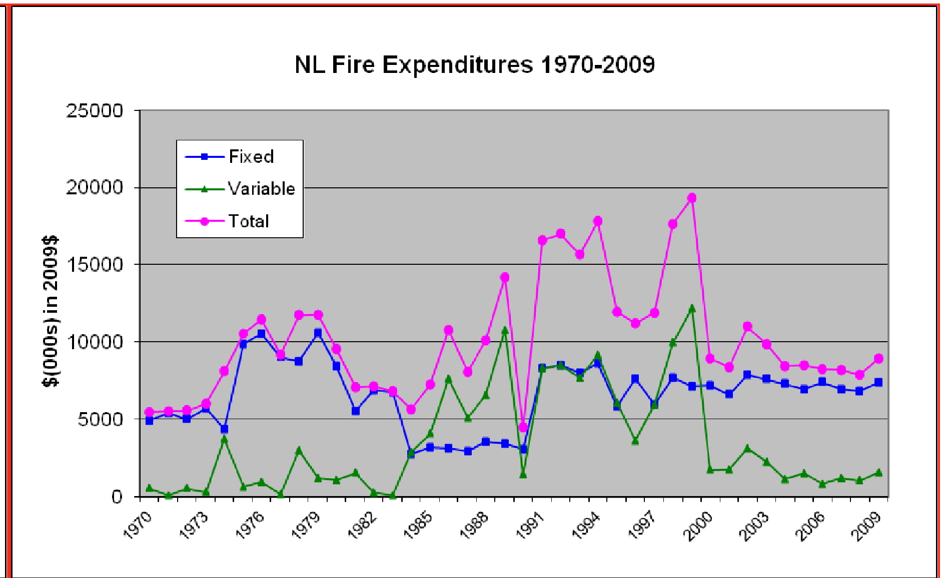
2009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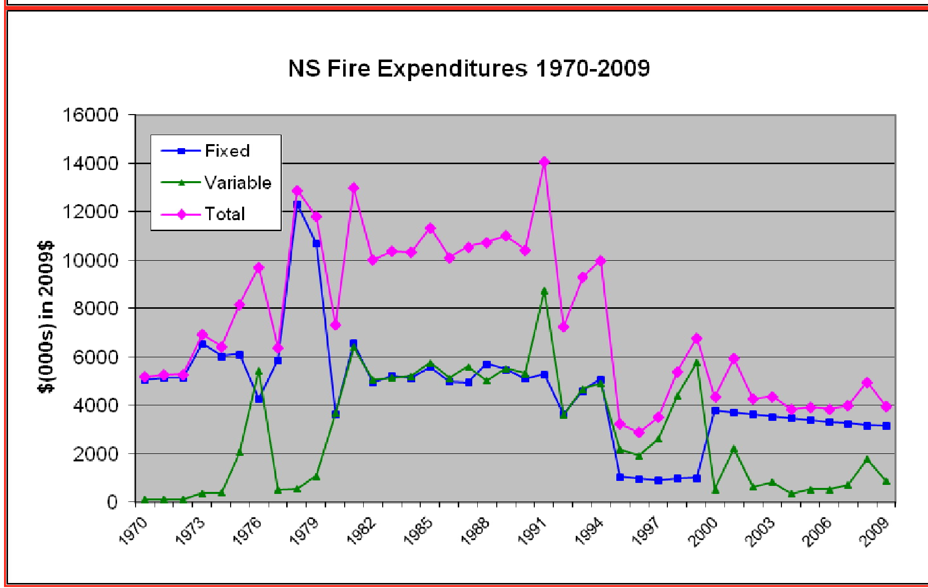
2006
2009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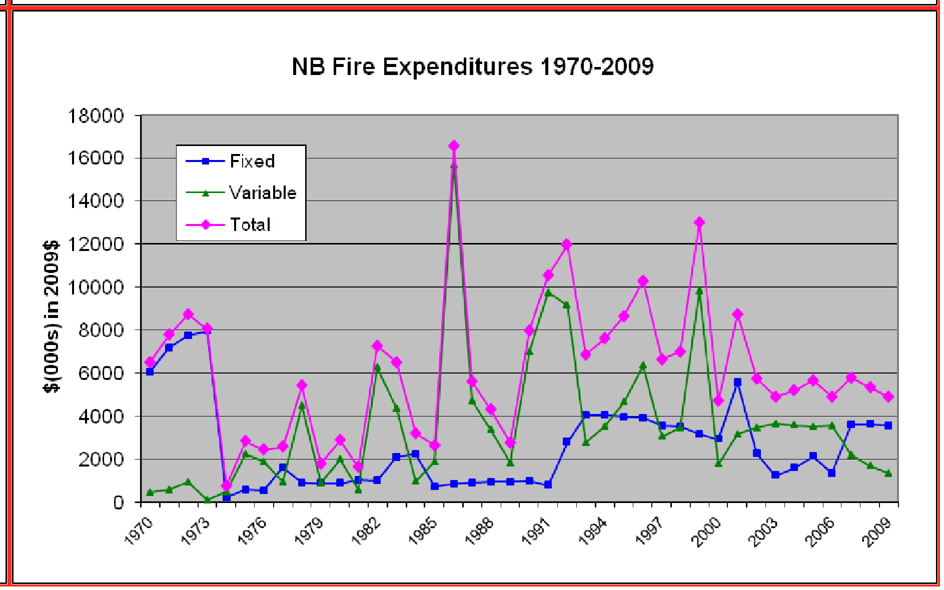
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Variable
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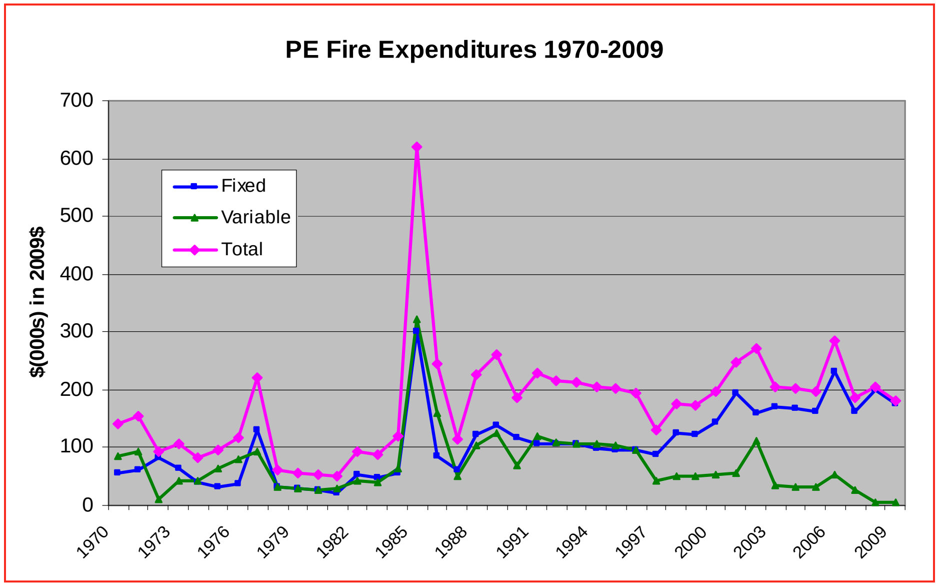
2006
2009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$(000s) in 2009$
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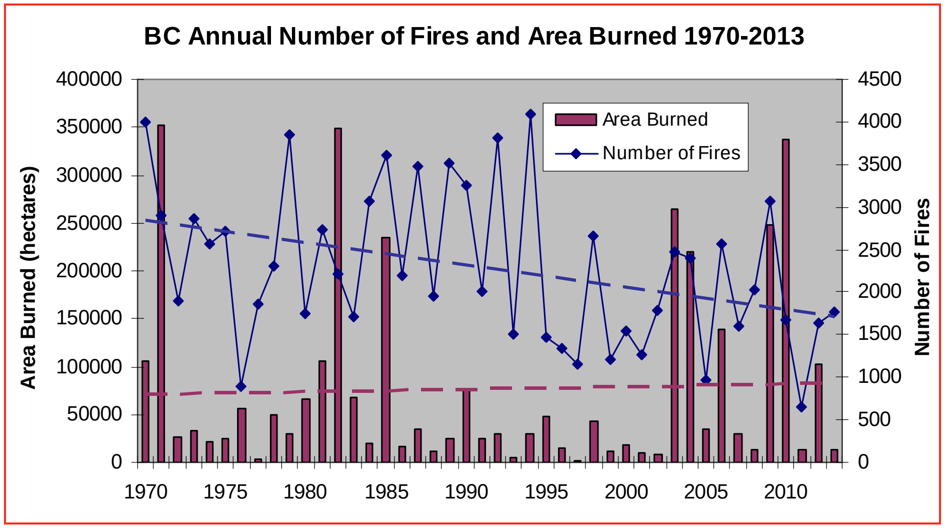
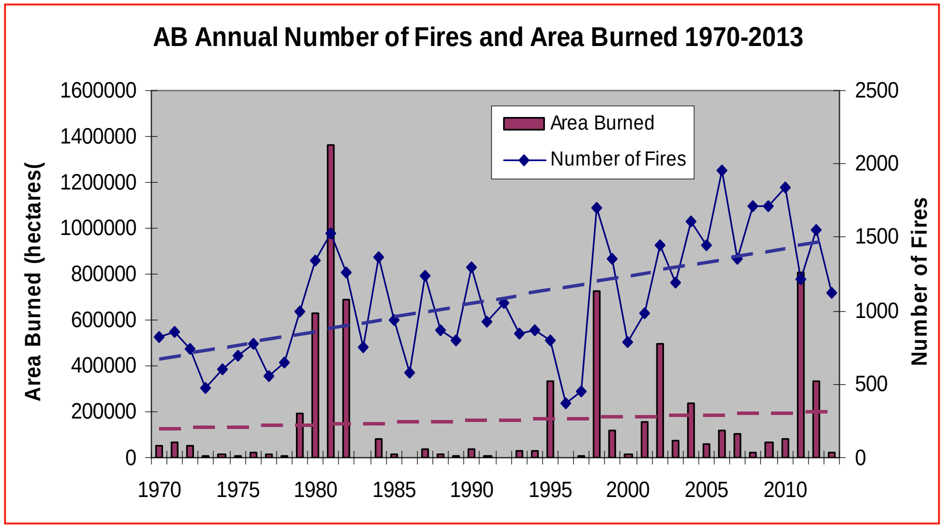
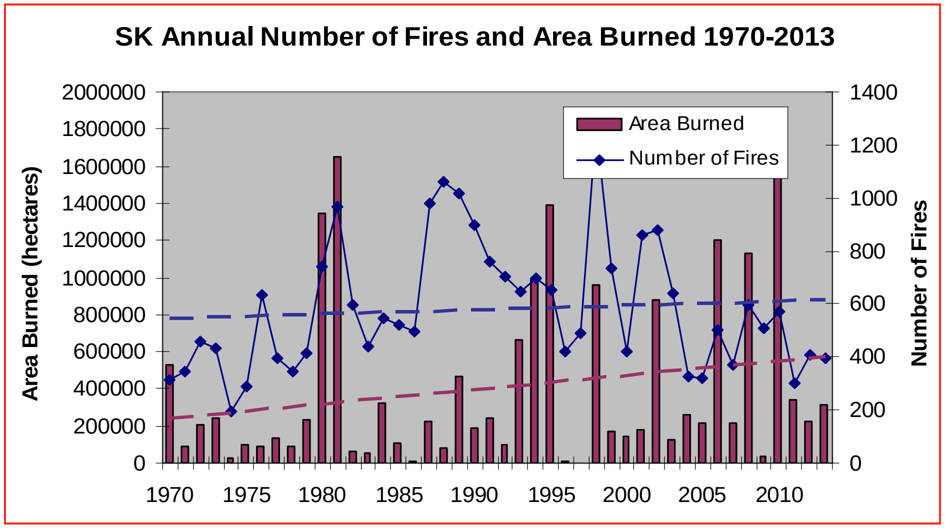
100
200
300
400
500
600
700
Fixed
Variable
Total
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009

