Project Title: Development of a Computer Model for Management of Fuels, Human-Fire Interactions, and Wildland Fires in the Boreal Forest of Alaska

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ABSTRACT

Interior Alaska contains 140 million burnable acres and includes the largest National Parks and National Wildlife Refuges in the country. On average, wildland fires burn 1,000,000 acres in Interior Alaska each year and threaten the lives, property, and timber resources of Alaska’s sparse but growing population. Wildland fires threaten human values, but they also are crucial for the maintenance of forest ecosystems. ***How do we manage wildland fire in Alaska for the mutual benefit of humans and natural ecosystems?*** We aim to develop a computer-based, fire-management and planning model called Boreal ALFRESCO. This model utilizes physical, biological, and human thematic layers to simulate ecosystem dynamics. It outputs transient maps depicting the responses of vegetation cover and fuel accumulation under different scenarios of fire management and climate change. Developing this model will accomplish two objectives. First, it will synthesize our existing knowledge about wildland fire in interior Alaska and reveal critical gaps in our knowledge. Earlier versions of the model reveal that we lack basic information concerning stand age and hazard-of-burning for different fuel types. Our proposed fieldwork will obtain this new data. Second, once tested by field data, the model will provide a planning tool for land managers who are designing fire-management plans that can balance the needs of both natural ecosystems and of the humans living around and in them.

This project addresses JFSP’s Task 1 (evaluate fire-management strategies in roadless areas), Task 3 (determine effects of fuel buildup), Task 6 (incorporate climate-change predictions into fire management), and Task 7 (develop scientific support tools for fire management). Project cooperators include representatives of Federal and State, land-managing agencies in interior Alaska, including the Bureau of Land Management, U.S. Fish and Wildlife Service, the U.S. National Park Service, U.S. Geological Survey, and Alaska Department of Fish and Game. After developing the Boreal ALFRESCO model in Alaska, our ultimate goal is to apply it to more complicated settings of the Intermountain West. Interior Alaska has relatively simple vegetation types and human infrastructures, so it is an ideal place for the initial development of an integrated model of human-fire-ecosystem interactions.

INTRODUCTION

Fire management issues are growing in importance as human populations progressively expand into former roadless areas. The same natural fire regimes (i.e., fire frequency, intensity and size) that underlie the structure and function of many wildland areas also threaten human life and property. In many parts of North America, the buildup of wildland fuels caused by fire management activities over the past 50-100 years have increased the dangers posed by wildland fires. Fuel buildup–either in the form of dead, woody debris or, as is the case in interior Alaska, increasing continuity of flammable forest cover– is undesirable for two reasons. First, it can cause future catastrophic wildland fires; second, it may cause changes in the natural fire regime that adversely affect flora and fauna. An understanding of the processes that control wildland fuel accumulation, including the role that fire management activities play, is crucial for designing wildland management policies.

Fire management is complicated by natural and anthropogenic trends in climate change. Wildland fire is predicted to increase globally under forecasted future climatic warming (Overpeck et al., 1990). The area burned in western North America is thought to have increased two-fold over the past thirty years (Kasischke et al. 2000), and it is forecast to increase by as much as 80% over the next century (Price and Rind, 1994). To effectively manage fire in the future, managers have to make decisions based on a complicated matrix of interacting and changing factors. These factors include human geography, economic interests, ecosystem maintenance, fuel buildup, hazard-of-burning, and climate change. To design long-term plans that optimize multiple management goals, we need a tool to model and visualize the legacies of alternate management scenarios.

Here we propose developing a computer model, Boreal ALFRESCO, to assist land managers who design and implement fire-management plans in the boreal forest of interior Alaska. This model will integrate fuel buildup, vegetation, climate, and fire-management policy with real geography over time scales of years, decades, and centuries. We have successfully used earlier versions of this model to simulate shifts in fire-vegetation dynamics in response to changes in climate over century time scales (Rupp et al. 2000b, 2001a, b). We want to develop these earlier model versions into a fire-management tool by adding new GIS-based layers of human infrastructure (e.g., roads, settlements), and fire management options. Important new additions to existing model versions will be made that relate vegetation type and age to hazard-of-burning and fire size/type. Because the model is spatially explicit and proceeds through time, Boreal ALFRESCO can be adapted for use in multiple management situations. We think this computer model has the potential to become a widely applicable management tool for integrated fire management.

PROJECT GOALS

Our goal is to develop a computer-based, fire-management modeling tool that is consistent with ecological processes in the boreal forest of interior Alaska and tested by field data. This model will depict the responses of vegetation to multiple scenarios of fire-management, fuel buildup, and climatic change. It will aid in fire management within the expansive, roadless forests of interior Alaska between the Alaska Range and the Brooks Range. For example, a means of comparing the regional risk of very large fires, based on model inputs including fuel condition, is of great interest to fire managers. This type of fire activity may have profound short- or long-term effects on the resources and users in an entire refuge, park, or conservation unit. Model outputs will be transient depictions of vegetation, fuel, and fire extent over defined landscapes. The end users of our model will be Federal and State land managers concerned with integrating fire-management activities around human settlements with the multi-decade maintenance of natural ecosystems.

