Design and development of a Spatial Fire Simulator for the Remsoft Spatial Planning System.

The intent of this document is to describe the direction and potential of a Spatial Fire Simulator for the Remsoft Spatial Planning System.

The information provided represents a basic overview of the key development challenges as well as the implementation in a module that may be released as an extension to the Remsoft Spatial Planning System. It is hoped that comments, questions and suggestions from the potential user-community will arise from it.

Background:

Although there are several fire growth models available to the forestry community (Farsite, Prometheus, FireNB etc.), a number of issues which make using these models poorly suited to analysts using the Remsoft Spatial Planning System.

These challenges led Remsoft to research and develop a fire spread simulator that would function properly as a completely integrated component of the Remsoft Spatial Planning System – thus taking advantage of all of the data and models already built by the user-community.

In the pages that follow, we address each of the issues outlined below and describe the solution we developed.

1) **Fuel Types.** When modelling with Woodstock we deal with forest types/species that are important for harvest scheduling and growth models. These forest types don't correspond to the fuel types that drive the fire spread models. The challenge was to develop the capability for representing these fuel types in a Woodstock model.

2) **Raster and Vector files.** The fire spread models mentioned above all require raster files for fuel type information, while the requirements for spatial data in the Remsoft System are vector coverages (i.e. shapefiles). The challenge was to translate raster based information from Remsoft's older fire spread model into vector format for use in the Remsoft Spatial Planning System (RSPS) and vice versa.

3) **Fire spread calculation**. Fire spread is a function of the codes in the Canadian Fire Behaviour Prediction System (FBP system), and the US BEHAVE System. These in turn are a function of weather and other parameters and can be difficult to calculate in most software packages. The challenge was to implement fire behaviour and spread calculation in the RSPS that could be considered valid for modeling purposes.

4) **Integration with the Remsoft Spatial Planning System (RSPS).** Finally, fire shape and other information resulting from the fire simulations in earlier Remsoft fire spread models was not designed to be incorporated the into Remsoft Spatial Planning System models, thus losing the opportunity to consider fire spread issues alongside wood supply, habitat and other analyses commonly performed using Remsoft software. The challenge was to develop a smooth, integrated flow between existing fire spread models developed by Remsoft and the RSPS.

1. Modeling Fuel types in Woodstock/Spatial Woodstock.

In the Canadian FBP System, fuel types are classed into one of 17 major types. C1, C2 etc., where C1 corresponds to Lichen Spruce while C2 corresponds to Boreal Spruce. There are also a few mixed fuel types including M1 (Boreal Mixed wood - before leaf) out that contain a number of additional properties. In the case of M1, modifiers may include the percentage of conifer in the type (a M1 fuel type with 50% conifer will burn at a different rate than an M1 type with 75% conifer).

In the US BEHAVE System (Burn Subsystem), fuel types are classified in a similar manner and given a numeric value (e.g. 1 = short grass, 4 = chaparral). These simply take into account the different tree species and conditions that exist in forests commonly found in the United States.

Solution: New class of yield tables in Woodstock

To allow these fuel types to be recognized in a Woodstock model, Remsoft has introduced a new class of yield table to allow fuel type modelling.

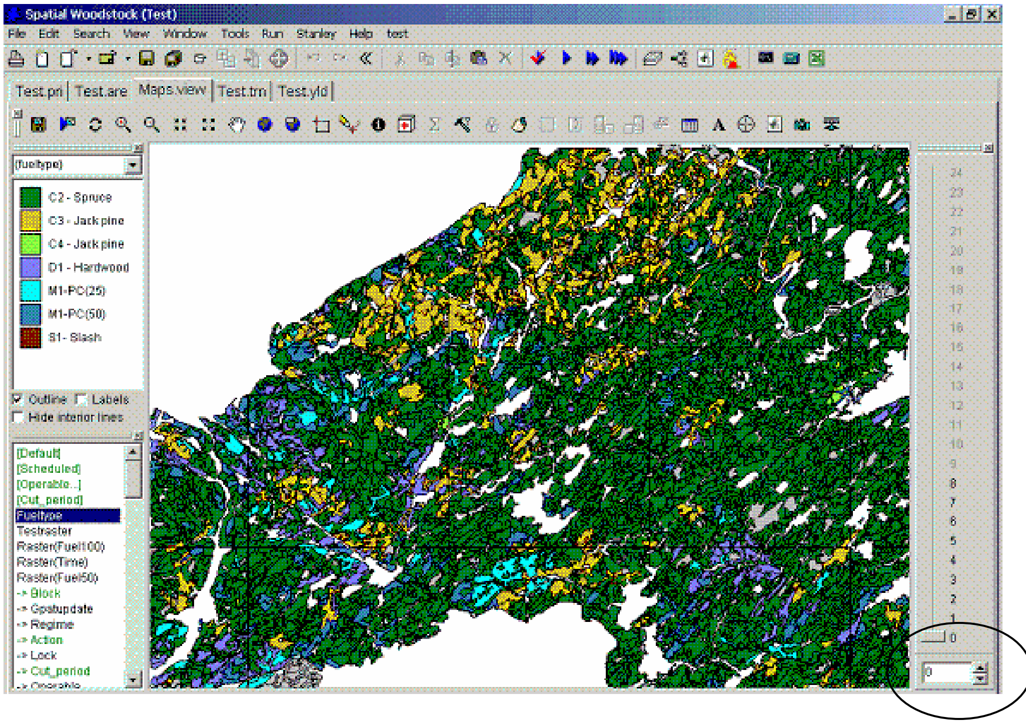
For example consider a type in our Woodstock model that we wish to model as a M1 fuel complex.

```
*Y  ?  MXWD3  ? ?
_Age    FuelType
  1      S1
  2      M1-PC(10)
  3      M1-PC(20)
  4      M1-PC(30)
  5      M1-PC(40)
  6      M1-PC(50)
  7      M1-PC(90)
```