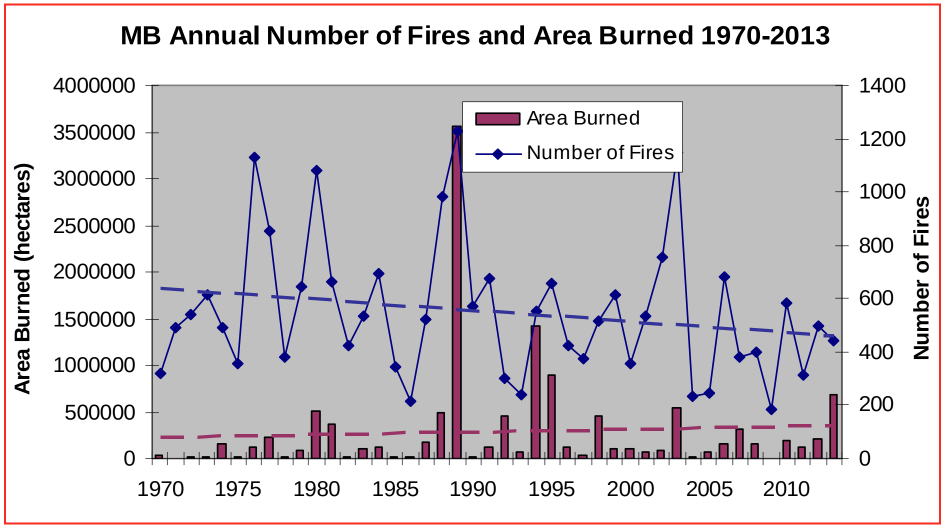
Appendix B – Fires and Area Burned

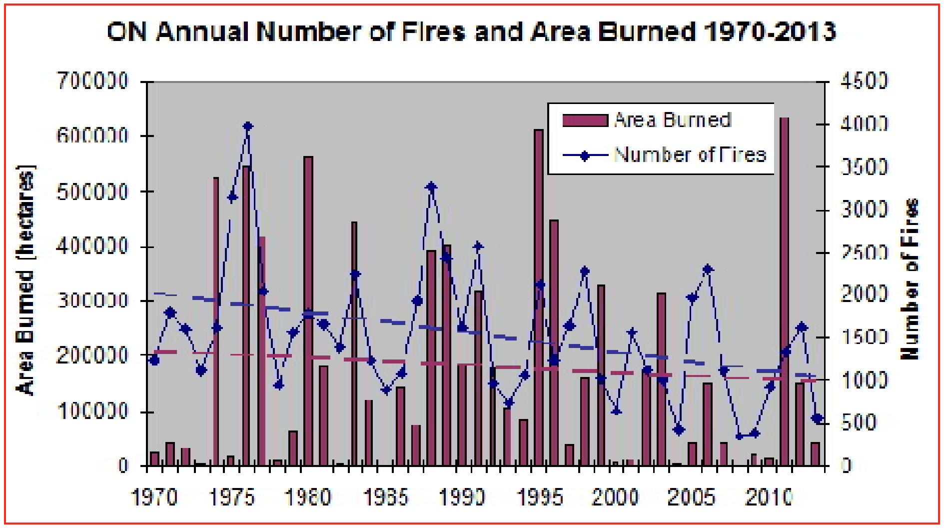
FIRES AND AREA BURNED BY INDIVIDUAL CANADIAN JURISDICTIONS 1970-2013







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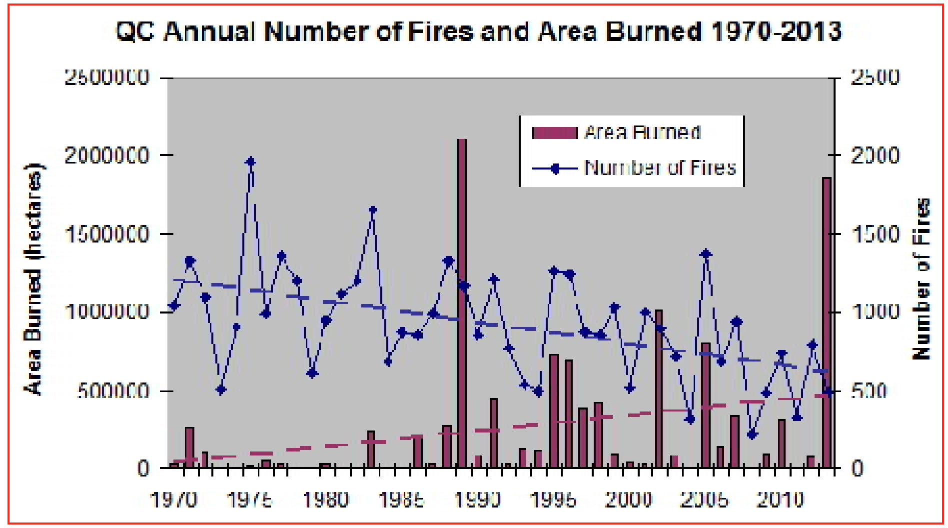
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
700000
600000
500000
400000
300000
200000
100000
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1970
1975
1980
1985
1990
1995
2000
2005
2010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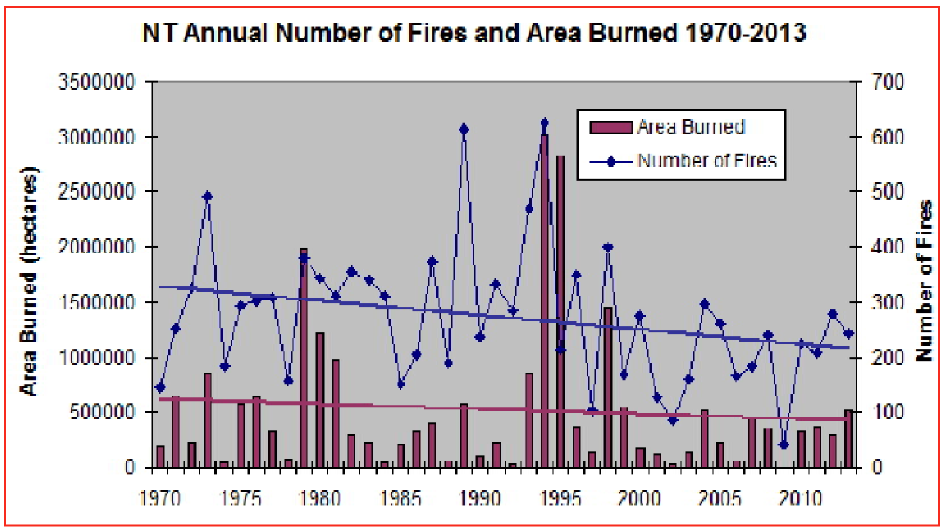
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
2500000
2000000
1500000
1000000
500000
0
2500
2000
1500
1000
500
0
1970
1975
1980
1985
1990
1995
2000
2005
2010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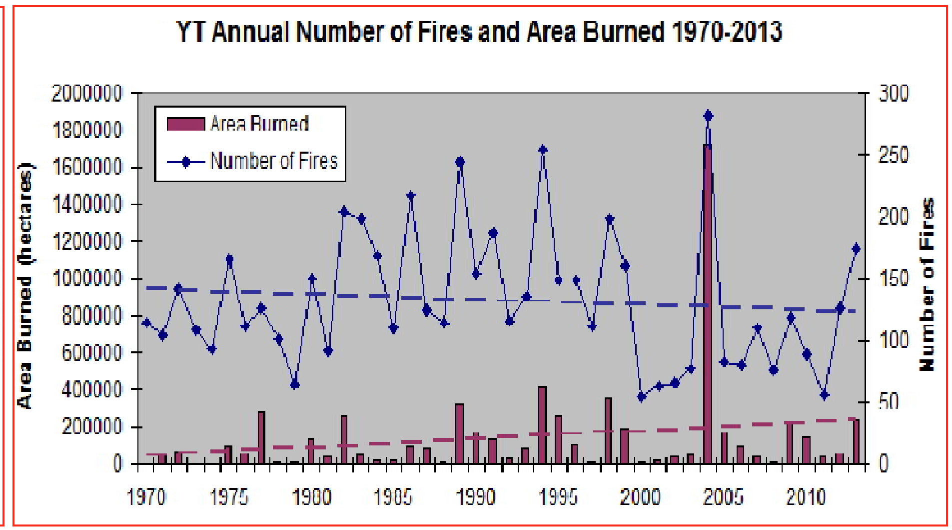
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
700
600
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995
2000
2005
2010


