

Dynamic Fire Modeling using GRASS 4.0

Developed by NPS and University of Arizona

By George Ball, Michael R. Kunzmann, & Peter S. Bennett

The use of Geographical Information Systems (GIS) for static modeling has been a major emphasis for implementation of GIS within the National Park Service. Linking dynamic models directly to existing NPS GIS data bases would provide the manager with the capability of examining "what if" scenarios that are directly related to the landscape area in question. The Advanced Resources Technology group at the University of Arizona in cooperation with the NPS Cooperative Park Studies Unit (CPSU/UA) have been examining the feasibility of incorporating these dynamic GIS programming linkages to existing fire behavior and effects models. A primary goal has been to provide a

set of user-friendly GRASS 4.0 programming tools that can extend the range of park management analysis opportunities.

GRASS 4.0 Fire Modules

The Advanced Resource Technology Program at the University of Arizona has been developing, modifying, and adapting modeling extensions to the GRASS 4.0 programming environment. The program modules or processing extensions are collectively known as PROMAP and were developed by **Ball (1990)** to examine complex dynamic modeling as an extension of Geographical Information Systems and related tech-

nologies (e.g. resource management computer information and retrieval systems).

Spatial dynamic modeling requires algorithms and data storage that are consistent with iterative processing. The PROMAP programming operators use integer or real numbers depending on the type of operation and function being performed. Storage of integer information is in the standard GRASS format while the real number information is stored as a simple binary file. The modules that have been developed are shown in **Table 1**. The modules are compiled as contributed programs in the same manner as other GRASS functions.

In addition to the basic operations, two specialized modules have been developed for use in fire spread modeling. As an example of spatial dynamic modeling in GIS we will examine the fire simulation model known as FIREMAP (Vasconcelos, et. al., 1990; Ball and Guertin, 1990).

FIREMAP is based on the fire equations of **Rothermal (1972)** and the BEHAVE program of **Andrews (1986)**. In producing a fire growth simulation the GIS is used to develop the base maps for fuels, slope, aspect, moisture and other fire parameters. Once the base layers are constructed, the PROMAP programming modules called "Sbehave" and "Sfire" are used to produce the simulation. The first module calculates the fire characteristics for all the cells in the data base. The Sbehave module produces two files as standard output. These files represent the rate of spread, the mid-flame wind speed, and the direction of maximum spread. The second and third parameters as combined into a single file. The files, "hros" and "windms" respectively, are used as the input to the fire modules.

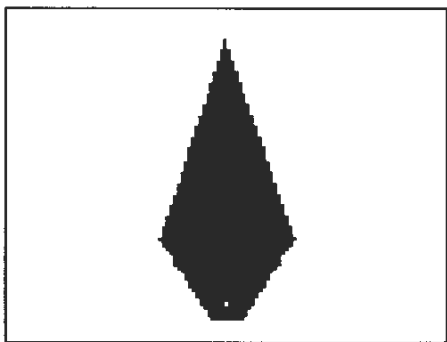


Figure 1

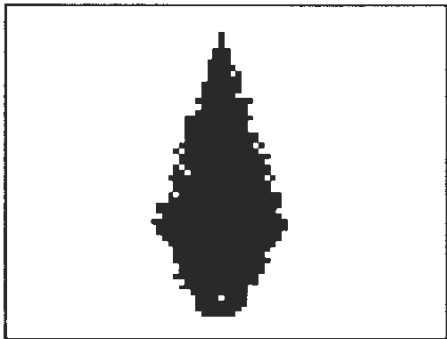


Figure 2

The fire module defaults to a 3x3 window to determine what cells have the potential to be ignited. The algorithm takes into account vector information (aspects as whether the fire will be entering as a head fire or as a flanking or backing fire). As a consequence, the modeled fire spread is a result of fire characteristics as well as terrain and fuel heterogeneity. **Figure 1** illustrates the results of fire growth over uniform terrain and with uniform fuels for a wind driven fire. **Figure 2** illustrates the results with the use of uniformly random fuel moistures.