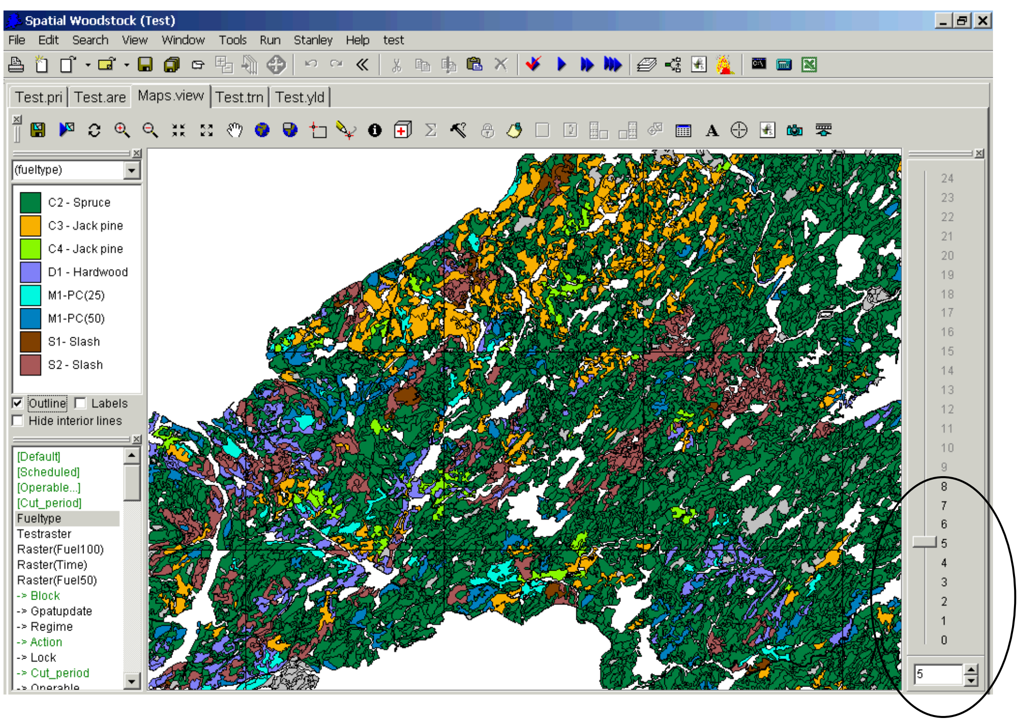
The yield table above describes the various fuel type changes as this stand ages. Initially after harvest (Age = 1) we have a Slash fuel type "S1", followed by a mixed stand dominated with hardwood "M1-PC(10)" As the stand grows the percent conifer increases until by age = 7, 90% of the fuel type is conifer "M1-PC(90)".

Results: Fuel Type Maps

These yield tables may be used in the software in the presence or absence of harvest activities. And by using the time selector it is possible create fuel type maps at various time periods into the future.



Canadian FBP System fuel types at displayed at time 0 (today).



Canadian FBP System fuel types 5 periods (25 years) into the future. Notice the presence of more slash fuel types (S1 & S2), which are located in recently harvested cut blocks.