PROJECT COOPERATORS

This project involves cooperation between several Federal and State agencies and will provide end products useful to a host of land managers across Alaska (see Appendix 2). Cooperating agencies include the Bureau of Land Management – Northern Field Office and Alaska Fire Service (BLM – NFO and BLM – AFS), U.S. Geological Survey – Biological Resources Division (USGS – BRD), U.S. Fish and Wildlife Service (USFWS), the National Park Service (NPS), and Alaska Department of Fish and Game (ADF&G).

SPECIFIC RESEARCH TASKS

Our specific tasks fall into two categories. First we want to develop the model so that it simulates ecosystem dynamics in the boreal forest in a realistic manner. Second, we want to make this simulation useful to managers.

<u>Informing the model about the forest</u>

The existing version of Boreal ALFRESCO predicts scenarios of interacting change between fire regime and vegetation over decadal time scales. Inputs consist of topography and existing vegetation. The existing model works: it accurately simulates currently observed vegetation distribution and fire regime (i.e., number of fires and area burned), under current environmental conditions in both northwestern Alaska (Rupp et al., 2000b; 2001a) and the central interior region (Rupp et al., 2001b).

However, we need to further develop functions relating vegetation composition and age to flammability. Relatively little is known about the fire ecology of the Alaskan boreal forest (see below), and a particularly large gap in our understanding of fire behavior is how hazard-of-burning changes with stand age. We need new field data addressing hazard-of-burning, fuel characteristics, and stand age to improve the accuracy of Boreal ALFRESCO.

The focus of our fieldwork will be stand-age analyses of forests representing the five major boreal forest fuel types. In future model runs, the abundance of these fuel types in a specific area will change, so we need to have age dependent, hazard-of-burning functions for each of them. These same functions will yield the first well-quantified and geographically representative estimates of fire frequency over the last several centuries in interior Alaska. Our fieldwork will take place along a climatic gradient stretching across interior Alaska. The idea is to use the climatic gradient to define the modeling space in which we can apply Boreal ALFRESCO to predict changes in fire regime caused by changing climate.

Developing the model and making it useful to managers

We are developing Boreal ALFRESCO to assess fire risk in Federal lands and adjacent communities and to understand the ecosystem impacts of fire-management policies. Integral to this process are inputs from fire-management specialists. They will tell us what they need the model to do and comment on the realism of the model's underlying assumptions. The main tasks in model development will be to modify the current model by incorporating the new data layers of human geography and fire-management options. Modifications to the structure of the code will improve the temporal and spatial resolution of the model, providing managers with annual results at a 1 x 1 km cell resolution (and 30 x 30 m cell resolution for the identified study regions, where adequate data is available). Additional modifications will incorporate the impacts of changing fire-management options and human geography on the fire regime and vegetation. The simulation of vegetation change over time allows us to perform additional analyses of how animals interact with fire, fuel, and vegetation change. Vegetation cover strongly influences animal populations, soils, hydrology, and microclimate. We will model the environmental changes associated with changes in fire regime and vegetation by adding modules to the basic Boreal ALFRESCO model. One management issue we plan to address through the model is how fire regime influences the abundance of caribou winter foraging habitat. We are collaborating on this part of the work with Layne Adams of the USGS –BRD and Bruce Dale of the ADF&G.

BACKGROUND

Fire Underlies the Structure and Function of Boreal Forest

Fire is the major disturbance factor in the boreal forest and it exerts pervasive ecological effects (Van Cleve et al., 1991; Payette, 1992). In interior Alaska, wind-throw, mammalian herbivores, disease, and insects are minor mortality agents compared with fire (Lutz, 1956). The landscapes of interior Alaska are mosaics of old burns and secondary succession after fire is the predominant process of vegetation change in the boreal forest (Zackrisson, 1977; Payette, 1992). Fire is the keystone disturbance that underlies the stability of boreal forest vegetation (Wright, 1974). Its relatively simple disturbance regime makes the Alaskan boreal forest ideal for computer simulations of boreal ecosystem dynamics.

Fire is Sensitive to Climate and Human Activities

Fire frequency is the average annual probability of a site being burned and its multiplicative inverse is the mean fire interval (MFI) (Larson, 1997). Fire frequency is climatically sensitive, so it varies on geographic and temporal scales (Johnson et al., 1990; Johnson and Wowchuk, 1993; Bessie and Johnson, 1995; McKenzie et al., 2000). Fire intervals in Alaska are poorly known but are probably >250 years in the moist, southern parts of the state (C. Fastie, personal communication), 80-100 years near Fairbanks in the interior (Mann et al., 1995), and <80 years in the Porcupine River valley (Yarie, 1981). Fire frequency varies on all time scales, from the several year cycles of the ENSO-El Nino (Swetnam and Betancourt, 1990; Veblen et al., 2000) to the century and millennial time scales associated with climatic changes occurring during the Neoglacial period and Little Ice Age (Clark, 1990; Bergeron, 1991; Larsen, 1997). Fire frequency is sensitive to human influences through changes in ignition sources and their frequencies, and through fire-management activities (Johnson et al., 1990; Johnson et al., 1998; Veblen et al., 2000). In many northern forests, fire frequency declined in the latter half of the AD 1800s (Clark, 1990; Mann et al., 1994; Larsen, 1997) probably in response to a combination of climatic factors and altered cultural patterns of forest use.