Testing of LD₅₀ GIS Model

As part of the field evaluation and testing program for the FIREMAP simulation we have been working with a Grand Canyon data base. The availability of fire data and statistics from Point Sublime, Grand Canyon, as modeled by **Kunzmann, Bennett, and Ball (1990)** for a Species Lethal Diameter Class Fire Mortality Model (at 50% class mortality; **Figure 3**), as abbreviated LD₅₀, has provided a starting point to estimate ecological fire effects for 4 species of coniferous trees.

The LD₅₀ data provides a quantitative data for fire intensity vs. species diameter for the fuel models on the North Rim of Grand Canyon National Park. Running simulations based on average meteorologic data and information collected by Kunzmann and Bennett, we have begun to examine how well the model relates to the measured conditions. Testing is still in the preliminary stages and we have been examining other potential sites for subsequent testing.

Discussion

In general, higher resolution DEM data, georeferenced site data and maps are requirements for spatial dynamic modeling. For example, the use of 200 foot contours does not provide sufficient resolution for most fire spread models. A Grand Canyon data set using available 200 foot contour data makes the North and South Rims appear very flat thereby reducing the effect of landscape factors which can play a major role in fire spread. Furthermore, the specific type of DEM algorithm utilized can significantly effect the results obtained even in the simplest viewshed analyses (**Christofferson, Potter, Guertin, & Kunzmann, 1991**). Greater emphasis must be placed on obtaining

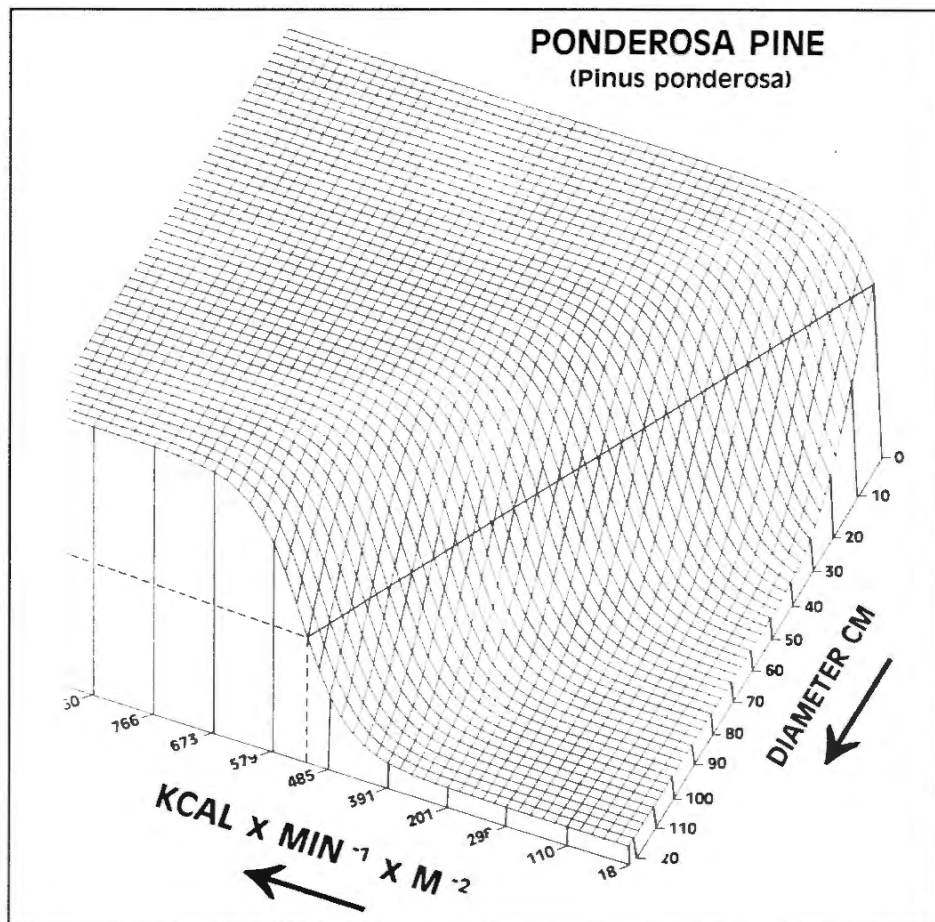


Figure 3. LD₅₀ Mortality Probability

better georeferenced information for site data and historical fire patterns. Better georeferenced site and DEM data are required to test modeling assumptions and computer algorithms. Quantitative evaluation and validation of site information are prerequisites to assessing the precision and accuracy of GIS computer models.