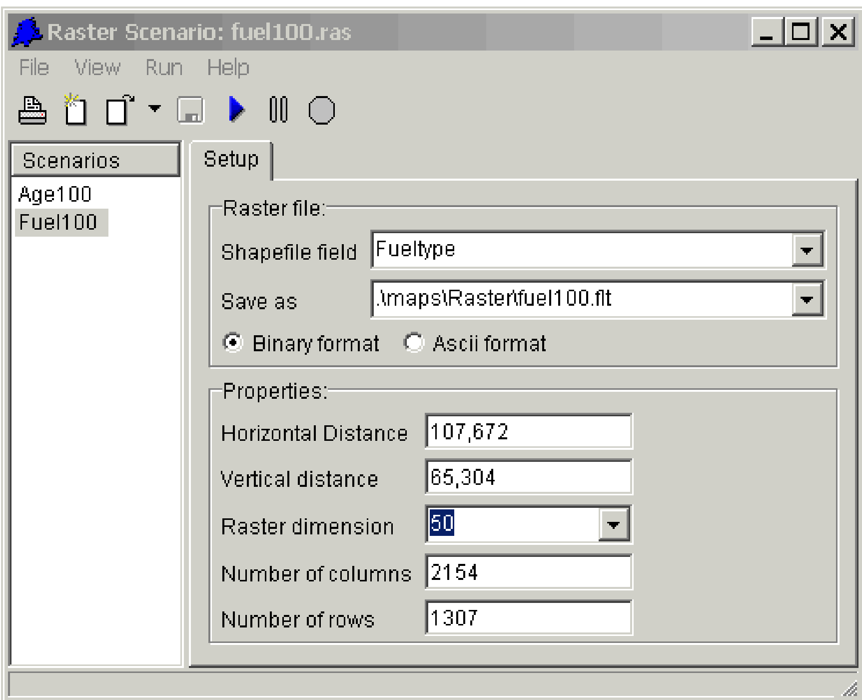
2. Building Raster files

This fire simulator like many others requires raster files to describe the fuel types under consideration. The images in the previous section illustrate the fuel types today or into the future, however this data is in the form of a vector (polygon) layer, and a raster file is required for fire spread simulation.

To simplify the creation of the files needed to run a fire simulation, a new option has been developed to automatically build ERSI arc grid raster files from a shapefile designed for the RSPS. Any field and/or virtual fields in the shapefile may be exported to a raster layer, making it simple to create raster inputs for the fire simulator.

In terms of fuel type layers, only one raster layer is required for the complete fuel type specification since our definition of fuel type - i.e. m1-pc(50) - includes all of the properties for that fuel type.

When building raster files, information can be stored in a manner similar to Stanley Scenarios making it possible to batch this process through the use of a script. The advantage is that the user can run a number of different scenarios unattended (overnight, over lunch, etc.).



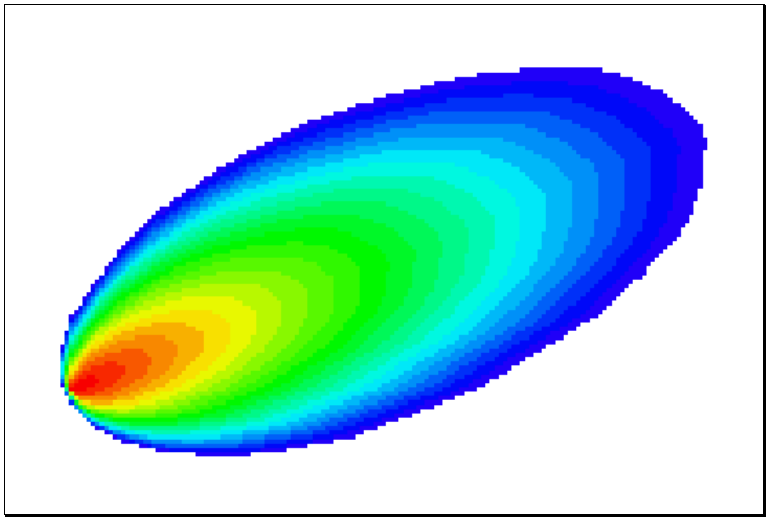
Setup form to allow creation of raster file using the virtual field "FuelType". If the time selector is active then the fueltype would represent the "projected" fuel type at the time shown.

3. Modeling Fire Spread

Fire spread

Remsoft has built a number of fire spread models over the years, based on a series of algorithms and code designed by Remsoft Vice President Ugo Feunekes (Feunekes, U. 1991. Error Analysis in Fire Simulation Models). The current model employs a cell-to-cell spread model – this differs somewhat from the Vector or wave type models used in Prometheus and Farsite.

References on the Internet indicate that this cell-to-cell approach produces fire shapes that have distorted fire fronts under homogeneous conditions, but our experience indicates that this is a result of implementation rather than the approach itself. In fact, our model produces very good elliptical fire shapes under homogenous conditions.



Elliptical fire shape produced by Remsoft's fire simulator when simulating fire spread under homogeneous conditions.

