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# Forest Fire Research--Hindsight and Foresight[1]

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Abstract: The evolution of Forest fire research in Canada first is examined through the works of Wright and Beall, at the Petawawa National Forestry Institute in Ontario, then some lessons are drawn from the past that ought to bear on the future. Some opinions are delivered on the future course of research in fire danger rating, prescribed fire and the impacts of fire on the forest economy.

The title of this presentation is based on the principle that the past is the key to the future. If not absolutely true all of the time, this principle works well enough that "to look backward as well as forward before leaping ahead" is always good advice in the world of research. Scientific investigation of forest fire is over 60 years old in North America, and already many older references have probably been abandoned or lost; new recruits steeped in computer technology have a harder and harder time evaluating what has gone before, and can easily lose confidence in any bit of work older than a decade or so.

But, when referring to the past why stop at 60 years? Familiarity with fire must be as old as the human race, and the taming of fire was possibly the first step in the development of human culture. Discovery of the basic principles of fire behavior must have followed quickly, whether around the campfire or cut in the landscape. Namely,

(1) fire ignites and spreads more quickly in dry fuel than in wet,

(2) small pieces ignite and burn easily while large pieces hold the fire longer, and

(3) there is an optimum spacing of pieces at which the fire burns best. And, just as modern fire research programs maintain a proper balance between the physical and ecological faces of fire, so the practical uses of an area as it redeveloped after fire were certainly learned, no doubt even before the taming of fire itself. For example, while the new stand of trees grew, the obvious concerns were

(1) the ready supply of dry firewood on the stump,

(2) how many years later to look for berry crops, and

(3) what kinds of animals returned first. What we call "fire science" is, in fact, the codification and quantification of a fair amount of basic knowledge known to the human race for a very long time indeed. Fire was also obviously two-faced, at times either an enemy or friend; we are still learning how to tell the difference.

## LOOKING BACK--THE WORK OF WRIGHT AND BEALL

Closer to home in time and place, the father of forest fire research in Canada was James G. Wright, who proposed a program to develop ways of measuring fire hazard in 1925. Field work began during the summers at the Petawawa Forest

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Experiment Station. and by 1929 was in full swing (Wright 1932). Herbert W. Beall joined Wright as a student in 1928 and between them they held the fire research stage in Canada with occasional help for about 20 years.

Their principal accomplishment was the Wright System of fire-hazard rating (Wright 1933, Beall 1950a), which to this day forms the basis of the Canadian Forest Fire Weather Index System. The original Tracer Index for pine litter (Wright 1937) has evolved into the Fine Fuel Moisture Code, and the current Fire Weather Index has direct physical and mathematical links with the old Fire-Hazard Index.

In fact, the research of Wright and Beall covered such a wide range of subject matter that it is hard to find an important aspect of forest fire science on which they left no mark. Here is a partial list (only a few references out of many possible are noted):

In fuel moisture research,

--sorption isotherms for fine fuels, showing the hysteresis between the drying and wetting parts of the cycle,

--development of the tray method of measuring change in fuel moisture content from day to day,

--clear evidence that moisture content decreases in proportion to current content (the negative exponential drying process, although they did not name it so), and

--joint effects of rain amount and duration in raising the moisture content of forest litter, dependent further on the initial content before rain.

In fire danger rating,

--development of the Wright System, based on the link between the behavior of standard 2-minute test fires and fuel-moisture-plus-wind,

--a method for varying fire danger around the clock (Beall 1934),

--evaluation of the accuracy of the danger index in terms of distance from the weather station (Beall 1950b), and

--the variation of fire hazard with the seasons (Wright and Beall 1934). In various other aspects of fire,

--analysis of long-term fire statistics (Wright 1940a), with the suggestion, still intriguing, of a periodic pattern in annual burned area that just happens to match the sun-spot cycle (Wright 1940b),

--a major scheme for acceptable maximum burned area for forest types across Canada, based on productivity, fire risk, flammability, current detection and attack potential, and harvest value (Beall 1949),

--studies on fire control equipment and gear such as pumps, hose, lookout towers (Wright 1942) (seen area, lightning protection, binoculars), fire-fighting chemicals, and so on.

During all this time, Wright and Beall paid careful attention to the similar work begun about a decade earlier in the United States. A review of the meteorological aspects of fire-hazard research (Wright and Beall 1945) lists a host of semi-forgotten references with quotations that demonstrate the considerable age of most of our basic principles. Beall (1947) alludes to certain differences in approach between the American and Canadian schools of fire research that have continued down to the present.

## LESSONS FROM THE PAST

The first lesson we have learned from the remarkable output of Wright and Beall is to study carefully the old fire research results and, if possible, to adapt them rather than to start again from scratch every time a problem arises. The second lesson is that the same practical research output may require continual redevelopment to keep one jump ahead of advances in modern technology. Fire danger rating in Canada is a good example; its evolution can be followed through at least six stages:

First, the Wright System began life as a hazard index based on empirical field data analyzed by complex graphical correlation methods and worked into a set of tables. It depended on considerable weather information.

