IDENTIFYING LIKELY WILDFIRE IGNITION POINTS USING TOPOGRAPHIC ANALYSIS, STATISTICAL INVESTIGATIONS, AND ARTIFICIAL INTELLIGENCE.

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ABSTRACT

Identifying likely wildfire ignition points has obvious significance to natural resource managers interested in effectively planning wildfire risk mitigation programs. Furthermore, it stands to reason that the risk of at least some types of wildfire ignition can be related to a variety of cartographic features (e.g., lightning strikes are more likely on ridge lines, accidental human-caused fire ignitions are more likely in heavily used areas, etc.). This study will use an extensive database from Yosemite National Park to investigate the feasibility of identifying wildfire ignition risk using standard GIS cartographic analysis procedures, statistical inquires, and artificial intelligence techniques.

INTRODUCTION

The risk of catastrophic wildfire is becoming a major source of concern for federal, state and local land managers. Increased human development in wildland areas, heavy fuel loads due to past fire exclusion practices, and increasingly frequent drought conditions are all believed to be contributing to increased risk for catastrophic fire across much of the United States. Large wildfires such those which occurred in 1988 and 1989 in Yellowstone National Park often result in large-scale property damage and can lead to the loss of human life. Wildfires of this magnitude are also extremely expensive to control and extinguish. As a result, more and more pressure is building to actively manage wildfire risk on public lands.

Unfortunately, not all public land managers are fire management experts and those who do have some expertise are usually working with limited time and within limited budgets. Currently, a large project is underway at Colorado State University to develop a technological support system to aid public land managers in managing wildfire risk. This paper describes efforts to date regarding one portion of this larger study; namely, an effort to predict likely wildfire ignition points based on cartographic features using combined GIS and artificial neural network technologies.

Artificial neural networks are a computer-based form of artificial intelligence inspired by the design and function of the mammalian brain. Neural networks have the capability of performing intelligent tasks such as learning by example, generalizing learned knowledge and recognizing patterns (Nigrin, 1993). The development of a neural network involves a training phase and a testing phase. During the training phase independent (input) variables and dependent (output) variables are fed into the network. The network thereby "shapes itself to reflect the relationships between the inputs and outputs" (Klimasauskas, 1991). During the testing phase a new set of input variables are given to the neural network and it predicts the outputs. These predicted outputs could then be compared to known actual outputs to determine the accuracy of the predictions.

Artificial neural networks were used to predict wildfire occurrence by Vega-Garcia et al. (1996), who examined human-caused wildfires in the Whitecourt Provincial Forest in Alberta, Canada. The neural network developed by Vega-Garcia et al. attempted to predict which (if any) of a number of geographic regions would experience a wildfire on any given day based on the cartographic and recreational characteristics of the regions. The network was tested using historical data for 1991-1992. Once refined, the neural network was able to correctly predict 85% of the no-fire observations and 78% of the fire observations.

The ability to predict wildfire occurrence in general geographical regions would no doubt be helpful to wildland managers, but in the present study we will attempt to develop an even more precise predictive model. The current study is attempting to develop a neural network that will produce maps of ignition likelihood for large areas. Maps of this sort will show the probability of wildfire ignition for every point in a region of interest. These maps will be both more geographically precise than those developed in the earlier study (by showing ignition risk on a point-by-point basis rather than simply showing an aggregate level of risk for a region) and provide probabilistic ignition risks rather than the simple binary "fire/no fire" predictions produced in the previous study.

Due to availability of data, diversity of terrain and fuel levels, and other factors, Yosemite National Park was chosen as the study site for this project. For initial model development, we chose to limit the study to only lightning-caused wildfire ignitions. In the future, we hope to relax this limitation and consider fire ignitions of all types.

METHODOLOGY

Data Acquisition

Most of the Yosemite National Park data used in this study was acquired from Jan van Wagtendonk, USGS, Yosemite Field Station. Data obtained from Dr. van Wagtendonk includes digital maps showing Yosemite National Park boundaries, historical wildfires (1930-1998) and fuel models. The fuel model data was derived from Thematic Mapper imagery taken by LandSat 5 on July 29th, 1992. Fuels were modeled according to the NFFL fuel model guidelines and iteratively ground verified over several years (van Wagtendonk, 1997). Digital elevation models for the Yosemite area were obtained from the USGS web site (edcwww.cr.usgs.gov/webglis).

Data Manipulation

This data required extensive manipulation and analysis before it could be utilized in building an artificial neural network. Unless otherwise noted all manipulations were performed using ArcInfo and ArcView GIS packages (ESRI Inc.).

