MODELING LIGHTNING AS AN IGNITION SOURCE OF RANGELAND WILDFIRE IN SOUTHEASTERN IDAHO

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ABSTRACT
Cloud-to-ground lightning strike events are a common source of wildfire ignition. In Southeast Idaho, most lightning-ignited wildfires occur during the summer and early fall. During this time, large areas of hot, high pressures zones occur within the basin and range topography of the Intermountain west. Precipitation inputs are minimal as weather patterns originate from monsoonal flows from the south (Fox 2000). Thunderstorm occurrences increase with atmospheric instability, which is influenced by topography, humidity, and temperature. Effects of topography on lightning strikes have not been previously analyzed using a geographic information system. Our objective was to model lightning strike events across Southeast Idaho using lightning strike data collected from mid-June to mid-September 1998-2000 (n = 42,666). We further analyzed coincidence of precipitation during storm events to better understand wildfire ignition potential. Our results show lightning strike events are substantially more frequent in areas in close proximity to mountains and that wildfire risk in mountainous areas is approximately twice predicted for the Snake River Plain.

Keywords: Lightning, wildfires, GIS.

INTRODUCTION

Wildfires are an increasing problem in Idaho because fuel stockpiles have developed during a century of fire suppression and because the prevalence of cheat grass (*Bromus tectorum*) has made the fuels on Idaho rangelands much more flammable. A particularly destructive fire season involving a number of extremely large wildfires occurred in the Intermountain West during the year 2000. Due to accumulated fuel loads many of these fires burned more intensely and severely than witnessed before. Consequently, soils in some of the more severely burned areas were sterilized and important nutrients volatized.

Southeastern Idaho's climate is fairly xeric and brittle (Savory 1999). Rangelands in this area will require many years to recover from wildfire events like those experienced in 2000. To further compound this problem, non-native species like cheatgrass will likely invade these sites and subsequently alter the future fire regime.

Lightning is a natural wildfire ignition source. In many areas of the intermountain west, the potential for lightning to ignite a fire is enhanced during "dry" thunderstorm events (i.e., a storm event accompanied by little (<0.25cm) or no rainfall). Characteristics of individual cloud-ground lightning strikes also influence ignition potential.

We examined the spatial distribution, polarity and multiplicity of lightning strike events, coincident precipitation, fuel load and continuity of fuel to develop a wildfire-associated-lightning model. This study was based upon data describing field conditions and lightning strike events that occurred between June 15 and September 15, 1998-2002.

METHODS

Our study area (18,800km^2) was contained within a single Landsat 7 ETM+ scene (path 39 row 30) in southeastern Idaho. All lightning strikes included in this study were located between 43^{0}36’00” and 42^{0}48’00” N latitude and –113^{0}35’00” and -112^{0}37’59” W longitude. This area is considered sagebrush-steppe semiarid-desert and has a history of livestock grazing and wildfire occurrence.

We acquired cloud-to-ground lightning strike events (*n*=42,666) from Global Atmospherics (2000). Visual observation of the spatial distribution of lightning strikes overlaid upon a digital terrain hillshade model indicated a strong relationship between frequency of lightning strike events and proximity to mountains.

For purposes of this study, mountains were defined as having slope ≥5%, elevation ≥500m above minimum relative elevation for the region and a minimum mapping unit of 25 ha. Elevation in the Rocky Mountain (RM) region ranged from 1386-3231m while elevation in the adjacent Snake River Plain (SRP) region ranged from 1258-2300m. The relationship between frequency of lightning strike and proximity to mountains was evaluated using use-availability and regression analyses.

We acquire precipitation data from AgriMet (2002). Six weather stations were selected to represent RM and SRP regions. Individual storm events were identified by date and time. The extent of each storm event was determined by the spatial extent (minimum and maximum X, Y coordinates) of lightning strikes. The weather station within the extent of the storm event or closest to each storm event was then examined for coincident precipitation. The precipitation recorded for the selected station was then assigned to the storm event. This process was repeated for all storm events (n=163).

Statistical analysis was performed to determine the relationship between precipitation and RM versus SRP storm events using regression analyses. Polarity of charge and multiplicity of strikes was examined in the same fashion.

Another associated wildfire risk component is fuel continuity. Horizontal fuel continuity was estimated using fuel load measurements (Anderson 1982) and vegetation cover characteristics (n=370). Maximum-likelihood supervised classification was used to produce a horizontal fuel continuity model for the region. Validation of this model was accomplished using boot-strap methods.