YT Annual Number of Fires and Area Burned 1970-2013
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
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300
250
200
150
100
50
0
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1975
1980
1985
1990
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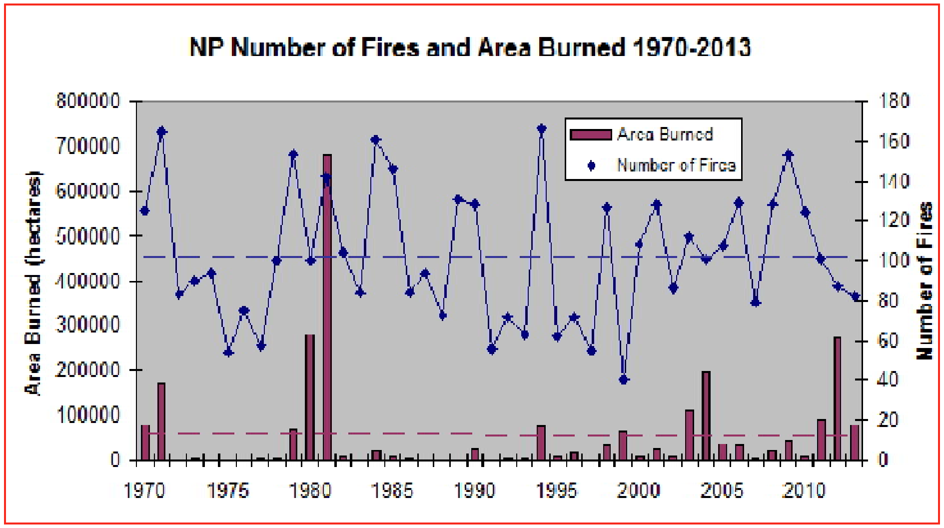
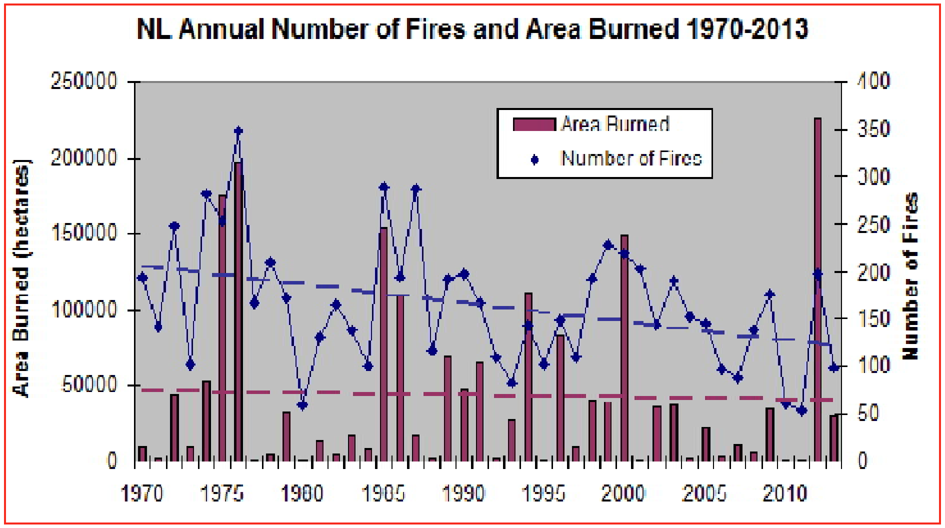
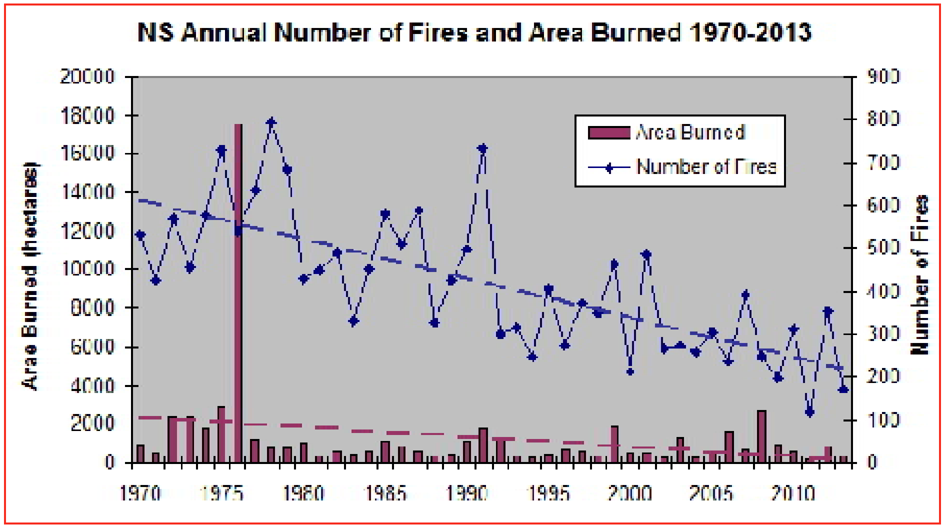
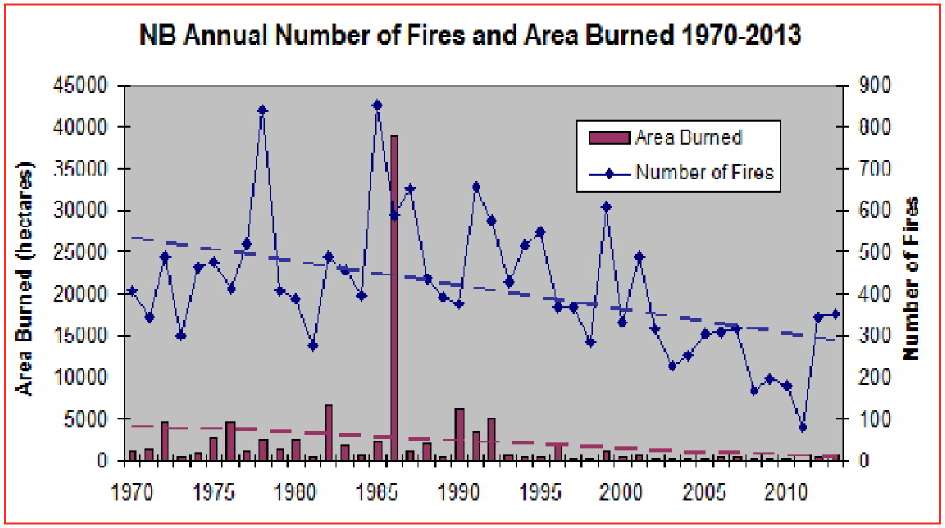
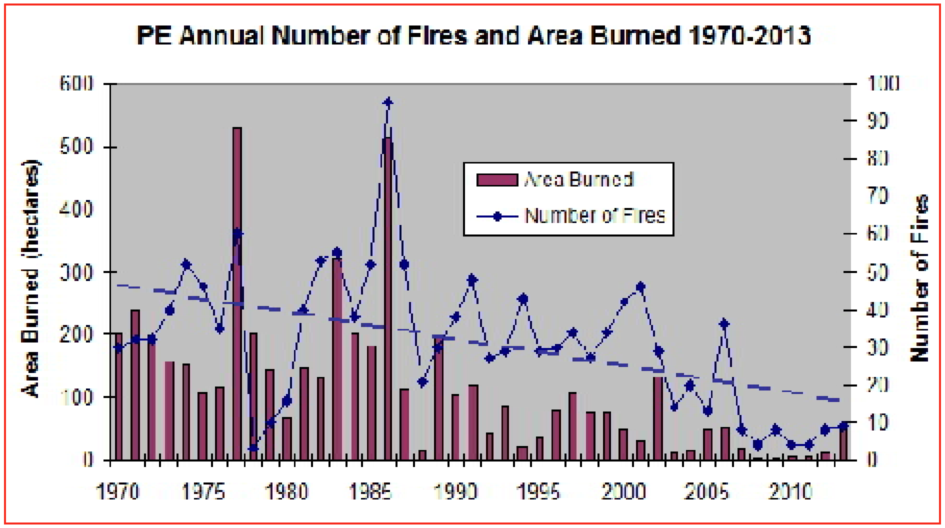
2005
2010


NP Number of Fires and Area Burned 1970-2013
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
800000
700000
600000
500000
400000
300000
200000
100000
0
180
160
140
120
100
80
60
40
20
0
1970
1975
1980
1985
1990
1995
2000
2005
2010


NL Annual Number of Fires and Area Burned 1970-2013
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
250000
200000
150000
100000
50000
0
400
350
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

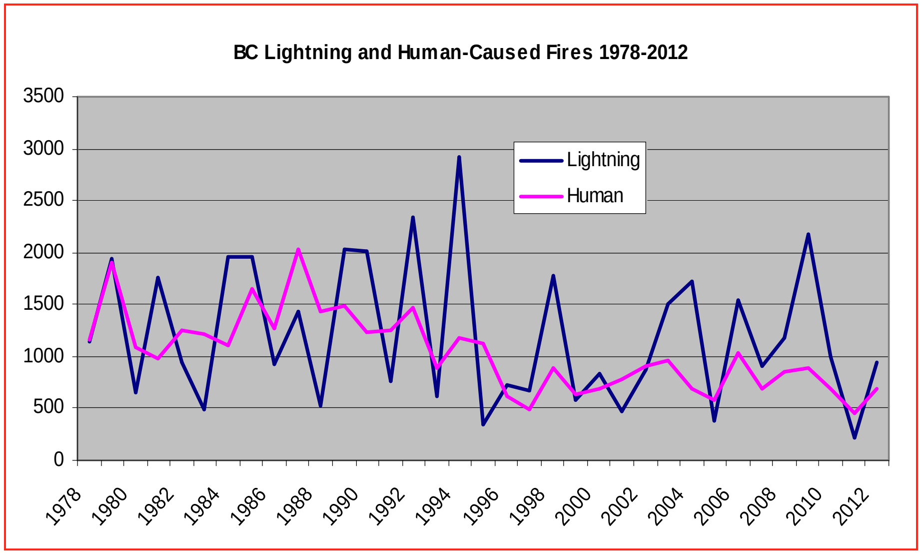

NS Annual Number of Fires and Area Burned 1970-2013
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
900
800
700
600
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

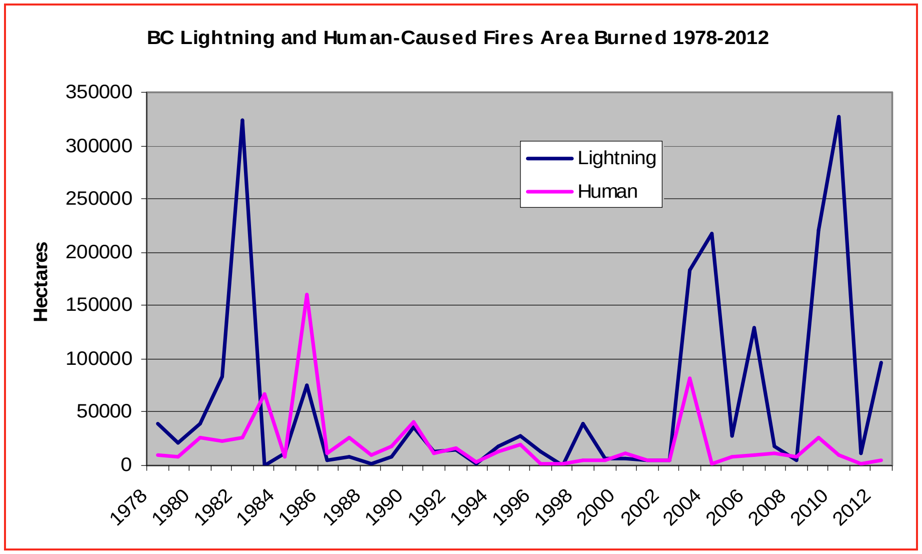

NB Annual Number of Fires and Area Burned 1970-2013
Area Burned
Number of Fires
Area Burned (hectares)
Number of Fires
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
900
800
700
600
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