The 33 DEM files covering Yosemite National Park were converted into ArcInfo GRIDs (raster based ArcInfo coverages) and resampled from 30 down to 5 meter cell sizes. The resampling was necessary due to the small size of many of the historical fires. These GRIDs were then mosaiced and clipped to the park boundary. The resultant DEM GRID was used to create slope and aspect GRIDs. Likewise, the 33 fuel files were converted into GRIDs, mosaiced, clipped and resampled to 5 meter cell sizes.

Next, it was necessary to locate ignition points of wildfires during a multi-year period. The wildfire data from 1990 to 1998 was considered to be the most accurate available and was temporally close to the imagery capture date and its subsequent ground-truthing. Therefore, this data was used to locate ignition points. Unfortunately, the existing data showed only the final perimeter of wildfires; it did not show exact ignition points. For small fires, deducing ignition points to the 30-by-30 meter spatial accuracy of the majority of the raster databases used in the study was not difficult. Experts familiar with fire behavior believe that in most cases, fire growth is primarily (but not exclusively) wind driven. Winds in the Yosemite area predominately blow west-to-east. Thus, in the majority of cases, simply selecting the westernmost raster cell of the three or four cells that represent a one acre or smaller fire is likely to produce a reasonable estimate of the fire's ignition point.

However, problems arose in deducing ignition points for larger fires. These large fires were typically multi-day events, and wind conditions usually changed at some point during the course of the fire. These wind shifts cause the fire to move in different directions during the course of its growth, thereby making the simple cell selection rule used to find ignition points of small fires invalid. Thus, it was decided to investigate the possibility of using the ignition points of small fires to represent all fire ignition points in Yosemite.

Lightning ignited wildfires that occurred between 1990 and 1998 were extracted from the historical wildfire file obtained from Dr. van Wagtendonk. These lightning-caused fires were separated into those that obtained a final (extinguished) size of equal to or less than one acre and those greater than one acre. A series of 18 GRIDs were then created, two grids for each year between 1990 and 1998. One set of nine GRIDs showed fires one acre in size or smaller that occurred in each of the nine years, and the second series of nine grids showed fires larger than one acre in size for each of the nine years. These 18 GRIDs were then used along with the elevation, slope, aspect and fuel model GRIDs to create a very large data file to be used in a statistical analysis. The data file contained thousands of records, six records for each raster cell in the GRIDs. Each record recorded the slope, elevation, aspect and fuel model of a particular cell, along with a binary variables that recorded either the presence or absence of a small fire during a given year and a second binary variable recording either the presence or absence of a large fire.

The slope, aspect, elevation and fuel model characteristics of both large and small fires were then compared statistically using the SAS statistical package. The results indicated that there was no statistical difference between the slope, aspect, elevation or fuel type characteristics of cells that supported large fires and the characteristics of cells that supported small fires. This allowed us to use only the small fires as a representative sample of all fire cells. This was helpful, because it allowed us to use the ignition points of small fires as a representative sample of the ignition points of all fires in Yosemite National Park.

Neural Network Development

Data from both cells representing wildfire ignition points and cells representing non-ignition points will be used to build an artificial neural network designed to predict ignition likelihood from descriptive cell data. The data describing each cell will include the slope, elevation, aspect, and fuel model data described previously, and will also include landform data and rain shadow information derived from topographic and climate data. The neural network will be created using NeuralSim software from Aspen Technology Inc. and will be based on the back-propagation and feed-forward approaches. When completed, this network will predict the likelihood of an ignition occurring on a particular raster cell during a nine-year period based on the cell's descriptive data. Optimal network parameters will be obtained via a controlled experimental process designed to investigate the plausible range of network parameters, including number of hidden nodes, form of activation function, training rate, etc.

As a second stage of this study, we plan to build a second neural network designed to predict all fire ignition probabilities (instead of just lightning-caused ignitions) from an expanded set of cell descriptive variables. This expansion will likely involve a number of variables designed to measure human use, similar to the variables used in the Vega-Garcia et al. (1996) study. However, no effort has been made to capture these expanded variables at this time.

EXPECTED RESULTS AND APPLICATIONS

The accuracy of the neural networks developed in this study will be tested by applying them to a evaluation data set completely independent of the data used to develop the networks. It is hoped that the resultant networks will have accuracy levels of at least 70 to 80%.

Assuming an acceptable predictive model is developed, it will be incorporated into a larger model designed to assist fire managers in identifying wildfire hazard mitigation strategies. This larger model will be based on the concepts and ideas developed by Dean and Pool (1996) and Heimiller and Dean (1998), and will incorporate the algorithmic improvements described by Valdez and Dean (2000).

CONCLUSION

As evidenced by their number and severity in the summer of 2000, wildfires are a serious problem throughout the United States. Anticipating where these fires will ignite has mostly been limited to educated guess work. It is the hope of this study to provide a technological support system for predicting likely points of wildfires ignition.

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