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Use of Experimental Prescribed Fires in Building Future Knowledge Bases for Fire Management Decision-Making

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Introduction

The use of prescribed fire has had a long history in many parts of the world. Prescribed fire by definition is any fire that is deliberately used for prescribed burning, which is the knowledgeable application of fire to a specific land area to accomplish predetermined forest management or other land use objectives (Merrill and Alexander 1987). Prescribed burning is conducted for a variety of purposes including the removal of harvesting debris and site preparation for regeneration objectives (e.g., McRae et al. 2001, Walstad et al. 1990), for fuel management (e.g., Omi 2002), and for restoring fire back into natural fire-dependent ecosystems (e.g., McRae et al. 1994). In Canada, areas up to 2000 ha have been burned in a single 4-5-hour burning period, usually in the afternoon or evening, when burning conditions are best. The operational use of prescribed fire in Russia has been examined recently by Valendik et al. (2000, 2001) through a series of trials located in central Siberia. However, there is another important use of prescribed fire that may not be as familiar, which is the use of experimental prescribed fires or simply experimental fires.

Experimental prescribed fires are purposely ignited for a reason; hence, they are by definition prescribed fires. Forest fire researchers intentionally set these fires to study wildfire behavior, fire suppression strategies, ecological fire effects (forest health), emissions, and issues pertaining to climate change under controlled conditions. In most cases, these fires occur in standing forest fuel types to document what may occur in a naturally occurring wildfire. These empirical fires help researchers to better understand what can happen under the full interaction of all environmental factors (e.g., fuel beds, weather and atmospheric conditions, large fire physics, etc.). This approach has been extensively used in both Canada (e.g., Stocks 1987; Stocks et al. 1999) and Australia (e.g., CSIRO Forestry and Forest Products. 2003) in studying wildfires. For modelling purposes, a replicated plot design is used so that for a given fuel type a full range of burning conditions can be monitored and documented. This approach recognizes, and rightly so, that fires burning in a similar fuel type can be vastly different given the actual burning conditions (i.e., fire danger). This variation, of course, affects the fire severity that is experienced (e.g., tree mortality).

Experimental fires are usually small in size (<4 ha). The reason for the small size is that it assists in the control and suppression of the fire especially if a crown fire were to develop, which can be extremely hard to control without fuel breaks. In many cases, wide bulldozed firelines are used in places such as Canada to effectively contain these fires. More important, the small plot sizes assists in the full documentation of fuels (i.e., consumption) and ecological conditions both before and after the fire. Sampling is often established on a gridded system so that measurements are taken in a similar systematic way across the plot for all science disciplines. In all cases, quantitative (i.e., actual) rather than qualitative (i.e., descriptive) values are gathered so that predictive models can be produced. For a modern fire management organization, it is no longer suitable to descriptively describe a fire using qualitative terms (i.e., light- versus high-intensity fires). Fire behaviour characteristics, such as rate of spread and fireline intensity, are gathered during the actual fire event based on the grid system. Experimental plots are the only means of acquiring this type of quantifiable documentation, as it is impossible to do so during a wildfire because of the time needed to do the pre-fire sampling, especially in front of a rapidly approaching wildfire front that could adversely affect research personnel safety.

A complete fire weather station must be established and maintained at the experimental site for the season. Daily observations of dry-bulb temperature, relative humidity, 10-m open wind speed, wind direction, and precipitation are taken to assist in calculating different fire behaviour danger rating systems. Fire modelling often uses the fuel moisture codes and fire behaviour indices from these systems to predict what may occur during a fire (e.g., rate of spread, fireline intensity, fuel consumption, emission amounts, tree mortality, etc.). It is from these predictive models, using fire behaviour danger rating system values obtained from different districts, that fire managers at regional coordination fire management centers can better anticipate burning conditions for appropriate allocation and pre-positioning of suppression resources. These models can be used to predict anticipated fire behaviour and fire occurrence. Models play an important role when conducting prescribed burns operationally to understand the expected fire behaviour characteristics, the anticipated control problems, and ecological effects. More important, these models indicate when it is safe to burn so that the prescribed fires can accomplish the objectives for the burn without escaping control.

Experimental Fires in Russia

A recent attempt to use experimental fires in Russia occurred in 1993 during the Bor Forest Island Fire Experiment in central Siberia (Firescan Science Team 1996). The primary objective of Bor Forest Island Experiment was to assess whether an international collaborative research team could successfully conduct and monitor an experimental prescribed burn in Russia. While this fire did show that such fires could be conducted safely, the Bor Island experiment was only a single burn conducted in one fuel type under one particular burning condition.