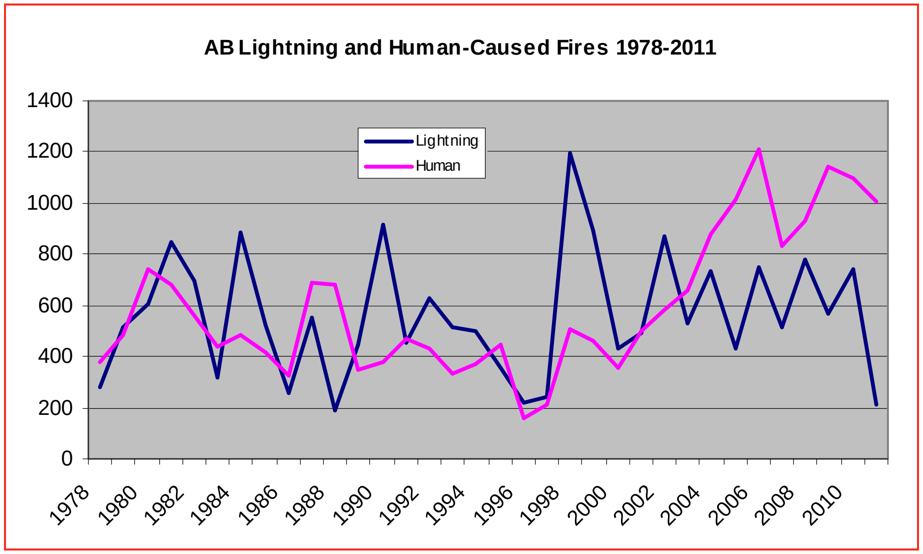

PE Annual Number of Fires and Area Burned 1970-2013
Area Burned (hectares)
Number of Fires
Area Burned
Number of Fires
600
500
400
300
200
100
0
100
90
80
70
60
50
40
30
20
10
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

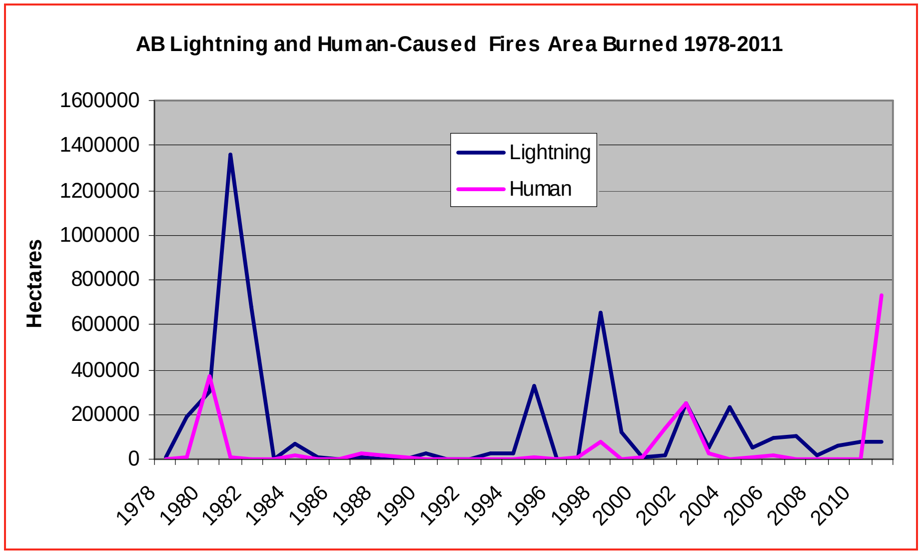
Appendix C – Lightning and Human-Caused Fires

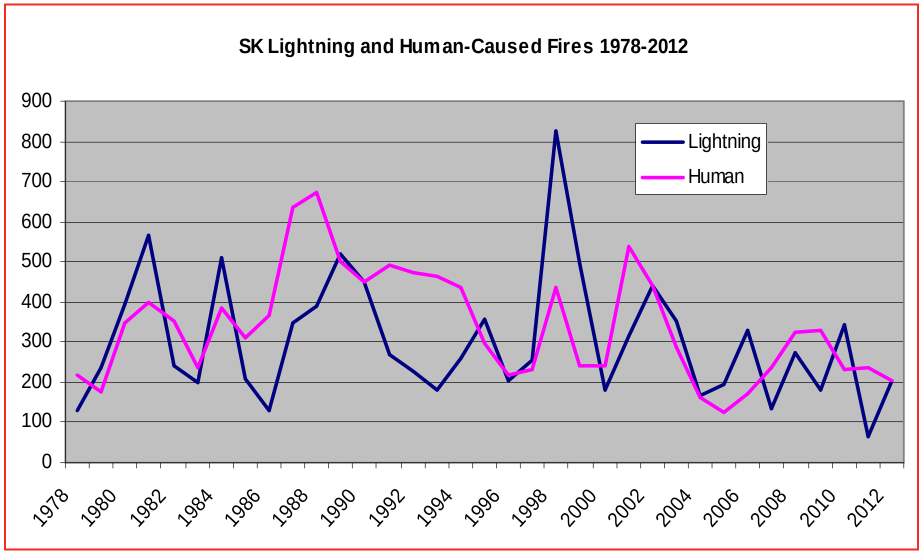
LIGHTNING AND HUMAN-CAUSED FIRE NUMBERS AND AREA BURNED BY INDIVIDUAL CANADIAN JURISDICTIONS 1978-2011/12

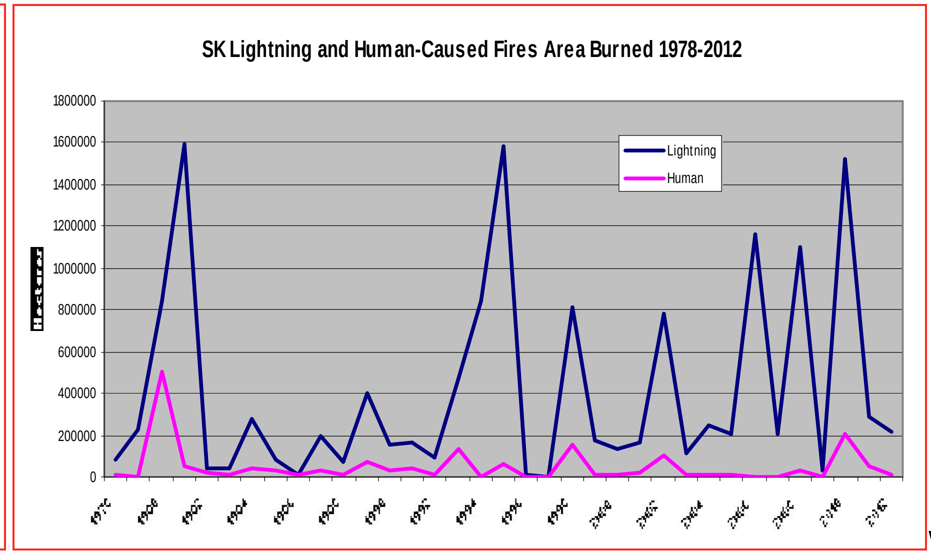


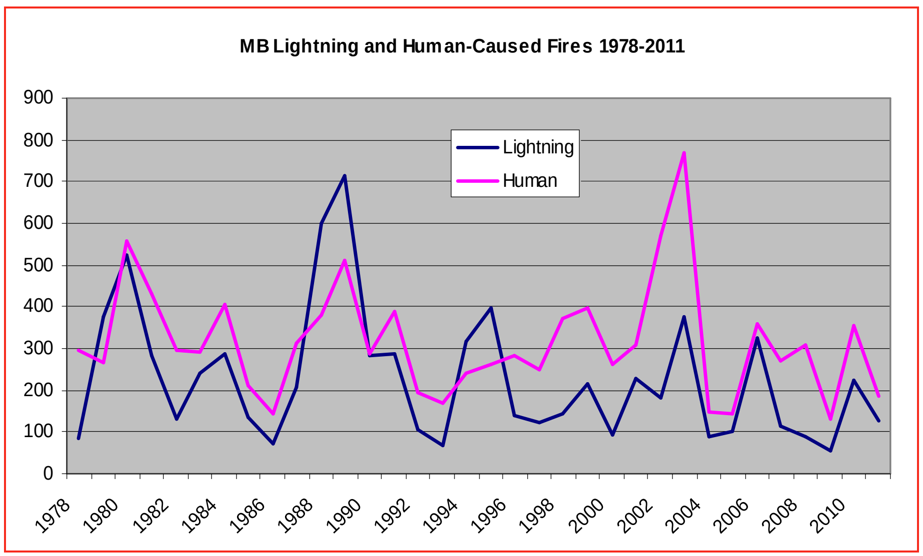


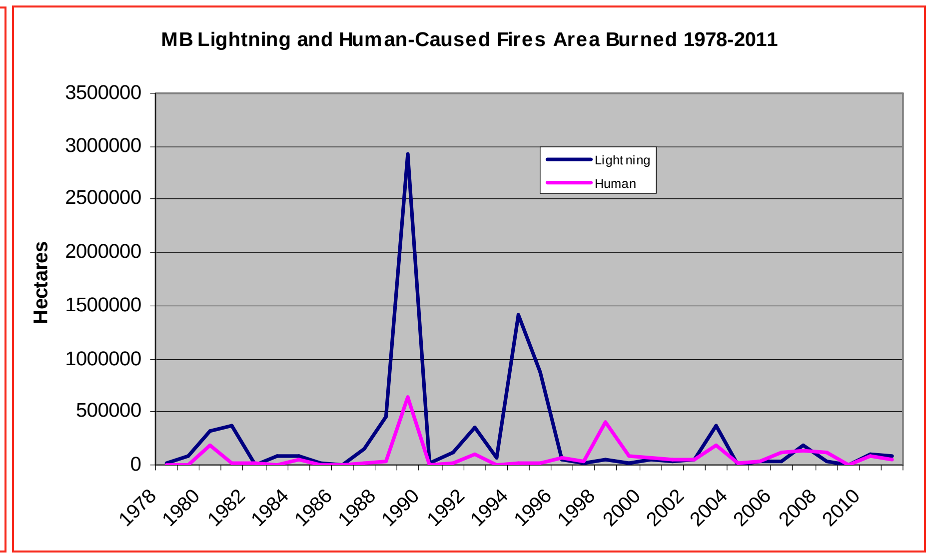


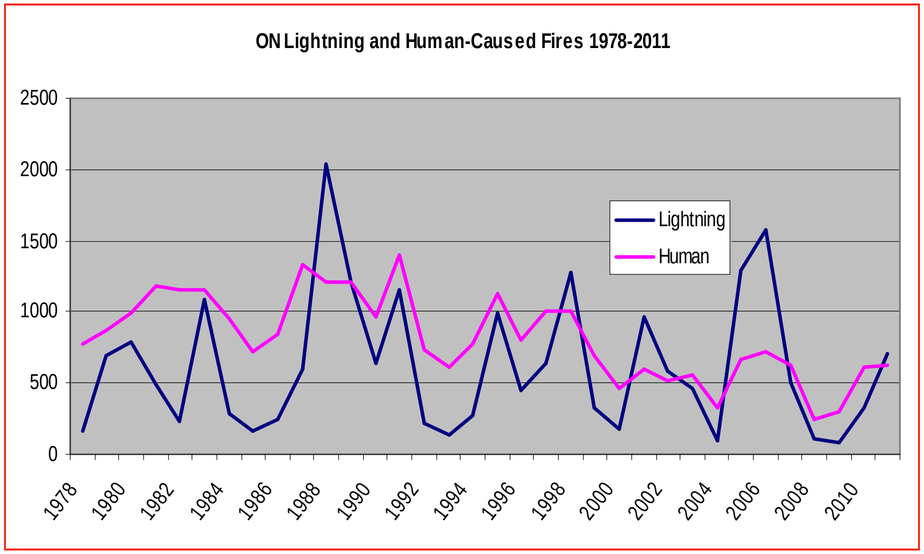


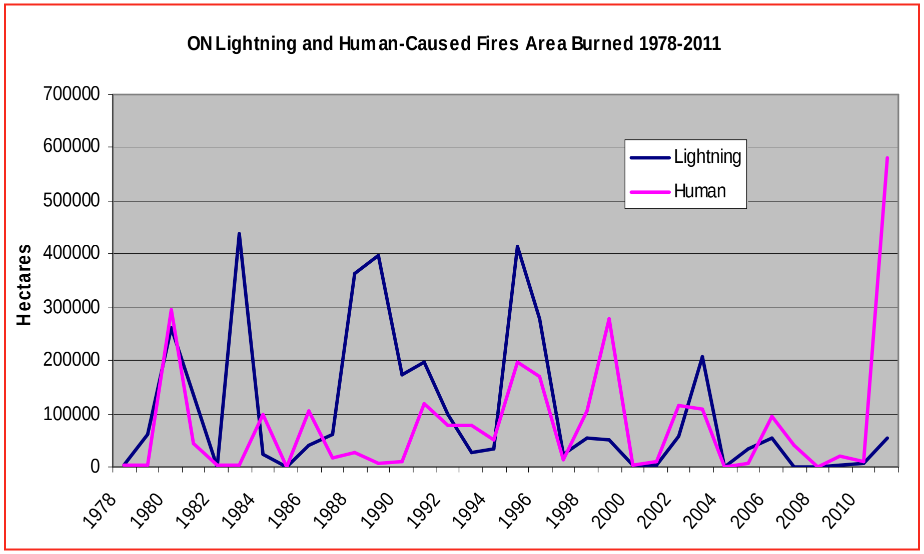

SK Lightning and Human-Caused Fires 1978-2012
900
800
700
600
500
400
300
200
100
0
Lightning
Human
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