Directly related to fire, there are problems that need to be addressed in some of the current analytical programs being used such as the BEHAVE system. BEHAVE was not intended for use in computer simulations and therefore algorithms need to be adjusted to make them more useful in a GIS environment. At the University of Arizona, modeling adjustments are being tested and enhanced wind profile and fuel models are being incorporated into the GIS GRASS environment.

Other resource applications of spatial dynamic modeling include: watershed problems such as erosion, sediment transport, and water quality. The analysis of traffic patterns, usage levels and other temporal problems are also possibilities for this type of modeling. For more information concerning PROMAP contact George Ball at the School of Renewable Natural Resources at the University of Arizona or Mike Kunzmann at the CPSU/UA.

Ball is a Research Specialist on the UIAZ faculty; Kunzmann is an Ecologist and Bennett a Research Scientist at the UIAZ Cooperative Park Studies Unit.

References

- Andrews, Patricia L. (1986). BEHAVE: Fire behavior prediction and fuel modeling system - BURN subsystem, part 1. USDA Forest Service, General Technical Report, INT-194, Intermountain Forest and Range Experiment Station.

Ball, G.L. (1990). "A spatial dynamic approach to ecological modeling: simulating fire spread." Ph.D. Dissertation. School of Renewable Natural Resources. The University of Arizona. Tucson, Arizona. April 1990.

Ball, G.L. and D.P. Guertin (1990). "Fire simulation in natural ecosystems." In Proceedings Resource Technology 90: Second International Symposium on Advanced Technology in Natural Resources Management, November 12-15, p. 108-117, 1990.

Christopherson, G.L., D.P. Guertin, M.R. Kunzmann, K.L. Kvamme, and T. Potter (1991). The Affect of DEM Interpolation Algorithms on Viewshed Analysis." In the Proceedings of the First Biennial Conference on Research on Colorado Plateau National Parks (In preparation).

Kunzmann, M.R., P.S. Bennett, and G.L. Ball (1990). "The use of ecological modeling in geographical information systems: the prediction of LD₅₀ species mortality from fire intensity." In Proceedings Resource Technology 90: Second International Symposium on Advanced Technology in Natural Resources Management, November 12-15, pp. 118-127, 1990.

Rothermel, R.C. (1972). A mathematical model for predicting fire spread in wildland fuels. USDA Forest Service, Research Paper INT-115, Intermountain Forest and Range Experiment Station, pp. 161.

Vasconcelos, M.J., D.P. Guertin and M.J. Zwolinski (1990). "FIREMAP: simulation of fire behavior with a geographic information system. In Effect of Fire Management of Southwestern Natural Resources (Krammes, J.S. ed.), p. 217-221. General Technical Report RM-191, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Note: The PROMAP code is listed as a SUN CATALYST product and is available free of charge to interested researchers. It is a research grade programming tool and should be used as such. The use of PROMAP is encouraged for the development of end user applications. It has been developed and runs on SUN SPARCstations and should run on all UNIX based computer platforms. There is no display capability built into this software as of this date and PROMAP documentation is preliminary.

Table 1. PROMAP - GRASS Operators

Operator	Function
Sbool	Performs boolean operations
Scode	Reclassify values on a map
Sdrain	Find drainage paths over a terrain surface
Smath	Perform mathematical calculations using maps as input
Smm	Minimize or maximize values on a series of maps
Spoint	Change values at specific locations or block areas
Sscan	Analyze the attributes of a neighborhood
Sslice	Create interval map from continuous data
Ssprd	Propagate values from a source
Sterr	Calculate slope, aspect and ridge lines from DEM
Sview	Performs viewshed analysis
Sbehave	Specialized operator for calculating fire characteristics
Sfire	Specialized operator for simulating fire growth