A replicated fire experiment in central Siberia was begun in 2000. The Russian FIRE BEAR (Fire Effects in the Boreal Eurasia Region) Project is a long-term forest fire research study developed to provide answers to basic questions on the management of fuels, fire behaviour, and fire regimes to enhance carbon storage, and forest sustainability in ways that minimize negative impacts of fire on global environment, wood production, and ecosystem health (McRae et al. 2004). Stands in the research area are representative of the central taiga pine forest (Parmuzin 1985) containing Scotch pine (*Pinus sylvestris)*, lichen (*Cladonia* sp.), and feather moss (*Pleurozeum schreberi*). To date, a total of fifteen 4-ha plots have been burned.

Fires were carried out in June and July, which corresponds to the main fire season for this region of Siberia. Plots were burned under a wide range of fuel moisture and weather conditions to observe effects on fire behaviour, fire severity, emissions, and other ecological factors. All experimental plots were burned using line ignition along the windward side to quickly create equilibrium fire behaviour that mimics wildfires under similar burning conditions (Johansen 1987, Weber 1998).

A complete inventory of the fuels was made both before and after the fire to understand fuel consumption. Ground fuels consisting of the organic forest floor (litter, fermentation, and humus layer), surface fuels representing dead and down woody fuels, and crown fuels were sampled. The vegetation and tree seedling regeneration (<5 years old) on the experimental plots was described based on standard Russian inventory methods (Sukachev et al. 1957, Pobedinsky 1966, Alexeyev's 1989). Stand structure of trees greater than 10 cm diameter at breast height (DBH) was measured using the point-centered quarter (PCQ) method (Cottam and Curtis 1956). Each tree was characterized by basic mensurational parameters (e.g., height, DBH, and height to live crown) as well as by measures of char height after the fire. Stand density and tree basal area were also determined from the PCQ data. In addition, other studies looked at changes in soil nutrients, soil microfauna, soil and tree respiration, wildlife, disease, and insect populations.

To enable accurate measurement of fire spread, electronic timers similar to those of Blank and Simard (1983) were used. In addition, an infrared camera was flown overhead to record digital images of the fire's progress, as infrared wavelengths are not obscured by smoke (McRae and Jin 2003). The digital images when geo-referenced and analysed provided reliable estimates of rate of spread for any area of the fire. Rate of spread is used to calculate the fireline intensity developed during each test fire (Byram 1959). Fireline intensity is an important indicator of the type of fire and the suppression resources needed to extinguish a fire. A number of depth-of-burn pins (McRae et al. 1979) were placed on the site to record the depth of ground fuel consumption. Trace gases and aerosol particles were sampled at ground level and aerially using a Russian MI-8 helicopter to characterize emissions. Aerial sampling provided a better collection of emissions released into the atmosphere after scrubbing by the tree canopy.

The Need for Knowledge in Fire Management

Initial reactions for improving fire suppression efforts, especially when new funding becomes available, can be solely directed towards procuring more fire fighting equipment (e.g., hand tools, mist blowers, chainsaws, pumping units, vehicles, etc.), aircraft, and facilities (e.g., buildings, air strips, etc.), and increasing available manpower. However, a modern fire management approach cannot rely solely on its physical assets for controlling fire. The annual current fire loads of many countries, including Russia, are being overwhelmed by the sheer number and sizes of wildfire. For Russia, wildfires affect as much as 12-14 million ha annually (Cahoon et al. 1994, Conard and Ivanova 1997, Conard et al. 2002, Dixon and Krankina 1993, Kasischke, et al. 1999). In 2003, it has been estimated that approximately 22.6 million ha has been burned (Global Fire Monitoring Center 2003).

The recent implementation in the Far East of Russia of a coordinated fire management center system indicates how Russia is changing and modernizing its fire management systems to increase efficiency. However, this modernization must be coordinated with better predictions of expected fire occurrence, fire behaviour, and fire effects. Given the current and predicted increases of fire loads (i.e., too many fires to adequately action all at the same time given limited suppression resources), deployment of suppression resources will have to be determined by decisions based partially on the best available information from computer-based models. This will require an improved knowledge base to run these predictive models. Knowledge comes from dedicated wildfire research and any funding proposals for the improvement of fire suppression capabilities should consider what is required and be prepared to fund it appropriately. Ignorance of this simple fact will only hinder the overall modernization of any fire management program.