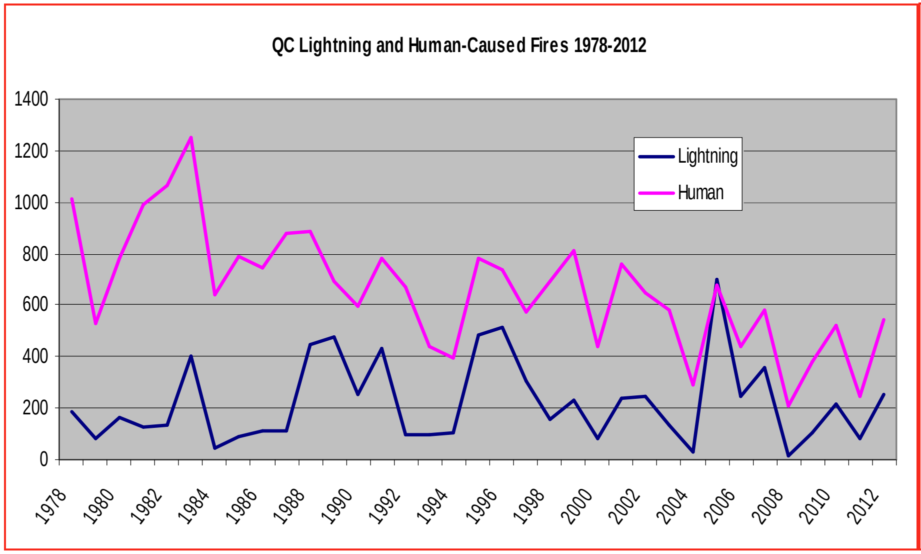

SK Lightning and Human-Caused Fires Area Burned 1978-2012
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
Lightning
Human

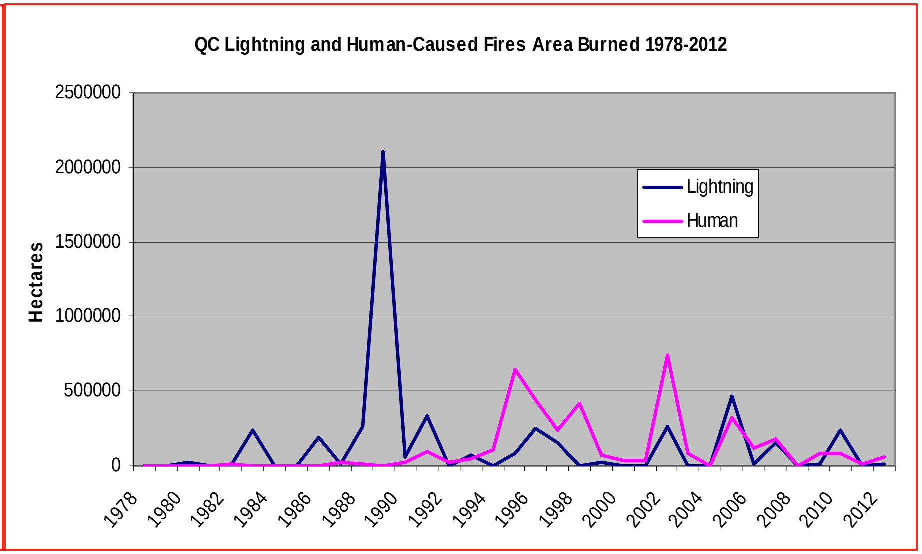

MB Lightning and Human-Caused Fires 1978-2011
900
800
700
600
500
400
300
200
100
0
Lightning
Human
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

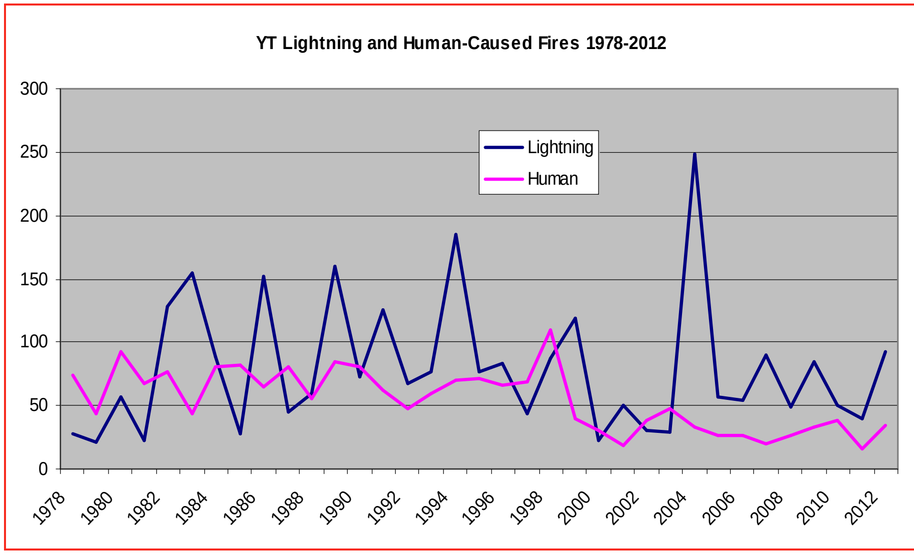

MB Lightning and Human-Caused Fires Area Burned 1978-2011
Hectares
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
Lightning
Human
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

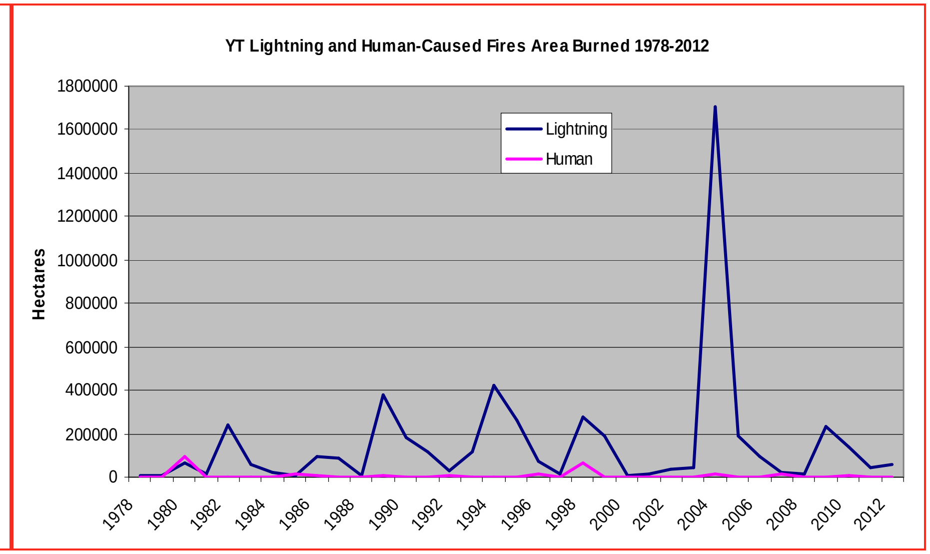

ON Lightning and Human-Caused Fires 1978-2011
Lightning
Human

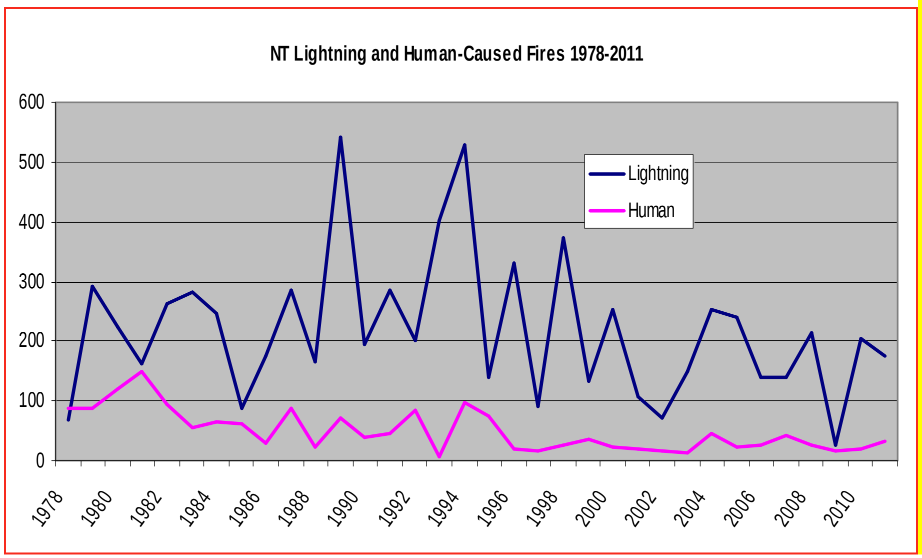

ON Lightning and Human-Caused Fires Area Burned 1978-2011
Hectares
Lightning
Human

