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MAPPING RISK OF WILDFIRES FROM HUMAN SOURCES OF IGNITION WITH A GIS

The risk of wildfire associated to human sources of ignition in a forest is a variable difficult to assess, but a very important one for several fire management applications.

The geographic distribution of risk can be considered to be dependent on site-related attributes. It is through the management of these site attributes, in digital form, that GIS systems facilitate the analysis of the geographic arrangement of risk levels in a forest management area.

Using ARC/INFO, several geographic variables were tested for their relationships to human-caused fires locations in Whitecourt Forest, Alberta. Risk factors were established using distances away from a road, town, or campsite, low elevations, presence of some fuels (deciduous, slash, grass), privately owned area, and highly uncommercial stands. These risk factors were combined into a composite Map of Risk for the Whitecourt Forest.

A discussion is presented as to how such a map can be utilized in fire prevention, fuel management, values-at-risk identification, lookout tower positioning, aerial patrol routing, and presuppression planning.

INTRODUCTION

Every year, human-caused fires produce great losses in timber and non-timber values from the forests, force heavy investments in suppression resources, and even threaten human lives. Nevertheless, the risk associated to human sources of ignition is the least understood component of the fire environment that generates wildfires. Human risk is a function of the number and location of people in a forest, and their behaviour. The numbers and locations of people remains very difficult to estimate for any period of time, and little is known about the people who start these fires.

In attempts to identify high-fire-risk behaviour researchers have found that the activity people were engaged in (ocupational, recreational, or residential) was more related to their use of fire than their personal characteristics (Folkman 1977). Studies of recreational use of the forest established that the environmental and social attributes of the sites are the most important external factor in making recreation choices (Watson et al. 1991). Visitors in the forests look for certain site attributes that can be anything from abundance of firewood, flat spots for tents, to landing areas for canoes. In the same way that the setting shapes recreational activities, it also shapes all other activities taking place in the forest, including the ones that involve the use of fire. An arsonist, for instance, will require a fast escape route (i.e. the presence of a road), logging companies will operate in areas of high timber value, and so forth.

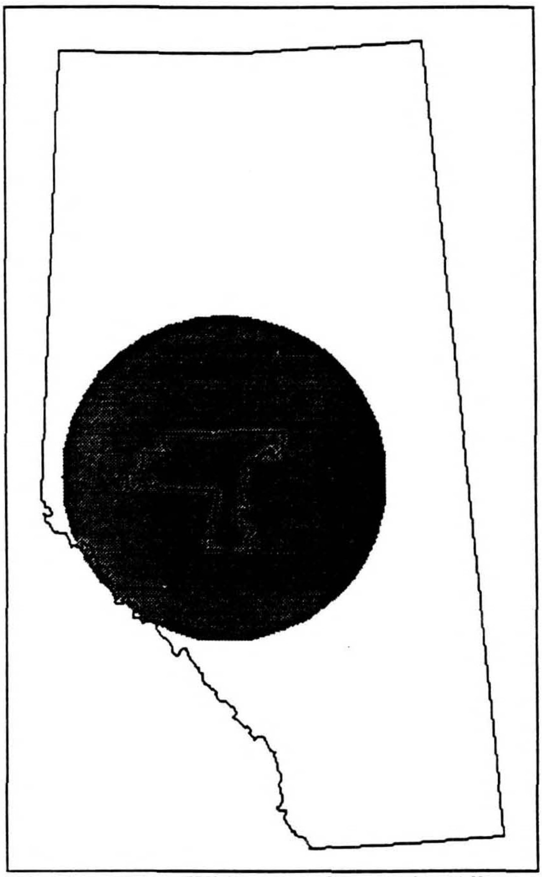

Figure 1. Whitecourt Forest in Alberta, Canada

Site attributes then, can be used to determine the geographic distribution of human risk in a forest. Site attributes and their geographic variability can be best managed within a Geographic Information System.