Second, as its use expanded, the demand to "keep it simple" led to reduction in the weather requirements to a bare minimum of four elements (temperature, humidity, wind, rain) taken once daily at solar noon. This easy-to-use version then spread throughout Canada.

Third, in response to pressure for more information than the simplified system could provide, physics and laboratory results plus more field experiments were added to the data base, and the whole redeveloped into a set of standard equations. The Fire Weather Index (FWI) System was born, equally adapted to computer processing as to manual table entry.

Fourth, as computer capacity increased at a remarkable rate, the way opened to the development of comprehensive computerized fire management systems, incorporating and using the FWI System as a basis for any management operation needing an estimate of ignition potential or fire behavior.

Fifth, the now obvious need for absolute rather than relative values has led to a set of spread-rate equations based on empirical field data, and using components of the FWI System. A companion set of fuel-consumption (and hence intensity) equations is in process. Fire danger rating thus blends into fire behavior prediction, and management system output can in turn take a more quantitative form.

Sixth, as computer capacity expands in almost open-ended fashion, expert systems and artificial intelligence have entered the scene. Who knows what wonders will follow?

Obviously the story has not ended, and presumably never will.

## LOOKING AHEAD--THE MAJOR ISSUES IN CANADA

What then of the future? Let us look in turn at several aspects of the fire research business, asking not just whether a potential goal is possible, but also whether it is practically feasible and worthwhile as well.

Take fire danger rating as the first case. The weakest link in the present chain is clearly the weather input. The entire structure of standard fire danger rating and fire behavior prediction in Canada rests at present upon the slim basis of four elements read once daily at noon, one instantaneous sample of a 24-hr continuum. Furthermore, the data are accumulated at a series of single stations, not necessarily spaced to best advantage. I suppose that means of weather interpolation throughout time and space will be more and more in demand. There is now no technological limitation on more frequent automatic weather readings from anywhere, say once per hour. Potential methods for interpolating temperature, humidity, and wind exist or are under development, while radar holds promise for areal rainfall measurement. In serious fire situations or prescribed fire operations, this whole apparatus can be brought to bear, and methods of computing fire danger at any time interval around the clock are well in hand. As remote weather measurement becomes more and more sophisticated, let us even contemplate continuous computation of fire danger at the site from mathematical functions of weather at the differential level, to be called upon at will. All this stream of information is grist for the mill of fire growth modelling.

What about direct means of determining fuel moisture? Exposure of analogs or quick field methods will always have their advocates; however, the former need careful maintenance and the latter depends critically on sampling intensity. Moreover, neither lends itself to prediction from forecasted weather. For this reason alone, as long as we can do reasonably well with weather-based models, I doubt that direct measurement will ever replace weather-based moisture schemes in Canada.

Take fire behavior prediction as the second case. We, in Canada, are fairly well committed to empirical means, namely linking observed real fire behavior to components of our Fire Weather Index System. At any time in the future, a physical model that takes full account of vertical gradients in fuel moisture content, bulk density, and size variation may become available. Even though it may prove superior to empirical means, the problem of acquiring all the necessary data to feed such a model looms as the stumbling block. It is one thing to measure carefully every aspect of fuel quantity and arrangement for an experimental fire, but quite another to assemble and digitize such data for extensive areas. For example, all the skills of remote sensing cannot yet match the simple mensurational data on tree species, diameter, height and stocking produced by a simple surface cruise. In other words, to replace a well-established empirical system for predicting fire behavior, not only will an adequate comprehensive model be required, but the means of acquiring the necessary data on a large scale must be available as well.

There is one other intriguing aspect of fire behavior that will require more and more attention in Canada. This is the large-scale mass-ignited prescribed fire. The first question concerns the ignition pattern: how best to arrange the points and lines of fire, and how to judge the length of time needed to burn out between lines. The second question concerns the convection column: what cause-and-effect link, if any, exists between surface combustion and the column, and what will be the pattern of smoke dispersal? The third question concerns fire whirls: the circumstances causing them, and whether they pose any threat to the surrounding area. For purposes of economy, the larger the burn the better. Thus, single prescribed fires may encompass as much as 2000 ha, and the practical limit of this upward area trend is in question. For both safety and efficiency, better understanding of their behavior is highly desirable.