The Need for Fire Histories

Fire regime prior to the last few decades is poorly understood in the boreal forest of Alaska. Systematic record keeping and reporting of fires in interior Alaska was started by the Bureau of Land Management in 1950, but was incomplete, with emphasis on fires near human settlements. More complete, aerial monitoring of fires in the entire region began in the late 1970s. There are only four published studies from Alaska that utilize fire-scar and/or tree age distributions to infer fire regime over decadal to century intervals (Yarie, 1981; Mann et al., 1995; Mann and Plug, 1999; DeVolder, 1999). The sites of these four studies are scattered over a region the size of Montana.

Recent Trends in Landscape/Fire/Succession Models

Predicting the broad-scale occurrence and effects of wildland fire is an important challenge for scientists and resource managers (McKenzie et al., 2000). Computer simulation models of ecosystem dynamics that incorporate fire behavior and fire effects provide researchers with a tool for understanding how ecosystems and disturbance regimes respond to climatic and land use change. Landscape-fire-succession models (LFSMs) are computer programs that simulate the processes of fire and plant succession in a spatial domain with resolutions and extents of 10-1000s meters and 1-1000s kilometers, respectively. These types of spatially explicit models are needed to account for the heterogeneity of fire patterns and effects, even within large regions.

A number of different LFSMs have been developed in recent years, corresponding to a wide range of objectives, approaches, and scales (Gardner et al. 1999). Some of these models have been developed to address issues pertinent to fire management. For example, Li (2000) developed a model (SEM_LAND) to estimate historical fire cycles prior to intensive human settlement in western Canada and to aid forest managers in evaluating forest policy. This model also predicts how climate-fire regime interactions might impact wildlife habitat (Li et al., 2001). Hargove et al. (2000) developed a similar model (EMBYR) for the Intermountain West and have applied it to Yellowstone National Park to understand the ecological effects of fire. Another model (FIRE-BGC), which simulates landscape-fire-succession dynamics for the Intermountain West, was developed by Keane et al. (1996) based upon an earlier model (FIRESUM) by Keane et al. (1989). FIRE-BGC is a complex mechanistic model that simulates the gap-phase dynamics of individual trees. It too has been used to understand how fire-management policy affects landscape dynamics. One disadvantage of these models is the constraints on both the spatial and temporal domain due to large amounts of empirical data needed as inputs. As described below, our modeling approach takes a similar approach, but aims to explicitly integrate climate, vegetation, fire, and fire management at the regional-level while providing transient depictions of vegetation and fire across the landscape. Additionally, our model structure allows for efficient, multiple depictions (under varying parameterizations) that will better serve the land manager in the management decision process. Basically, our frame-based model is faster, requires fewer details about individual species interactions, is easier to input new data layers, and consequently is more responsive to diverse management issues at landscape scales.

ALFRESCO, a Frame-Based Model of Interacting Vegetation, Fire, and Climate Change

ALFRESCO, described in detail by Rupp et al. (2000a,b), simulates the responses of subarctic and boreal vegetation to transient climatic changes. The model assumptions reflect the hypothesis that fire regime and climate are the primary drivers of landscape-level changes in the distribution of vegetation in the circumpolar arctic/boreal zone (cf., Payette, 1983; Van Cleve et al., 1991; Bliss and Matveyeva, 1992; Holling, 1992; Starfield and Chapin, 1996). Furthermore, it assumes that vegetation composition and continuity serve as a major determinant of large, landscape-level fires (Rupp et al., 2001b). Currently, ALFRESCO operates at decadal time steps, which is approximately the current average frequency of severe fire years in the North American boreal forest (Flannigan and Harrington, 1988). The model calculates vegetation change in a landscape composed of 2 x 2 km pixels, a scale appropriate for interfacing with mesoscale climate and carbon models (Starfield and Chapin, 1996). The model currently simulates five major subarctic/boreal ecosystem types: upland tundra, black spruce forest, white spruce forest, deciduous forest, and grassland-steppe. These ecosystem types represent a generalized classification of the complex vegetation mosaic characteristic of the circumpolar arctic and boreal zones of Alaska (Solomon, 1992; Starfield and Chapin, 1996; Rupp et al., 2000a).