In a previous study (Vega-Garcia et al. 1993), ARC/INFO was used to evaluate 17 geographic variables in their relationship to human-caused fire starts and found 10 to be significant. The 7 most significant variables of the aforementioned study were selected as the explanatory variables in our present work with the objective of defining and mapping arrangement of human risk levels in Whitecourt Forest, Alberta, Canada (figure1).

METHODS

The variables related to locations of fire starts in the Whitecourt Forest, in order of priority are:

Distance to the closest road,
Land ownership (classified as forest management area, forest quota area, private land and other),
Distance to closest town,
Distance to closest campground,
Topographic elevation,
Fuels (classified as in the Fire Behaviour Prediction System (Forestry Canada 1992)), and
Forest commercial value (classified as lumber, roundwood, low uncommercial, high uncommercial).

The geographic information required for the risk analysis had to include the following ARC/INFO coverages: Roads (arcs), towns (points), campsites (points), elevation (grid), and forest (polygons). Grids for fuels, land ownership, and forest commerciality were derived from de forest coverage through a gridding process in ARC/INFO's GRID (ESRI Inc 1991). Grids for distance to road, town, and campsites were calculated by ARC/INFO's euclidean distance function in GRID.

A grid for the fire locations in the period 1986-1990 (in agreement with the dating of the geographic data) was developed from the fire history database of the Alberta Forest Service, Forest Protection Branch, in Edmonton. Since the fire locations are recorded using the Alberta Township System, to the level of a quarter section (0.5 mile by 0.5 mile), the minimum cell size possible is 800 m. This coverage then, limited all others to that same cell size.

By overlaying the fire grid over the others, data values were obtained for the fire cells with respect to distances to road, town, campsite, elevation, fuels, land ownwership, and forest commercial value.

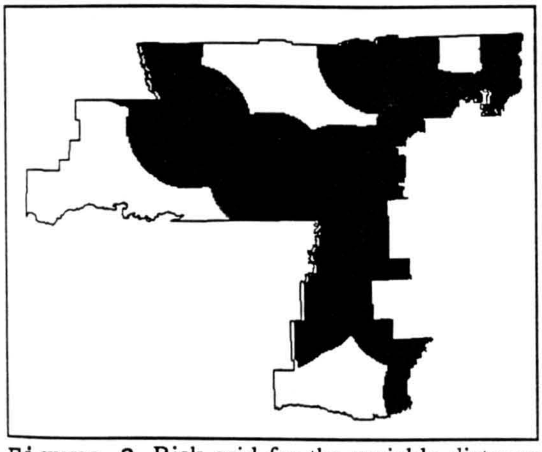

Figure 2. Risk grid for the variable distance to closest town

Frequency distributions for each variable among the fire cells were analyzed. For each distance variable and the elevation variable, there is a value such that 90 % of all fires fall below it.

This threshold value was used to define risk. For instance, we found that 90 % of the human-caused fires started within 4.8 km from a road; areas within 4.8 km from a road were declared at risk due to their situation with respect to the risk factor roads. A grid was then developed reclassifying these risk areas to 1, and the rest to 0. The same process was followed for distance to closest town (figure 2), distance to closest campsite and elevation variables. The threshold values were respectively, 35 km, 30 km, and 1,000 m (rounded).

The frequency distributions for the categorical variables fuels, land ownership, and forest commerciality were analyzed differently. The categories represented in the fire cells with percentages higher than the corresponding ones in the forest were declared categories of risk. For instance, fuels in the forest were distributed as follows: 61.8 % conifers, 34.9 % deciduous, 0.6 % open fuels, and 0.8 % slash. Fuels in the fire cells, though, were: 47.9 % conifers, 42.5 % deciduous, 2.7 % open fuels (grass), and 1.6 % slash. Deciduous vegetation, grass, and slash areas were declared as risk factors, and an ARC/INFO coverage (grid) was developed reclassifying these areas as 1, and the rest (conifers, water, nofuel) to 0. Risk categories associated to land ownership and commerciality were Private land and Highly uncommercial, respectively.

The seven partial risk grids were then summed in GRID to obtain a composite grid, a Map of Risk for the Forest.