Take forest development after fire as the next case. Two great practical issues promise heavy debate during the next decades. One is the question whether prescribed fire may have negative effects on tree growth over the entire subsequent rotation. In Canada this issue is warmest in British Columbia, especially on the heavy-timbered West Coast. The important point in my opinion is that the final judgment be deferred until the long-term evidence is in hand. The nutrient dynamics of any site will certainly be rearranged by traumatic events like clear-cutting or fire, or both. But most forested areas in Canada have burned, say, 20 to 100 times in the past 5000 years. and the proper basis for the study of nutrient effects is clearly the entire cycle from one fire to the next. The other major issue is how to come to terms with fire in the national and other large natural parks. After decades of fire suppression the age-class distribution in many large parks is bell-shaped and overmature. Parks Canada particularly, has produced an enlightened new policy in the past few years; it is now the operational problem that faces us. The challenge will be to maintain a philosophy based on the logical principles established by research through all the growing pains of developing the means or reintroducing fire into fire-dependent ecosystems. Whether this can ultimately be done adequately is simply not certain.

Take the impact of forest fire on the forest industry and economy as the next case. In spite of the considerable literature on the economic issue I cannot regard the matter as settled, in Canada at least. It is only several years since the first analyses of how fire affects the timber supply have appeared. Here the logic is inexorable; salvage aside, the annual harvest comes from the whole forest, not the burned area. Conversely, the traditional basis for evaluating economic impact has been the burned area only. The obvious question is, why not analyze for economic impact as well on the whole-forest basis? The principle might be called "maximized net return" rather than "least cost-plus-loss." I believe that the stage is set for a proper debate on this issue in Canada. Throughout the argument run threads of various familiar issues such as "forest rent vs. soil rent," the "annual allowable cut effect," and whether forest industry should aim to maximize wood production or direct economic return. The outcome will decide whether fire management is an integral part of forest management as a whole or rather just a self-contained entity of itself. The driving force will come as more and more forestry people desire the rationalization of exactly what fire does to the national forest economy.

An incidental result of acceptable rational analysis of fire's impact will be to place some economic limit on the benefits of fire management. Whether researchers should worry about this depends on one's point of view. My own is that because forest fire is an integral part of the forest's environment, scientific expertise in it will always be in demand. Our function should be, I believe, to shed rational light on all aspects of fire management in the larger sense. The actual reduction of fire losses is the responsibility of the fire management agencies, and it would hardly be fair to ask the researchers to stand or fall on the success or failure of this enterprise.

Take possible trends in annual weather and climate as the last case. Not only is the weather the principal driving force behind the phenomenon we study, but the success of fire management depends on how well we adapt to the annual variation in weather from year to year. The story of the past two decades in Canada is instructive. As of the late 1960's, the running 10-yr national average annual burned area stood at about 900,000 ha following an almost continuous downward trend of four decades. Between 1970 and 1983 all but three fire seasons registered over 1 million ha including, back to back, the two highest values on record, 4.8 and 5.4 million ha in 1980 and 1981. The running average reached 2 million ha; it has fallen somewhat since, but still stands as high as at any time in the period of record.

There is nothing in this story for the fire management agencies to be ashamed of. Advances in fire control technology notwithstanding, the overwhelming factor was simply, year after year, the weather. But why this concentration of severe fire seasons such as were seen only occasionally during the previous several decades? This is a question for the climatologists. Perhaps this episode is in fact a portent of the climate change that will gradually occur as the concentration of carbon dioxide in the air increases. There is more and more agreement that global temperature will indeed rise, and that the increase will be felt most in the high latitudes. If, as further expected, higher temperatures would be accompanied by an increase in the ratio of evapotranspiration to precipitation, the result is a recipe for more severe fire weather. As soon as rough quantitative estimates of the net change become available, they can be modelled into a picture of the fire weather of the future. As interest in this subject increases, one can expect more and attempts to predict the nature of the forthcoming fire climate, and to plan some response. The outcome could range all the way from an increase in seasonal severity well within the present range to a challenge so profound as to shake fire management to its foundation. By the time the year 2000 dawns, we will, I have no doubt, a much better sense of this issue than at present.

## CONCLUSIONS

Having run out of major fire research subjects on which to comment, let me now reaffirm my belief in the basic principles of science that have brought us thus far in the past six decades: certainly the deductive rather than the inductive strategy, and a balanced respect for both the empirical and theoretical approaches. New fire control technology may come on stream at a bewildering rate, and the computer revolution will lead who knows where. The development of expert systems and artificial intelligence will certainly run its course and their products will find their place. Throughout all this excitement, a firm scientific conclusion based on a well-conceived field or lab results backed up by the appropriate physics and biology will, I believe, continue to be the basis of every real advance.

Beyond science, I believe also that because fire has such deep and ancient roots in human history and culture, social and political reactions as well as objective reality will always affect strongly what is done about fire in our forest. Our part in the future of fire management will provide the most rigorous, objective view of the phenomenon itself, its role in nature, its impact on the economy, and the practical means of controlling it as "enemy" while utilizing it as "friend." And, to echo my opening statement, we are well advised to look backward first every time we contemplate a leap forward.

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