ALFRESCO is a frame-based, spatially explicit model. Frame-based models partition temporal changes in vegetation into a set of states or frames. Each frame represents a different vegetation/ecosystem type, and it runs within ALFRESCO as an independent submodel to simulate the processes important to that particular frame. Over model time, these processes may cause a switch to a different frame/vegetation type (Starfield et al., 1993). The model uses rules to simulate the interactions between vegetation, disturbance regimes and a changing climate. This approach emphasizes the processes causing vegetation change, not the variables controlling productivity or species composition within a vegetation type, as is done in gap dynamics models (Shugart and West, 1980; Pastor and Post, 1986; Starfield and Chapin, 1996).

ALFRESCO generates climatic conditions stochastically by randomly sampling observed, growing season (May-September) climate data from Alaskan stations (Hammond and Yarie, 1996). Climate is input to the model as a series of alternative maps of growing-season temperature and precipitation. These maps have a geographic pattern of climate that is consistent with topography and latitude (e.g., colder in mountains and to the north) and with observed synoptic climatology. The temperature and precipitation in each pixel of the map is then converted to temperature and precipitation classes (1, 2, 3 or 4) that have defined effects on vegetation (Starfield & Chapin 1996). Individual climate maps preserve the basic geographic patterns of climate, but uniformly differ in the magnitude of temperature and precipitation (Rupp et al., 2000b, 2001a). An 'effective drought' index (Trigg 1971; Clark 1988) provides a measure of drought severity and is utilized in determining vegetation growth, and vegetation flammability. The database for probability distributions of temperature and precipitation for different climate scenarios and the relationships of climate to vegetation growth and composition and to flammability are presented in Starfield and Chapin (1996) and Rupp et al. (2000a, b).

Climate, vegetation type, and time since last fire drive the wildland fire regime. Fire spread across the landscape is simulated using a cellular automaton approach, where an ignited grid cell may spread to any of its eight neighboring cells. Fire ignition within a cell is determined stochastically as a function of the flammability of the cell. The flammability of each adjacent cell and the effects of topographic barriers determine the probability of fire spread. In all ecosystem types, fire probability (the probability of a fire that kills the majority of trees in a cell) is proportional to the drought index, because the drought index increases with increasing temperature and decreasing precipitation (Thornthwaite and Mather 1957; Starfield and Chapin 1996). The relationship between fire probability and the drought index is assumed to be the same among all vegetation types (based on data from boreal forests), but actual probabilities differ among vegetation types due to factors that are specific to each (Rupp et al., 2000a,b). For example, white spruce and deciduous forests differ in their fire probabilities, but fire probability in these two forest types shows the same responses to changes in the drought index.

MATERIALS AND METHODS

Study Sites

The model domain includes all of Interior Alaska, the region north of the Alaska Range and south of the Brooks Range (Fig. 1). The field component of this study will take place in three study areas, each 150 x 150 km, arranged across the strong gradients in precipitation and summer temperature that occur in an east-west direction across Interior Alaska. All three study areas are covered by boreal forest containing white spruce, black spruce, aspen, cottonwood, and birch, but also have tundra regions near and above treeline. They are situated in areas of similar topography (low hills with topographic relief of 100-300 m), similar geomorphic histories (unglaciated since the Tertiary), and similar bedrock geology (low-grade metamorphics). The three study areas are: (**A**) the lower Yukon/Kuskokwim region in southwestern Alaska just east of the village of Aniak, (**B**) the White Mountains located north of Fairbanks, and (**C**) the Black River drainage in the upper Yukon Flats north of Fort Yukon (Fig. 1). Mean annual precipitation is 500 mm at Aniak, 300 mm at Fairbanks, and 200 mm in the Black River drainage (Prism, 2000). Mean July temperature ranges from 13.2^{o} C at Aniak, to 16^{o} C at Fairbanks, to 16.3^{o} C at Fort Yukon (Leslie, 1989).