Results of lightning strike pattern, coincident precipitation, and continuity of fuel analyses were ranked to describe relative risk and combined into a final wildfire-associated-lightning model.

RESULTS AND DISCUSSION

During the fire season (1998-2000) 42,801 lightning strikes were recorded. Nearly 8% were positive strikes (n=3,372). Typically, 10% (DeCoursey et al 1983) to 20% (Brookhouse 1999) of all lightning strikes are positively charged. Wildfire ignition risk due to lightning is primarily a function of long continuing current. Long continuing current occurs with 80% of all positive strikes and 10% of negative strikes. The proportion of positively charged lightning strikes was equal in the RM and SRP regions.

Lightning strikes did not occur randomly within the study area. Based upon use-availability analysis (i.e., Chi-square and Bonferroni-Z) the number of lightning strikes in the RM region was twice its proportion of land area. In contrast, the number of lightning strikes in the SRP was half of its proportion of land area. In foothill regions (that area within 10km of a mountain) the frequency of lightning strikes was readily predicted using proximity to mountains ($y = -759.24\mathrm{Ln}(x) + 1939$, $R^2 = 0.985$, where y = frequency of lightning strikes and x = proximity to mountain in km). A relative risk model was then produced for lightning strike events where mountain areas were assigned a value of 2.0, foothills were given a value of 1.0, and the SRP region was given a value of 0.5. We realize however, that actual risk could be effectively reduced if heavy precipitation occurred during storm events.

Average rainfall in the study area during the entire fire season (1-June through 15-September) was only 3.6cm (RM) and 4.6cm (SRP) for 1998-2000. Precipitation --albeit very little-- in both the RM and SRP regions occurred concurrently nearly 70% of the time. Twenty-three percent of storm events in the RM region had coincident precipitation (≥0.25cm) while 36% of storm events in the SRP region had coincident precipitation. Due to the uniform and minimal amount of rainfall associated with storm events in both the RM and SRP regions, we conclude that coincident precipitation had no measurable effect upon our study. However, higher precipitation events would effect wildfire risk.

Results of the fuel continuity model predict clusters of highly continuous fuel in the RM region as well as portions of the SRP region. Pixels were classified with values ranging from 0.0 (low fuel continuity (e.g., isolated pockets of vegetation within lava flows)) to 5.0 (high fuel continuity (e.g., areas with high percent cover of grass and shrubs). Overall accuracy (67%) of this model was determined using boot-strapping techniques.

The lightning strike events relative risk model and fuel continuity model were multiplied together to produce a final wildfire-associated-lightning model (fig. 1). Based upon these results, wildfire risk in the RM region is approximately twice that found in the SRP rangelands.

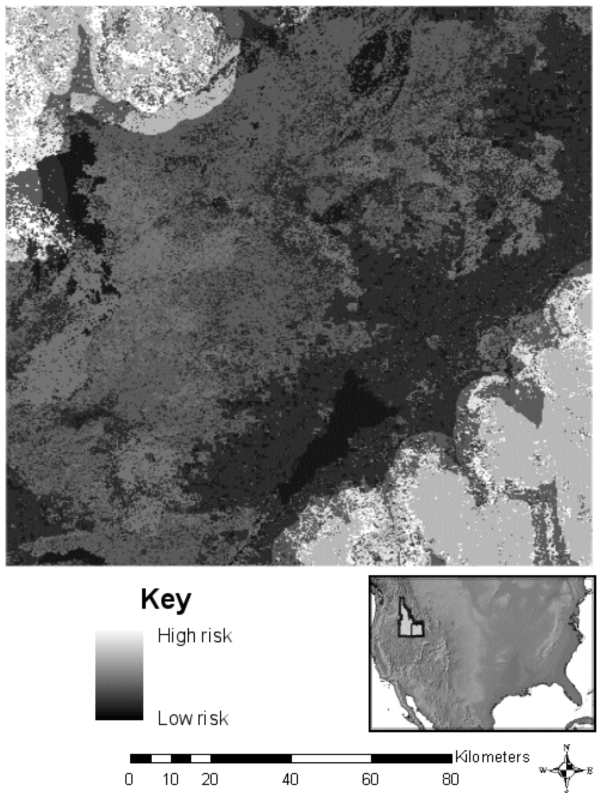

Figure 1. Final wildfire-associated-lighting risk model for the study area.

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