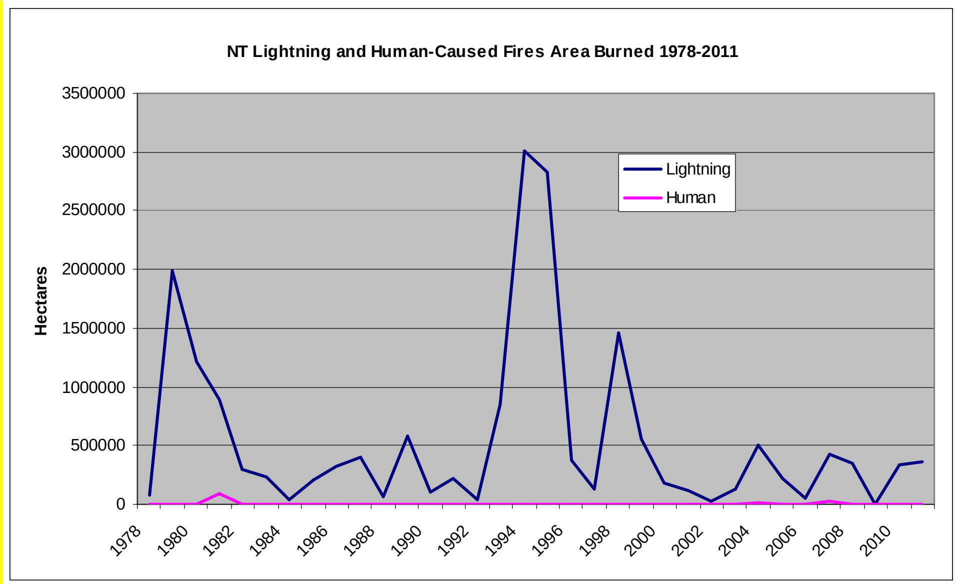

QC Lightning and Human-Caused Fires 1978-2012
Lightning
Human

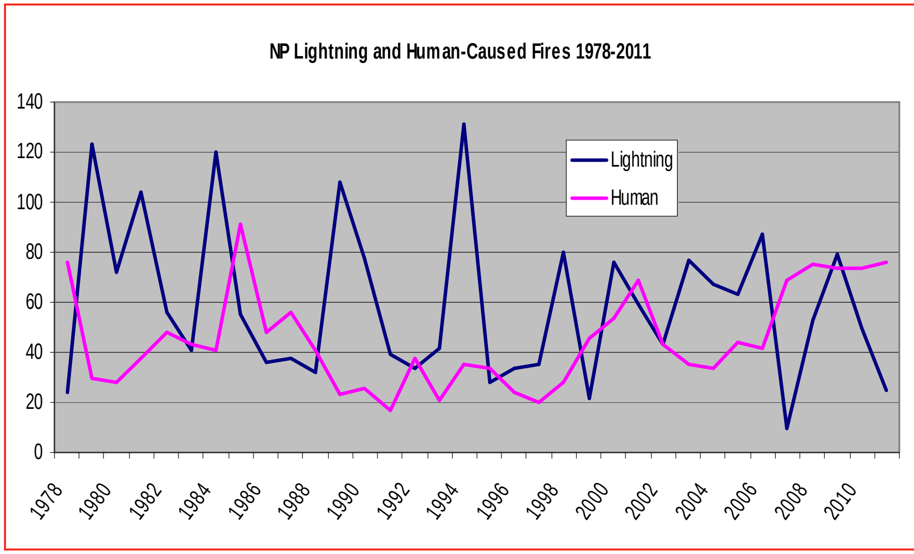

QC Lightning and Human-Caused Fires Area Burned 1978-2012
Hectares
Lightning
Human

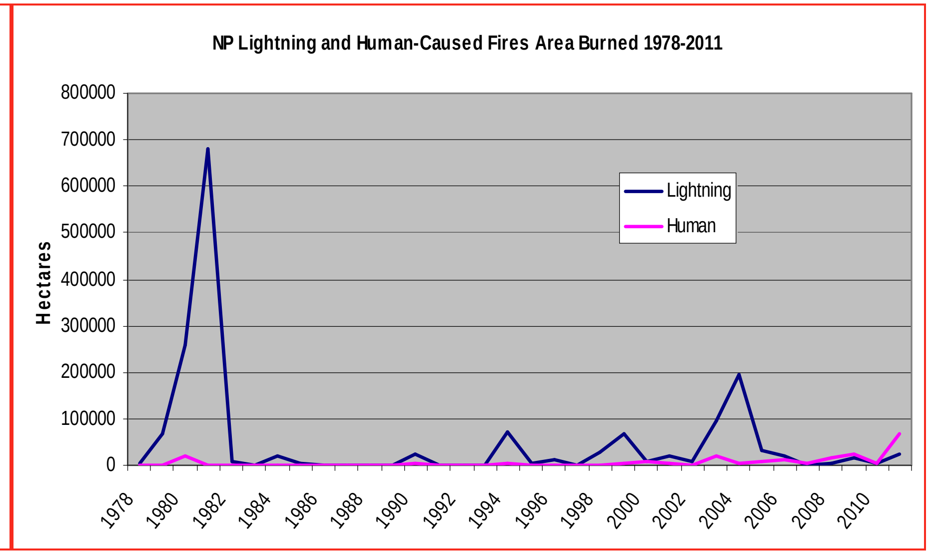

YT Lightning and Human-Caused Fires 1978-2012
Lightning
Human

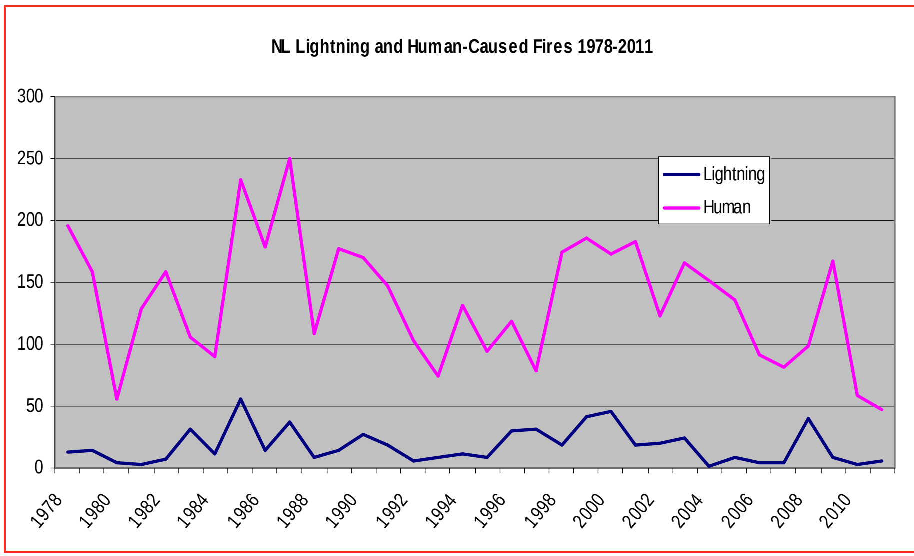

YT Lightning and Human-Caused Fires Area Burned 1978-2012
Hectares
Lightning
Human

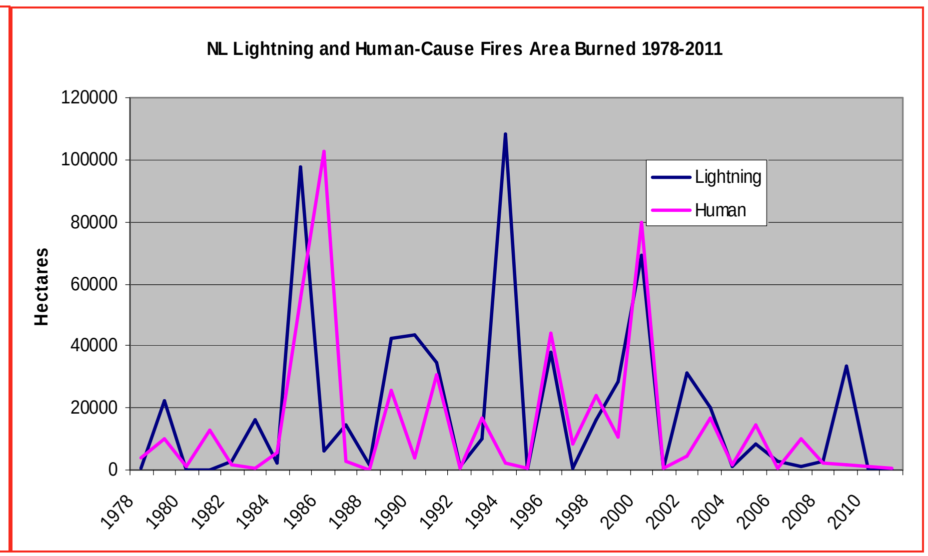

NT Lightning and Human-Caused Fires 1978-2011
Lightning
Human

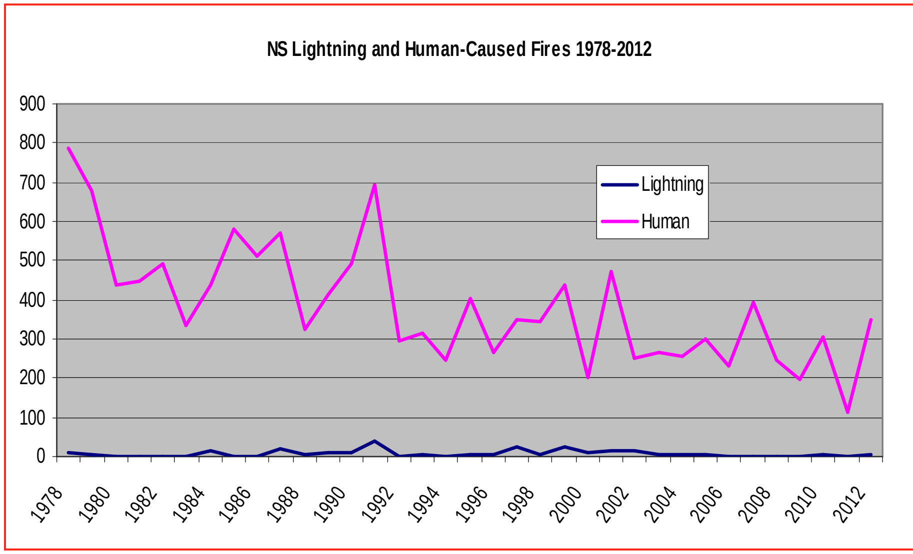

NT Lightning and Human-Caused Fires Area Burned 1978-2011
Hectares
Lightning
Human