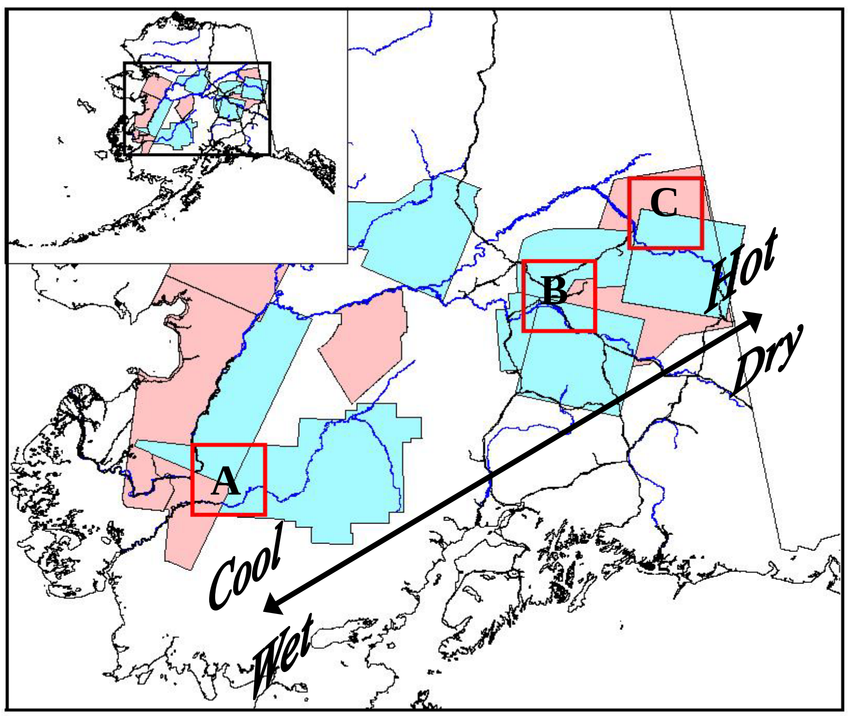

Figure 1 – Map of Interior Alaska showing the location of the 3 study areas (red boxes A, B,C) and the interagency Landsat TM land cover classification project (see below) indicating completed project regions (Blue) and regions with a 2001 scheduled completion (Pink). The study areas lie along a climatic gradient from west to east. The study areas are 150 x 150 km.

Initial Classification of Vegetation and Fuel Types from Remote Sensing

The vegetation cover of our three study areas has been previously classified at 30-m resolution from Landsat Thematic Mapper satellite data as part of a Federal interagency effort in partnership with Ducks Unlimited. The vegetation units we will enter into Boreal ALFRESCO to depict present vegetation include deciduous forest (birch and aspen), open black spruce forest, closed black spruce forest, upland white spruce forest, riparian white spruce forest, tussock tundra, and upland tundra. Development of fuel-type maps based on the flammability and fire spread characteristics of these Landsat-derived vegetation cover is currently underway by a research committee within the Alaska Wildland Fire Coordinating Group, an interagency consortium of Federal land managers in Alaska. These fuel-type maps will be used as inputs into the model to depict present-day fuel-type distribution and composition. In the future, Boreal ALFRESCO will take advantage of satellite-derived fuels data being developed by Zhu et al. (JFSP 2000 funded project) to accurately represent current vegetation/fuels distribution and composition.

Field sampling

The primary goal of data collection activities is characterization of vegetation age structure for each of the fuel types. Estimates of MFIs derived from the age structure data will be checked using estimates of MFIs derived from fire scarred trees (see below). Within each of the three study areas, we will visit 250 randomly chosen plots. A combination of fixed-wing aircraft, helicopter, waterway, and ground transportation will be used for field transport. Each plot will encompass 1 km^2, the spatial resolution used in Boreal ALFRESCO. Plots will be stratified by fuel type, with 50 plots in each of the 5 vegetation/ fuel types. In each plot, we will ground truth the vegetation and fuel type, and describe organic soil horizons (an important fuel component in the boreal forest). We will determine time since last fire (TSLF) in each plot by felling 10 randomly chosen trees and retrieving a full-cross section from each near the root crown. This sampling density will equal or exceed that of similar studies in the boreal forest (cf., Yarie, 1981; Larsen, 1997). We will also search out and collect cross sections from any fire-scarred trees within a kilometer of our landing zone.

Laboratory Work: Ring Counts and Statistical Analyses

Cross sections will be trimmed and polished, then their rings counted and ring widths measured on a Bannister Bench under a binocular dissecting microscope. All sections will be cross dated to correct for missing rings. Initial cross dating will be done visually using marker rings. These results will be checked using the computer program COFECHA (Holmes, 1983).

We will derive estimates of the hazard-of-burning for different fuel/vegetation types from data describing times since last fire (TSLF). In the boreal forest of interior Alaska, fire is the dominant mortality agent for trees, and tree ages describe TSLF and fire-interval distributions. We will use likelihood techniques to estimate parameters in statistical models of fire-interval distribution (Johnson, 1979; Reed et al., 1998). Using methods from the statistical field of survival analysis, the probability of fire (mortality) during a given time interval can be expressed analytically according to stand age. Parameter estimates from the maximum likelihood estimation (Reed, 1994) will be used to specify an analytic hazard function (based on the data) for each vegetation/fuel type within the fire subroutine in Boreal ALFRESCO. Through the use of exploratory data analysis, a statistical model will be constructed for the TSLF data. The distribution chosen for the statistical model (i.e. exponential, Weibull) will determine the explicit form of the corresponding hazard-of-burning as a function of tree age (Johnson et al., 1995; Weir et al., 2000). The use of the negative exponential distribution for fire intervals assumes that the hazard-of-burning is constant through time (Johnson and Van Wagner, 1985). If the data suggest this is not the case, we will use another distribution such as the Weibull or Gamma. These distributions can accommodate hazards that change with tree age. We will then use the Chi-square test and the Anderson-Darling goodness of fit tests to evaluate the statistical significance of differences between empirical data and the statistical model for fire frequency (Larsen, et al., 1997). For each vegetation/fuel type and study area (different climate regimes) a different hazard function will be utilized to depict fire-vegetation-climate interactions in Boreal ALFRESCO.

