Spatial Assessment and Hazard Modeling of Tropical Forest Fires

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ABSTRACT

This research study offers a quantitative understanding of the environmental factors related to fire occurrence and its potential distribution. The Huai Kha Khaeng Wildlife Sanctuary, located in the northwestern region of Thailand, serves as an example to analyze and expand the knowledge base of forest fire ecology in tropical environments. Specific objectives focus on establishing the relationship between physiognomic variables that are related to forest fuel loading among different forest types. In addition, this study aims at modeling and quantifying the relative importance of the biophysical variables associated with the occurrence of tropical forest fires.

The methodological framework links Geographic Information Systems (GIS) with the potential of statistical analysis. Thematic layers of several biophysical variables are combined in GIS, along with field measurements of fuel loading and stand physiognomy. Under the statistical analysis, the variability and interactions of spatial attributes related to fires are synthesized using the Decision Tree modeling. GIS is further employed to display the modeling results.

Rainfall pattern, geological material, aspect and vegetation index variables significantly influence the ability of the Decision Tree model to predict the likely occurrence of fire. They explain most of the processes underlying a hierarchical set of rules that help to distinguish the varying levels of fire hazards. The vegetation index in particular was found to be a strong potential indicator of fire incidents and an underlying driving factor behind fuel moisture dynamics.

At a certain vegetation index, two types of forest were distinguished as having wet and dry fuel conditions. The difference in the amount of fuel load between the physiognomically distinct evergreen and deciduous forests is proven to be insignificant, except in the variation of moisture content. Factors contributing to the varying levels of fuel moisture in evergreen forests are controlled by the micro-climate created by its intact crown cover. However, there is no distinct relationship concerning the stand structure of deciduous forest with regard to the dryness of fuel on its floor. The dominance of weather over the fuel variables suggests that forest fire situations in an open and dry stand of deciduous forest is driven by extreme weather conditions.

A GIS-generated map of the sanctuary illustrates the spatial variation in fire hazard probabilities as predicted by the Decision Tree model. The prediction accuracy of fire hazard zones based on bio-physical factors is further enhanced by incorporating the proportion of neighbouring areas with high potential for ignition. The potential combustibility and danger rating are determined for the predicted hazard zones. In addition, the spatial association of the neighbouring human settlements is analyzed.

This research expands the value of GIS from the usual selective retrieval and investigation of spatial patterns into the evaluation of the complex hierarchical combinations of spatial attributes. The combined effect of GIS and statistical modeling eliminates the problems of handling a mixture of environmental data and identifying both variables and attributes interactions. Likewise, the need to design site-specific fire management strategies, as guided by particular combinations of environmental attributes, takes into account the applicability of the data-driven Decision Tree modeling.

Key words: fire hazard modeling, fire management, GIS, Decision Tree analysis, Thailand.

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Content

Appendices

List of Tables

List of Figures

Glossary of Terms

DEM (Digital Elevation Model) – gridded representation of elevation.

Dry fuel – refers to the dead combustible materials available in the forest floor (e.g., grass, leaves, twigs).

Fire Intensity – energy output rate per unit length of fire front and directly related to flame size (Alexander, 1982).

Fire Frequency –the number of times fires have occurred at one location (Woods, 1995).

Hazard - the probability of occurrence, within a specific period of time in a given area, of a potentially damaging phenomenon (e.g., forest fire).

Knowledge-based GIS Model – equations/relationships are developed outside the GIS and applied to datasets in the geographic database (Harrison and Dunn, 1993).

Landsat TM – an electromechanical multi-spectral scanner carried on the Landsat 4 and 5 satellites which records seven channels of electromagnetic radiation from 450 nanometer up to 2.35 micrometer for an optical pixel size of 30 meters and 10.4 –12.6 micrometer for an optical size of 120 meters.

Risk - the expected number of lives lost, person injured, damage to property and disruption of economic activity due to a particularly phenomenon and consequently the product of specific risk and element at risk. (*Elements at Risk* - the population, buildings and civil engineering works, economic activities, public services, utilities and infrastructure at risk in a given area, and, *Specific Risk* - the expected degree of loss due to a particular phenomenon and as a function of both natural hazard and vulnerability) (Crozier, 1988).

Vulnerability - the degree of loss to a given element at risk or set of such elements from the occurrence of a phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss) (Crozier, 1988).

Wildfire – a fire, regardless of origin that gets out of control (Sarre and Goldammer, 1998). It burns outside of pre-determined conditions and moves into land not included in a fire management zone.