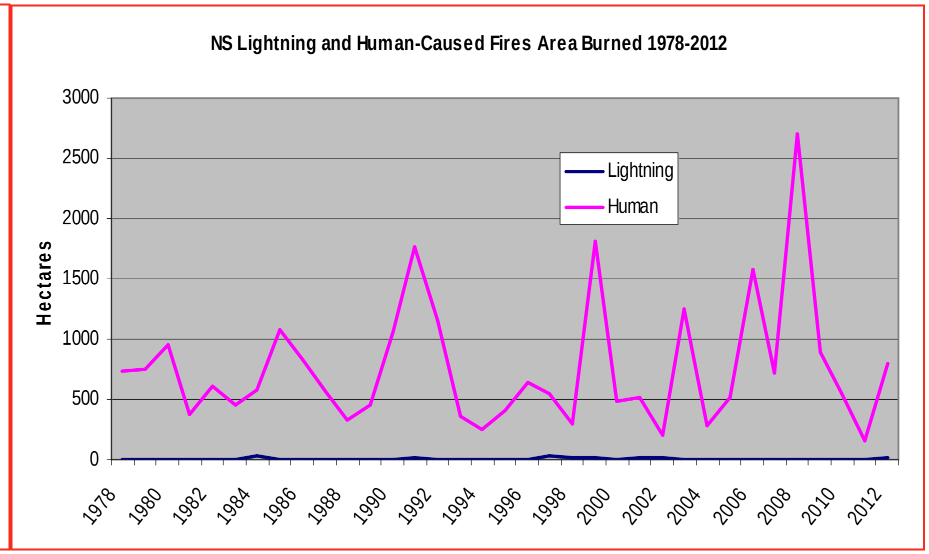

NP Lightning and Human-Caused Fires 1978-2011
Lightning
Human

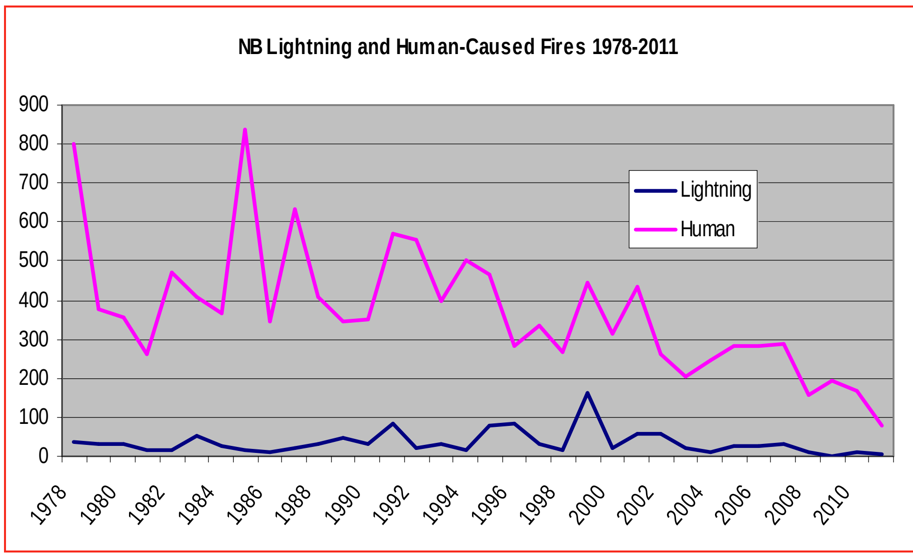

NP Lightning and Human-Caused Fires Area Burned 1978-2011
Hectares
Lightning
Human

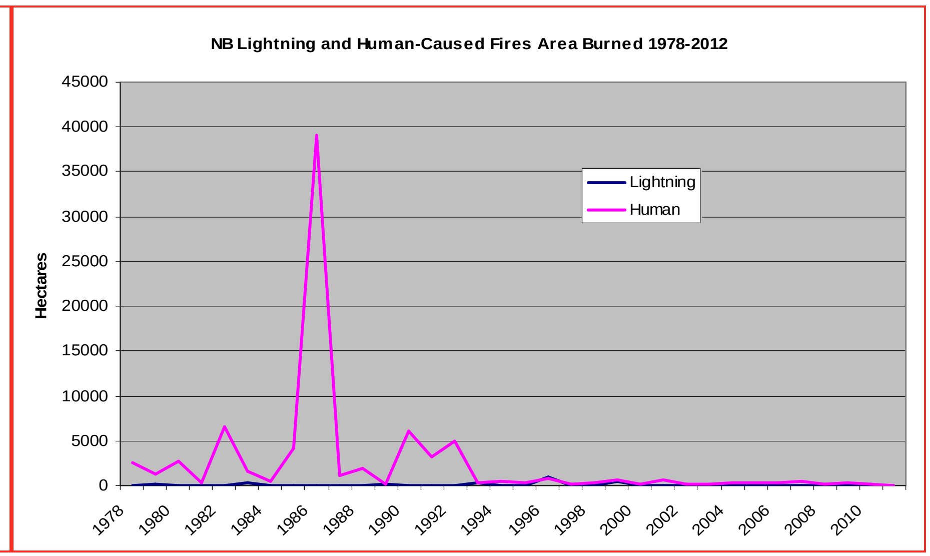

NL Lightning and Human-Caused Fires 1978-2011
Lightning
Human

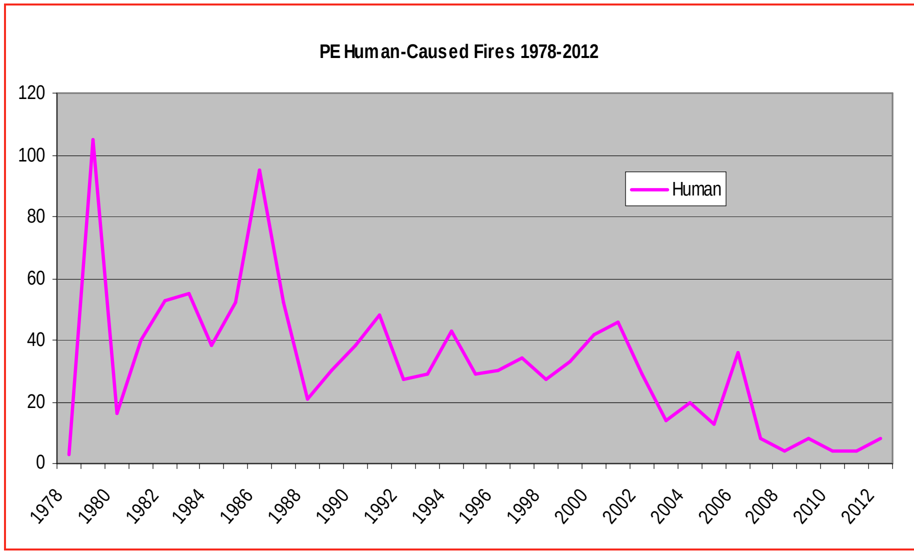

NL Lightning and Human-Cause Fires Area Burned 1978-2011
Hectares
Lightning
Human

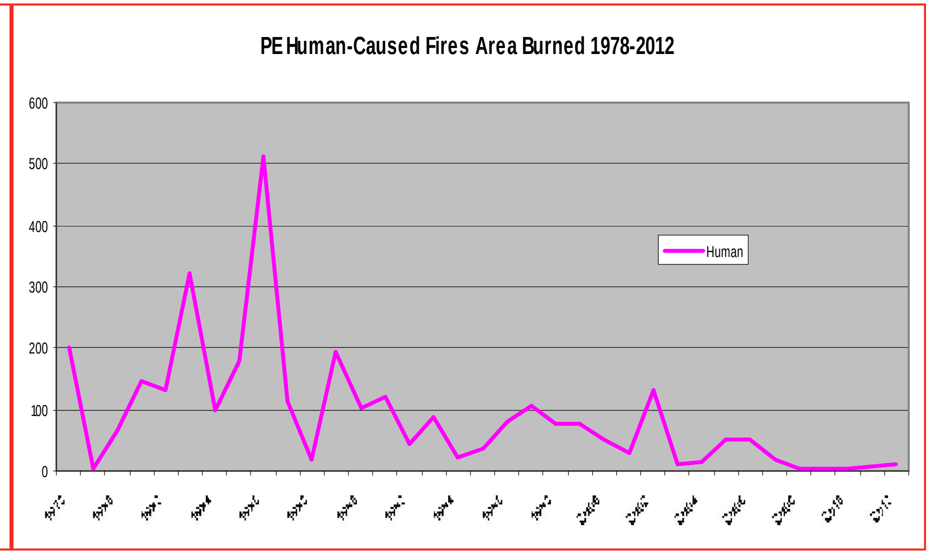

NS Lightning and Human-Caused Fires 1978-2012
Lightning
Human


NS Lightning and Human-Caused Fires Area Burned 1978-2012
Hectares
Lightning
Human


NB Lightning and Human-Caused Fires 1978-2011
Lightning
Human

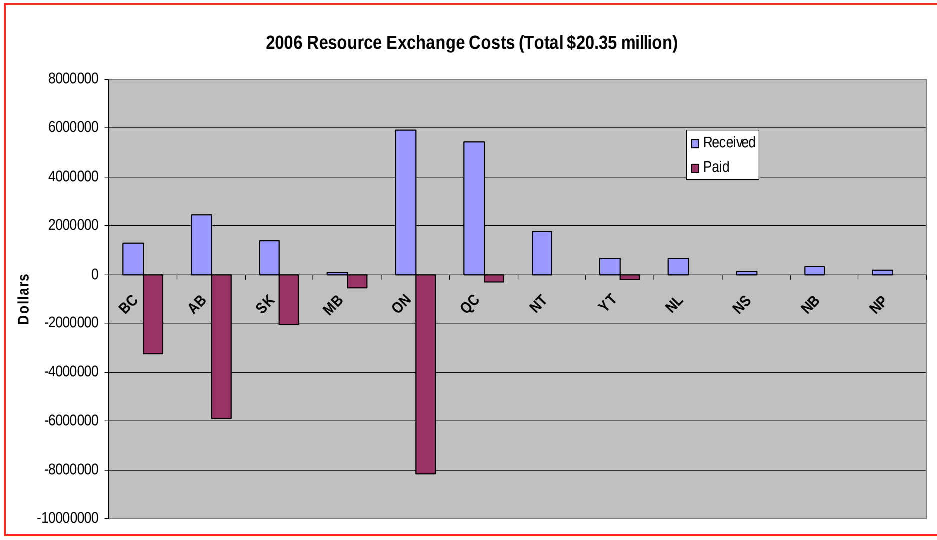

NB Lightning and Human-Caused Fires Area Burned 1978-2012
Hectares
Lightning
Human

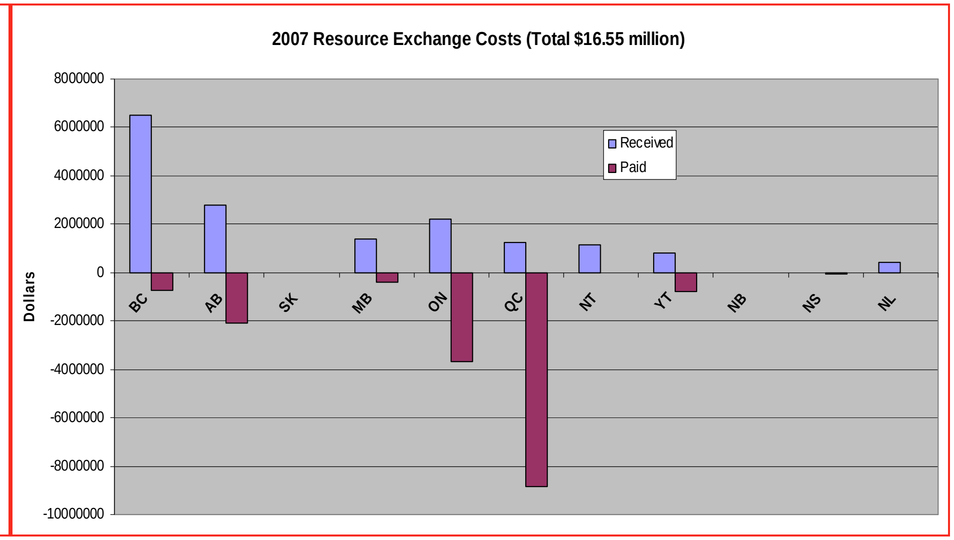

PE Human-Caused Fires 1978-2012
Human
0
20
40
60
80
100
120
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