We will use fire scars in tree cross sections to check the estimates of fire frequency made from tree-age distributions. Though fire scars are not common in interior Alaska compared to pine forests in the Rockies, they do occur and are common in some firebreak areas. Fire intervals are the periods between two consecutive fires or between tree establishment and the first fire scar. From fire-interval distributions for different fuel/vegetation types within each study area, we will derive MFIs, the average number of years between consecutive fire dates in a composite chronology (cf., Veblen et al., 2000). The construction of a composite (or master) fire chronology implicitly results in a measure of fire frequency that is dependent on the size of the study region, unless one can be sure that each fire recorded in the chronology burned uniformly in the area of interest. When this assumption is not satisfied, the estimate of fire frequency increases as the size of the study area increases. For this reason, MFI data can be used only as a lower bound on estimates of fire frequency that are obtained from the stand age analysis. Nonetheless, scar-derived estimates of MFI will provide a valuable check on the results of fire frequency estimated by stand age analysis.

Modeling Component

The changes we plan to make in existing versions of ALFRESCO emphasize improvements in how the model depicts feedbacks between vegetation, fuel, and fire regime. The current version of Boreal ALFRESCO simulates fire ignition and spread using coarse-scale rules relating ignition and fire-spread hazard to climate, vegetation type, and stand age. The model originally was parameterized to simulate general fire frequency trends in Alaska as reported in the literature. Our proposed research aims to improve the precision of fire hazard-fuel load relationships by using results from survival analysis. This will result in a more accurate simulation of fire regimes. We will use the hazard-of-burning functions developed from the analysis of field data (see above) to develop algorithms for the five major boreal forest fuel types. In addition, the climatic gradient of the study region will provide empirical data for improved representation of fire hazard-climate relationships within and among fuel types in interior Alaska. Currently, the successional dynamics component of Boreal ALFRESCO simulates five fuel types, including a dry grassland type (Starfield and Chapin, 1996; Rupp et al., 2000a; Rupp et al., 2001b). In this project, we will develop new frames (i.e., fuel types) that specifically represent the seven major fuel types that BLM now utilizes in fire management. The major fuel types consist of five forest types (deciduous forest, open black spruce forest, closed black spruce forest, upland white spruce forest, and riparian white spruce forest) and two non-forest types (tussock tundra and upland tundra). We will utilize the current flammability functions in Boreal ALFRESCO for the tundra fuel types, which were developed from the Alaska fire literature.

The new model version will function at a 1 x 1 km grid cell resolution and will have interior Alaska as its spatial domain. We are using a 1 x 1 km spatial resolution for three reasons. First, fires in Interior Alaska tend to be very large, and the spatial distribution of vegetation is homogeneous relative to that of the Intermountain West. Second, although 30 x 30 m data exist for our three study areas (Figure 1), only 1 x 1 km data are available for much of Interior Alaska. Third, computational efficiency inhibits finer resolution model simulations of the entire spatial domain. This is important because the objective is to provide an efficient decision support tool that can be easily used by managers. The current model structure runs on a 10-yr-time step and simulates system dynamics on century to millennia time scales. For this project, we will modify Boreal ALFRESCO to run on an annual time step to simulate inter-annual variability of the fire regime over decadal to century time scales in response to changing climate and management policies.

<u>Testing the Model</u>
In addition to informing model development, the field data and hazard-of-burning functions will provide tests of model performance in the three study areas. We will test the model by showing that the variability and measures of central tendency for the output variables of interest from the simulation results (e.g., number of fires and area burned) are reasonable when compared with the field data. In other words, we will test the model by seeing how closely it can predict the vegetation, fuel, and fire regime that we actually find on the present landscape. We will accomplish this by running the model to equilibrium (i.e., until vegetation and climate stabilize) over a period of several thousand years and under current climate conditions. Once it passes this test, Boreal ALFRESCO will be used to explore the interactions between climate, fire regime, vegetation, and fire management under different scenarios of future change.

<u>Model Application to Management Issues</u>
Following model calibration and testing, we will work with our agency cooperators to develop it into an useful management tool that is capable of simulating fire risk in interior Alaska and predicting the impacts of fires and fire management on ecosystem dynamics. The first step will be to develop georeferenced input data on fuel types across the model domain. This work already has begun by the Alaskan Wildland Fire Coordinating Group (see above). The model will use wildland fuel maps to estimate current fire risk throughout Interior Alaska based on the empirically derived hazard-of-burning functions. Boreal ALFRESCO dynamically simulates climate, the timing and location of fires, and the response of the individual fuel types to environmental change. Once the model is calibrated using field data, the only input data required for model simulations are the initial vegetation conditions and the user defined management options and climate scenario. This initial modeling exercise will allow BLM to conduct assessments of present day fire risk in communities adjacent to Federal wildlands.