Wildland Fire Research Needs

The FIRE BEAR Project is presently documenting and modelling fire in the Scotch pine forest fuel type of central Siberia. There is a need to expand this vital research to other important fuel types found across Russia that could include:

- Larch
- Far East mixedwood
- Siberian mixedwood
- Far East Korean pine (*Pinus koraiensis*)
- Dark conifer
- Peat
- Forest steppe
- Steppe

A number of other fire research areas not addressed by FIRE BEAR would be appropriate for consideration for funding. Given the need to prioritise fires to be actioned, fire occurrence (i.e., ignition source, fuel type, and seasonality of fires) and fire growth models might be appropriate areas of increased concentration. The importance of periodic fire in reducing fuel buildup and fire intensity (fire severity) in fire-dependent ecosystems has been well documented in the United States. The increasing occurrence of catastrophic fires in the wake of a total suppression policy has initiated the use of prescribed fires to reduce natural fuel buildups in a controlled manner. Fire research in Russia should be undertaken to study the use of prescribed fire in Russia for assisting suppression efforts in reducing the number and intensities of fires by burning out wildland fuel buildups periodically.

The Nesterov Index (Nesterov 1949) and Moisture Index (Vonsky 1975) are simple one-code rating systems used to assess forest fire danger in Russia. Although providing an adequate means of estimating the general fire danger, they do not necessarily lend themselves well as fire behaviour indexes. As an example, the Canadian Forest Fire Weather Index (FWI) System (Canadian Forest Service 1987), derived for the boreal forests of Canada, has 3 fuel moisture codes representing ground fuel dryness for 3 different zone depths and 3 fire behaviour indices indicating potential fuel consumption, rates of spread, and fireline intensities (Van Wagner 1987). The FWI system helps a modern fire organization by allowing for the understanding of drought conditions present and being able to assist in understanding the potential fire behaviour characteristics of any fires that should develop in a particular fuel type. The Canadian Forest Fire Prediction System (Forestry Canada Fire

Danger Group 1992) and BehavePlus fire modelling system (Andrews 2003) are examples of current modelling systems. Resource allocation, routing of detection flights, and prioritising of fires to be suppressed can be readily assessed using the FWI System. The codes and indices of the FWI System are used in developing a prescribed burn prescription in understanding when to best burn to achieve the burn objectives safely. In a modernization effort, a more complete fire weather index system should be developed for adoption in Russia.

A better record of the actual area that is annually burned is required for Russia. This is a large challenge because of Russia's vastness and many remote areas. The use of remote sensing, using satellite images to verify the annual burn area, is required. While products for recognizing burn scars (areas) are becoming better, there is an essential need to be able to recognize the fire severity better (e.g., crown fire with total tree mortality, high-intensity surface fire with total tree mortality, surface fire with partial tree mortality, low-intensity surface fire with no tree mortality, etc.) observed on these scars. The determination of fire severity remotely would assist to understand not only timber (economic) losses, but would be important to give more reliable estimates of carbon releases from fires for carbon cycling models. Some of this remote-sensing research would have to rely on other disciplinary research, such as FIRE BEAR, to be able to ground truth and verify the fire severity results observed.

Because of inherent differences between wildland fires across Russia and suppression equipment available on the market, technical and development research on the effectiveness and improvement of suppression equipment for Russian conditions would be worthwhile. The field of operational research and its role in resource placement could help in better pre-positioning limited resources (i.e., fire bases, positioning of manpower and location of aircraft bases, etc.), where they would be most efficient in fighting fire across a region (Hirsch and Martell 1996, MacLellan and Martell 1996,Islam and Martell 1998, Martell et al. 1998) rather than relying on subjective or personal biased placement.

International and interdisciplinary research approaches are required to make information available. Wildland fire is not unique to Russia, and researchers of all countries can help in understanding and dealing with this global problem. Sampling techniques and observation, accepted by the global fire science community, can be shared and used. Since research can be long-term and expensive, especially related to the use of experimental plots, it just makes good sense to have as many science disciplines involved in the research work as possible. Many of the disciplines piggy-back on to results obtained by other disciplines. For example, the prediction of many fire effects will require information from the fire behaviourist on the actual fire characteristics that existed.

Conclusion

Modernization of the Russian fire management system, while needing to rely on more or better physical assets, must be done in concert with acquiring essential information or knowledge in various aspects of fire occurrence, fire behaviour, ecological effects, fuel management, and the use of prescribed fire. This information can only be obtained through properly funded wildland fire research. Without it, decision-making in fire management will not have the proper support data needed to make the best choices. The neglect of this basic need can have large consequences given the economical and human losses that can occur during a wildland fire. Given that the prediction is for increasing fire danger and fire load across Russia due to forecasted climate changes (Stocks et al. 1998), it would be prudent to expand on this fire research in Russia now.

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