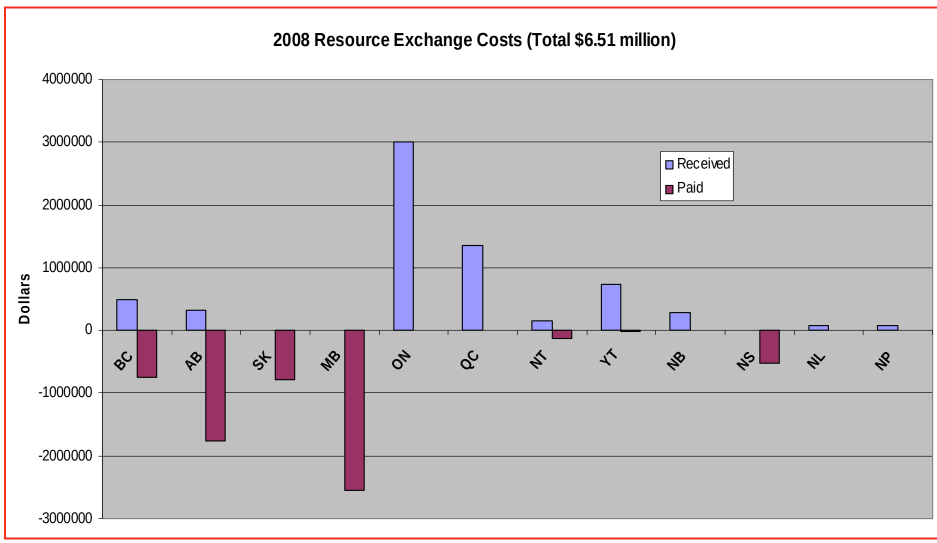

PE Human-Caused Fires Area Burned 1978-2012
Human
0
100
200
300
400
500
600

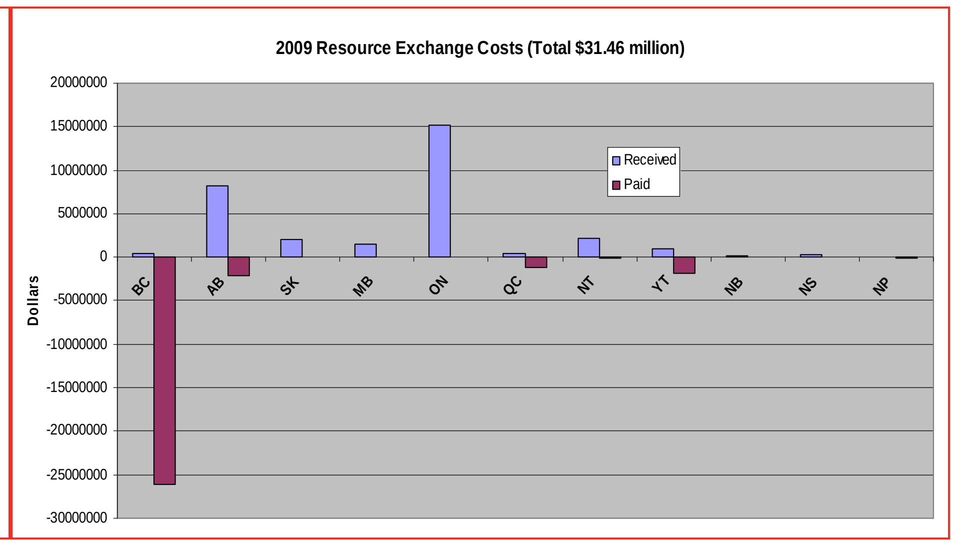
Appendix D - Resource Sharing Costs

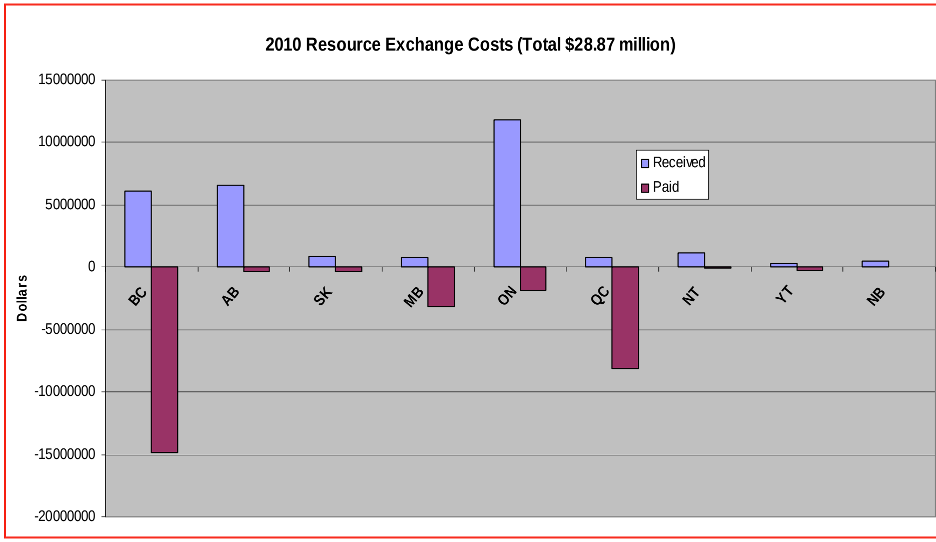
ANNUAL RESOURCE SHARING COSTS BY INDIVIDUAL CANADIAN JURISDICTIONS 2006-2013

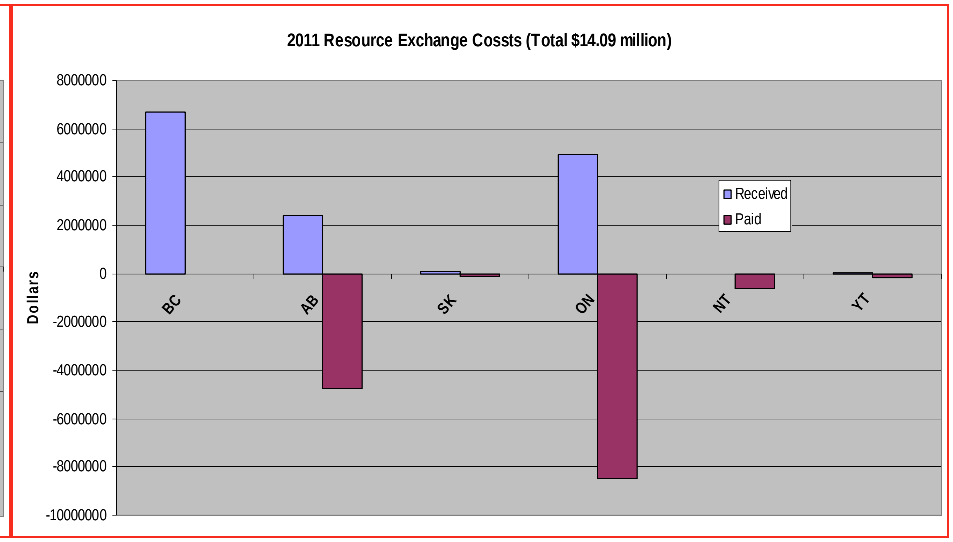


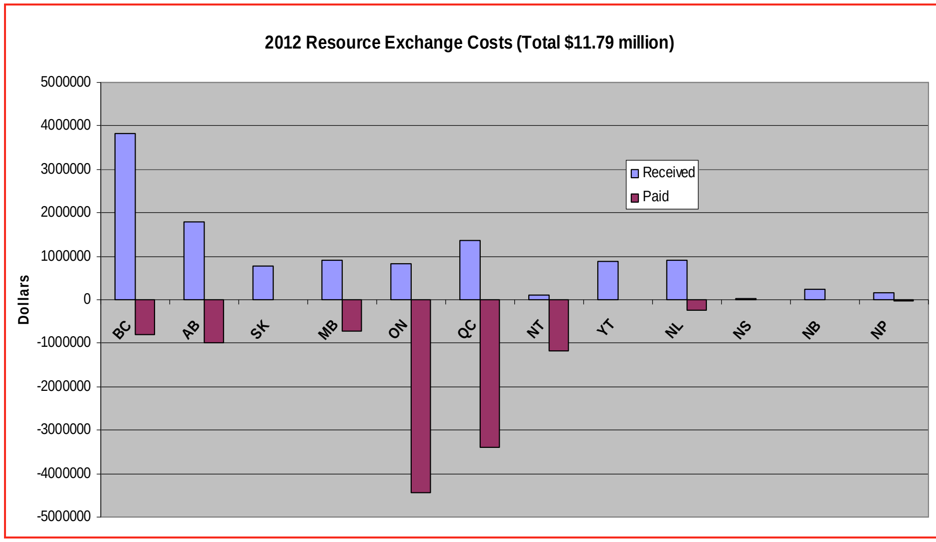


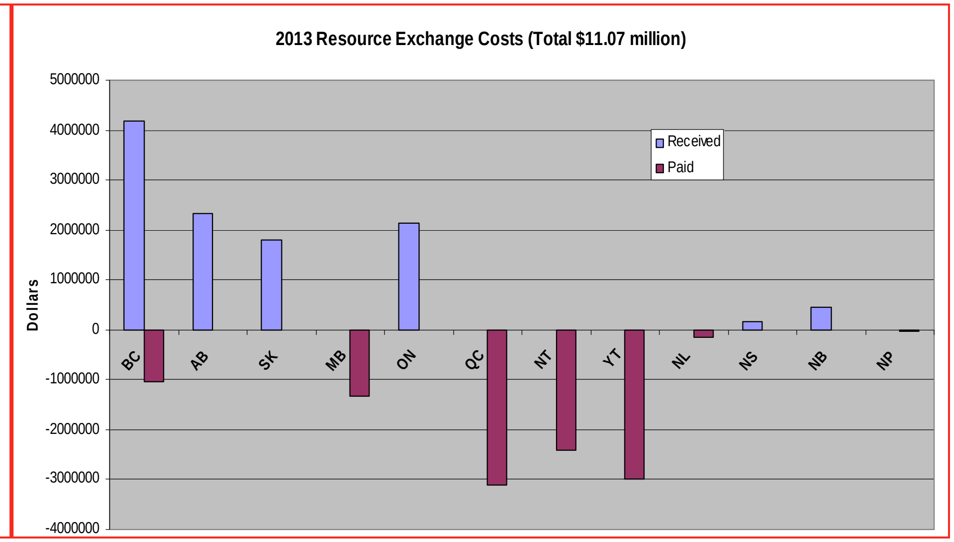





2010 Resource Exchange Costs (Total $28.87 million)
Dollars
Received
Paid
BC
AB
SK
MB
ON
QC
NT
YT
NB


2011 Resource Exchange Cossts (Total $14.09 million)
Dollars
Received
Paid
BC
AB
SK
ON
NT
YT


2012 Resource Exchange Costs (Total $11.79 million)
Dollars
Received
Paid
BC
AB
SK
MB
ON
QC
NT
YT
NL
NS
NB
NP


2013 Resource Exchange Costs (Total $11.07 million)
Dollars
Received
Paid
BC
AB
SK
MB
ON
QC
NT
YT
NL
NS
NB
NP