RESULTS

The values of this composite grid vary from 0 to 7. Areas of value 0 indicate that no risk factor, as defined above, is present. In this areas, humans pose very little risk of fire occurrence. Areas of value 7 have all considered risk factors present, and most fire occurrences are expected to start here.

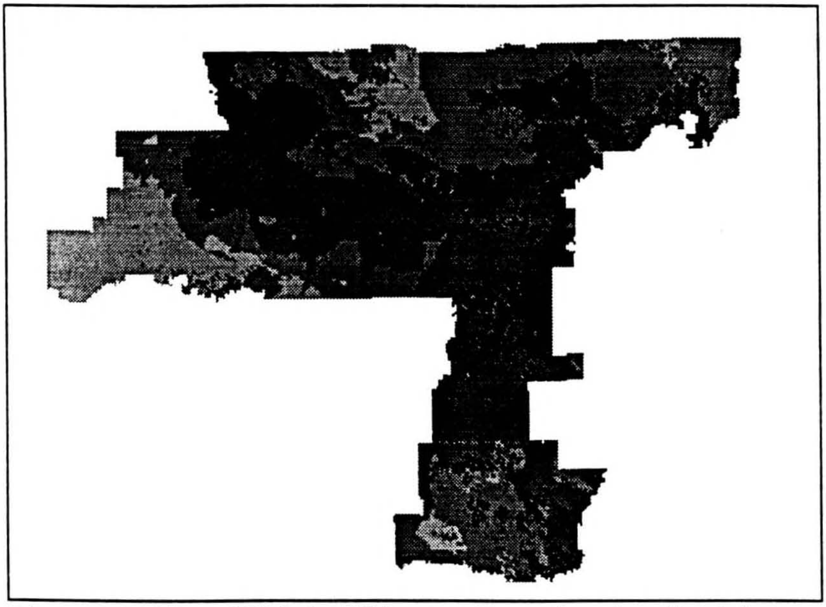

Figure 3. Map of Risk for Whitecourt Forest, based on 7 risk factors

For displaying purposes and easier interpretation, this grid has been reclassified according to the following table:

0-1 low risk,
2-3 moderate risk,
4-5 high risk,
6-7 very high risk,

and it is displayed in figure 3. Paler shades of gray indicate lower risk, black depictes very high risk areas in the Forest.

A grid developed with fire data from 1991-1992 was overlayed on this Map of Risk to test the validity of the geographic arrangement of risk levels found.

The number of fires in the very-low-risk zone was 1 (a hunting related fire) or 0.004 fires per 1,000 ha, in the low-risk zone was 13 or 0.022 fires per 1,000 ha, in the high-risk zone was 40 or 0.045 fires per 1,000 ha, and in the very-high-risk zone was 10 or 0.055 fires per 1,000 ha.

DISCUSSION

The Map of Risk seems to properly describe the arrangement of risk levels due to people in Whitecourt Forest according to the test. The Map of Risk developed also agrees with the actual perception of geographic distribution of human risk by the fire personnel in the Forest (Steiestol, pers. comm.), and consequently, prevention efforts are currently being applied to much of the area classified as of very-high-risk.

Phillips and Nickey (1978) stated that similar number of fire occurrences should be expected in areas of the same environmental fire-related characteristics, unless a difference was introduced by the prevention efforts.

Since prevention efforts are designed according to the locations of fires in the past five years, they can leave out areas of risk were fires have not yet occurred. Fire prevention programs could benefit from risk maps to identify zones where advertising and poster campaigns can be more effective, or areas where personal contact with the target public should be increased, or as an aid in routing of patrols that are currently done randomly in recreation areas.

In combination with more complete information about hazard levels (fuel related) in the Forest, these maps can aid in designing efficient strategies for fuel modification where required. Several examples of spatial strategies for prescribed burning in San Bernardino National Forest, California, using ARC/INFO, are given in Chou (1992).

There are other possible applications for a risk map in fire management. Incorporation of risk areas to the daily planning for aerial patrols should improve its effectiveness since one of the major difficulties these resources face in operation is the uncertainty associated to the route planning process. Usually, patrol routes and patrol frequencies are established using predefined guidelines depending on the daily weather parameters and visibility (Kourtz 1987).