The second collaborative task will be to develop predictions of fire-risk under different fire-management and climate scenarios. Alaska's interagency fire-management plans designate several fire-management options, which range from aggressive action on any new fire start to monitoring and structure protection with no interference with natural fire spread. Options are reviewed annually by land-management agencies comprising the Alaska Wildland Fire Coordinating Group. Boreal ALFRESCO will be able to analyze the long-term effects of different fire-management options simultaneously with different scenarios of human development, land-use, and wildlife populations. In addition, we will be able to input future climate-change scenarios covering the expected range of variability associated with anthropogenic climate change. The model will output short-term, long-term, and cumulative impacts of different management scenarios under different regimes of climate change. Impacts of using different scales will be assessed and output as well. Comparison of the results of model runs with both increased and decreased spatial resolution will be performed to accommodate differing management needs. Mapped time series of vegetation, fuel, and fire regime changes will provide Federal land managers with a useful planning tool for assessing management options.

The third application of Boreal ALFRESCO will be to model how changes in fire regime impact natural ecosystems. Rupp has initiated a pilot study complementing a research project funded by the Department of the Interior Fire Research Committee, led by USGS–BRD and ADF&G, to investigate how changes in fire regime affect caribou winter foraging habitat. Caribou are an important subsistence resource and game animal in Alaska. In winter, they rely heavily on lichens, which are abundant only during certain stages of post-fire succession. Wildlife managers want to know how changes in fire regime occurring under different fire-management and climate-change scenarios could impact caribou winter forage. Boreal ALFRESCO will predict future fire regimes and resultant vegetation distribution. From model output, we can make maps depicting how the quality of caribou winter range might change over decades to centuries. This application is one example of the many different potential applications Boreal ALFRESCO has for ecosystem management.

SIGNIFICANCE OF THIS PROJECT

Interior Alaska contains 140 million burnable acres and includes the largest National Parks and Wildlife Refuges in the country. Most of this huge area is roadless. On average, wildland fires burn 1,000,000 acres in interior Alaska each year, and they routinely threaten the lives, property, and timber resources of the sparse but growing human population. Wildland fires threaten human values, but they also are crucial for the maintenance of the boreal forest. ***How do we manage wildland fire in interior Alaska for the mutual benefit of humans and natural ecosystems?*** Our proposed work is important because it addresses this question directly. The Boreal ALFRESCO model will output mapped depictions of changes in wildland fuels, fire risk, and vegetation under multiple future scenarios of fire-management, climate change, and human development. The model will serve as an integrative and adaptive planning tool for land managers designing fire-management plans that can safeguard both human and natural values. Once it is perfected in the relatively simple setting of the boreal forest, we think Boreal ALFRESCO shows promise for application in the Lower 48 states.

RELEVANCE TO THE GOALS OF THE JOINT FIRE SCIENCE PROGRAM

The work proposed here directly addresses four of the tasks set forth in the 2001 Request for Proposals.

Task 1. *Evaluate impacts of alternative management strategies on fire regimes … in unroaded areas …Studies considering ecological, social, and institutional factors are encouraged. Areas of interest include such areas as unroaded areas, Federally designated Wilderness Areas, National Monuments, and National Parks.*

Our project will quantify and model the future implications of alternative management policies on fuel loading and structure, fire hazard, and their interactions with ecosystem structure, function, and ecological values in the largely unroaded region of interior Alaska. Development of the Boreal ALFRESCO model as a management tool will provide "improved tools for evaluating and understanding the effects of alternative regulatory and policy scenarios, management and restoration goals, or the tools used to implement these goals in unroaded, wilderness, and other areas with restricted access; evaluate fiscal, regulatory, institutional, and behavioral constraints within agencies to managing fire and fuels in unroaded, wilderness, and similar areas."

Task 3. *Within the matrix of land management practices, determine the cumulative effects of fuels manipulation/reduction methods and techniques on future landscape characteristics in terms of fire behavior and severity, wildlife population and habitat structure dynamics, hydrologic effects, soil processes, ecosystem health issues, and other environmental variables; develop one or more methods or approaches to integrate fuels management into landscape level processes.*

Our project aims specifically to accomplish Task 3 by integrating multiple data sources and value systems within an adaptable computer model that will be useful to multiple land managers. Boreal ALFRESCO will produce spatially explicit output at an annual resolution so it can be used to generate different scenarios of fire history and fire effects over multi-decadal time spans, given different fire-management policies and/or climatic changes. Additional analyses can be developed that relate the responses of hydrology, soil-organic matter, and different wildlife species to changes in vegetation cover resulting from shifts in fire regime.

Task 6. *Develop methods or systems for incorporating existing weather and climate predictions into tactical and strategic fire preparedness and planning, prescribed fire planning, mid- and long-range fire and land management planning, and assessments of the potential for success of post fire stabilization and rehabilitation treatments; evaluate and analyze the role of climate in interannual, decadal, or longer term changes in fire season characteristics.*

Our model predicts the outcomes of interactions between fire, climate, vegetation, and human management. If global warming occurs, climate change will be a crucial part of managing fire regimes in the boreal forest. Climate is an important variable in the predictive scenarios that Boreal ALFRESCO produces. Our model is flexible enough to provide a range of fuel-fire-response scenarios over both short and long time periods, based on the varying predictions of climate modelers.