A typical application of GIS to fire management is the determination of visible areas from fixed lookout towers. Mapping of areas of high risk that are non-visible from lookout towers allow managers to allocate other detection resources to them and make sure they are covered. Figure 4 shows the locations of those non-visible high-risk and very-high-risk areas in Whitecourt Forest. They have been calculated simply by combining within GRID visibility and risk grids. Also, high-risk areas can be taken in account when positioning new detection resources and maximize their efficiency.

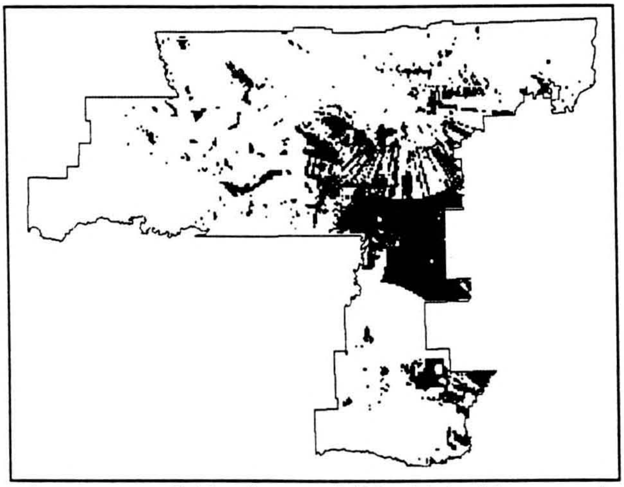

Figure 4. Grid of non-visible high-risk areas in Whitecourt Forest

Some of the most important values at risk in a forest can be expected to be close to human-caused fires starts: the humans themselves. It is important that towns, campgrounds, airfields, in general structures, are properly identified. This feature, and other values at risk such as timber, can be easily overlayed on a risk map (figure 5) and measures taken towards their protection through prevention activities and adequate prepositioning of supression resources.

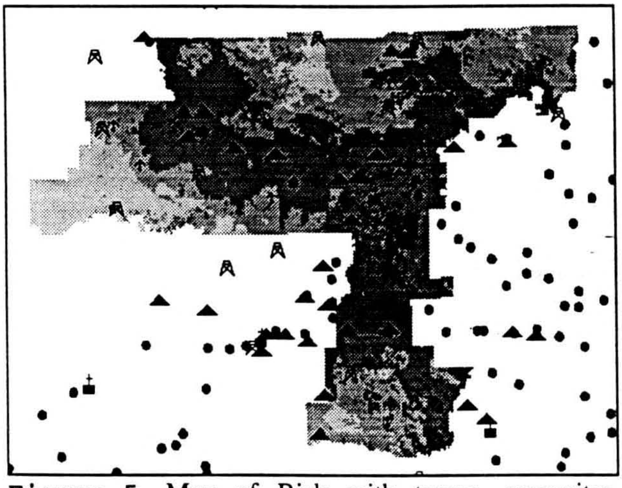

Figure 5. Map of Risk with towns, campsites, lookout towers, and initial attack bases overlayed

The usefulness of a human risk map is limited by the rapidly changing conditions in the fire environment, in particular fuels and weather. This problem can be partially solved by computing seasonal maps. These maps can account for well kown variations in combustibility of certain risk fuels along the fire season. The map in figure 3 is applicable when all grass, deciduous and slash areas are prone to burn, namely in Spring and Fall . During the Summer, after green-up has taken place, a map including only grass and slash areas may facilitate concentration of efforts and describe better the risk of fire occurrences.

CONCLUSIONS

Geographic variables such as distance to roads, towns, and campsites, topographic elevation, land ownership, forest commerciality, and fuels can be used to adequately describe risk associated to human activities in the Whitecourt Forest.

Mapping of risk associated to human sources of ignition can be of help to fire managers in making decisions about prevention, detection, and suppression actions.

This task is possible thanks to the capabilities of GIS systems in handling great amounts of geographic information related to fire occurrences.

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