Task 7. *Develop scientifically based support tools to improve fire management decision processes. Tools to support (fire-management) decisions (should) reduce uncertainty, identify risk, and improve decisions… These tools …must reflect the best available science, present a quantitative result, present visual outputs, and be easy to use.*
Boreal ALFRESCO will be built as a management tool with emphasis on ease of use by managers and adaptability to local geography and management priorities. The spatially explicit nature of the model will allow managers to add relevant georeferenced data such as road corridors, human settlements, fire-management options, and management resource locations. The model simulates transient successional dynamics, allowing for the direct analysis of both human and animal interactions with fire, fuel, and vegetation processes. Primary output will consist of spatially explicit, annually updated maps of vegetation distribution and fuel characteristics over real topography. The fuel-distribution maps can be used to derive fire hazard conditions.

PROJECT MANAGEMENT PLAN
The University of Alaska Fairbanks is the lead institution, with Rupp and Mann sharing overall responsibility for the project. Responsibilities are distributed primarily according to our two primary tasks, with Mann leading the field component and Rupp leading the modeling component of the study. Our main Federal cooperator is the BLM, with Jandt having overall responsibility for coordinating Federal cooperation. Rupp and Mann will co-advise and direct the graduate student, who will work primarily on the field component of the study, but will also be involved in the modeling. The entire research team (including all Federal and State cooperators) will have annual meetings to discuss strategies for developing, modifying, and implementing the model. Subsets of the larger group (Appendix 3) will meet more frequently to guide development of particular components within the modeling and field research programs (e.g., fuel-types classification and fire-spread algorithms). We will make these meetings accessible to other land managers who are not directly involved in the project, but who might benefit from the deliverables and provide input during development phases.

<u>Work Schedule:</u>

Year 1	- Research team organization and project initiation - Field preparation: site location, sampling design, logistical planning - Model development: modifications to temporal and spatial resolution - Fieldwork - All-Cooperators Meeting (presentation of field and modeling results, cooperators' feedback) - Annual report to JFSP and agency partners.
Year 2	- First technology-tranfer session with agency cooperators - Laboratory work - Initiate second field season - Develop prototype fire-management model working closely with agency cooperators. - Develop prototype fire-risk assessment - All-Cooperators Meeting (presentation of field and modeling results, cooperators' feedback) - Annual report to JFSP and agency partners. - Provide public access to fire risk assessment data layers via AGDC website
Year 3	- Provide public access to wildlife habitat assessment results - Peer-reviewed journal publications based on field data, modeling output and management implication - All-Cooperators' Meeting - Two training workshops with key agency personnel to transfer modeling program - Deliver user-guide for management model

DELIVERABLES
The primary goal of this project is to develop a computer-based management tool that is useful to land managers faced with the task of managing wildfires for the mutual benefit of the natural ecosystems and the human residents of Interior Alaska. The primary deliverable will be a user-friendly, fire-management computer model, Boreal AFRESCO. Details of how this model

works and its program will be delivered as described in the next section. In the process of developing this modeling program, we will develop spatial data sets and maps showing the results of our calibration studies in three study areas located along climatic gradients in Interior Alaska. These results will be posted for access by the cooperating agencies and the public on the Alaska Geospatial Data Clearinghouse (AGDC) website. All data sets will be documented using FGDC metadata standards.

TECHNOLOGY TRANSFER

The transfer of knowledge, data, and computer resources from this research will occur in six ways:

1) We will work with BLM's GIS coordinator, Mr. Tim Hammond, to ensure that model output (in the form of GIS coverages) will be accessible to cooperating agencies and to the public. We will use the Alaska Geospatial Data Clearinghouse website as an electronic forum to widely distribute field data, model results, and associated metadata.
2) Rupp and Duffy will work with BLM's GIS coordinator, Tim Hammond, to develop a version of Boreal ALFRESCO that can be utilized by the various Federal and State user groups. Both Duffy and Hammond have experience in technology transfer (see resumes). We will begin technology transfer in year two of this project and continue it during year three.
3) Our All Cooperators Meetings/workshops hosted by the University of Alaska Fairbanks will provide a forum for presentations and progress reports where managers and resource specialists can receive updates on the research and provide valuable input. We expect Boreal ALFRESCO to be a useful management tool for many other Federal, State and Native land managers in Interior Alaska including Native-village and regional corporations, State Department of Forestry, and the United States Army. All these agencies administer large areas of wildlands where fire is both a key ecosystem process and a constant threat to human affairs.
4) Reports will be delivered annually at JFSC workshops and several scientific papers will be developed for publication in peer-reviewed scientific journals.
5) A hard-copy and web-based user's guide will be developed that describes Boreal ALFRESCO and provides guidance for its application by resource managers.
6) Rupp, Duffy, and Hammond will conduct two training workshops with key agency personnel to transfer the modeling program and its application to the managers.

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