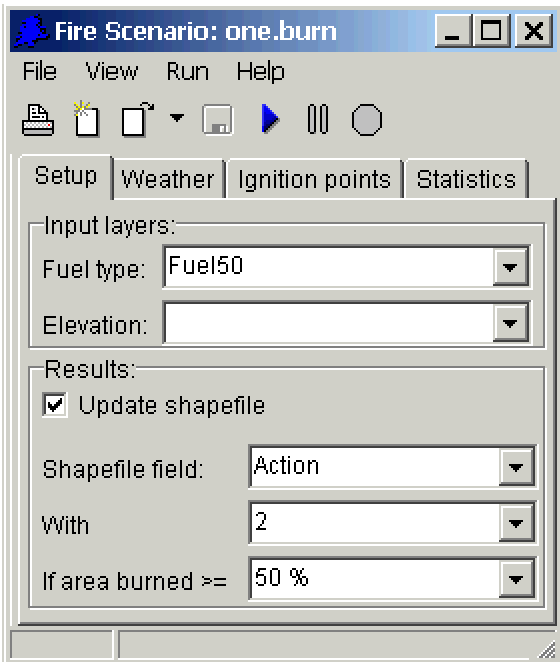
Fire behaviour calculations

Fire spread rates, intensities, and other data used in the model are based on either the Canadian FBP System or the US BEHAVE system (user's choice). The calculations employ the same code set that drives Remsoft's WeatherPro3 and Behave by Remsoft software programs. These applications are used extensively throughout North America and in New Zealand for fire danger and fire behaviour prediction calculations.

Updating vector coverages: linking back to the RSPS model

Although the fire shapes, fuel type maps and other spatial information produced are interesting to look at, the real power of the fire spread model lies in incorporating this information back into the forest cover so we can determine the impacts of these fires.

To do this we developed an update routine which examines each burned raster cell and determines the polygons to which these raster cells correspond. We then use a basic heuristic that states if more than x% of the rasters that comprise a polygon have burned, the entire polygon is considered to have burned as well.



Note: in this image we are updating the field with the value 2 which corresponds to our Woodstock action "Fire"

Processing speed

If the implementation is designed properly there are many analyses that can be envisioned, however the time required to run these simulations will be a prime consideration. If simulations run too slow it may be impossible or impractical to run long term analysis.

The following table illustrates the speed at which the current implementation is running on a 1.5Ghz P4.

Step	Detail	Time to completion
1. Build raster file	50 meter resolution - 2154 columns x 1307 rows	12 seconds
2. Burn 3 large fires	584,111 pixels / 146,027.8 hectares burned	22 seconds
3. Update shapefiles	800 polygons updated	7.7 seconds.

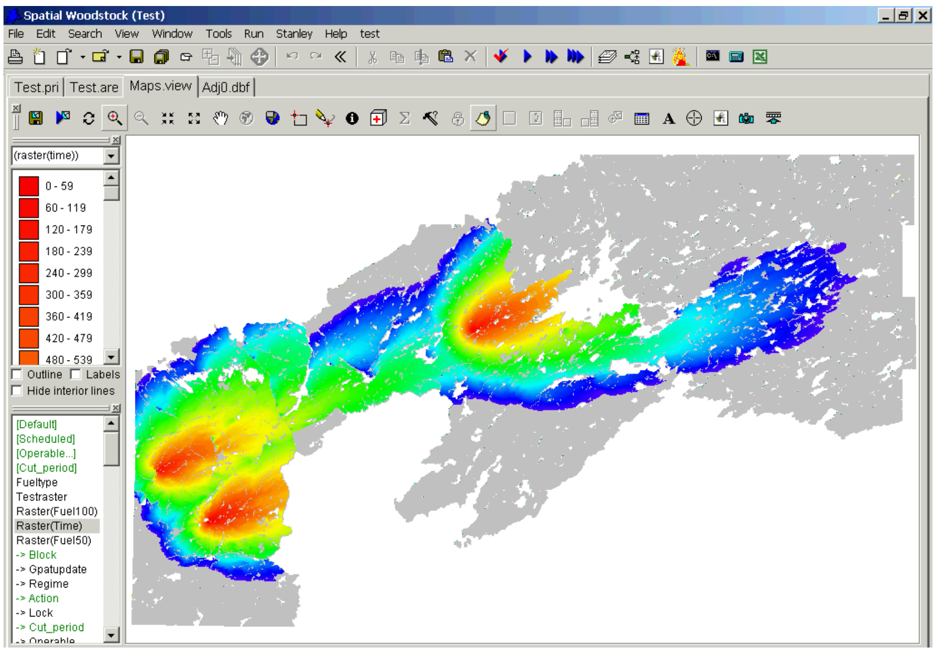
Data set 1 - 300,000 hectares 18,000 polygons

To a large extent, the time to perform step 1 is constant given the dimensions of the problem doesn't change. Steps 2 and 3 will vary with the size of the fires being modelled and the weather conditions used.

Typically, the time required to simulate fire spread will increase as the pixel dimension of the raster cells decrease (i.e. more pixels take more time). However, give the size of the above example, the simulator seems to be performing very well.

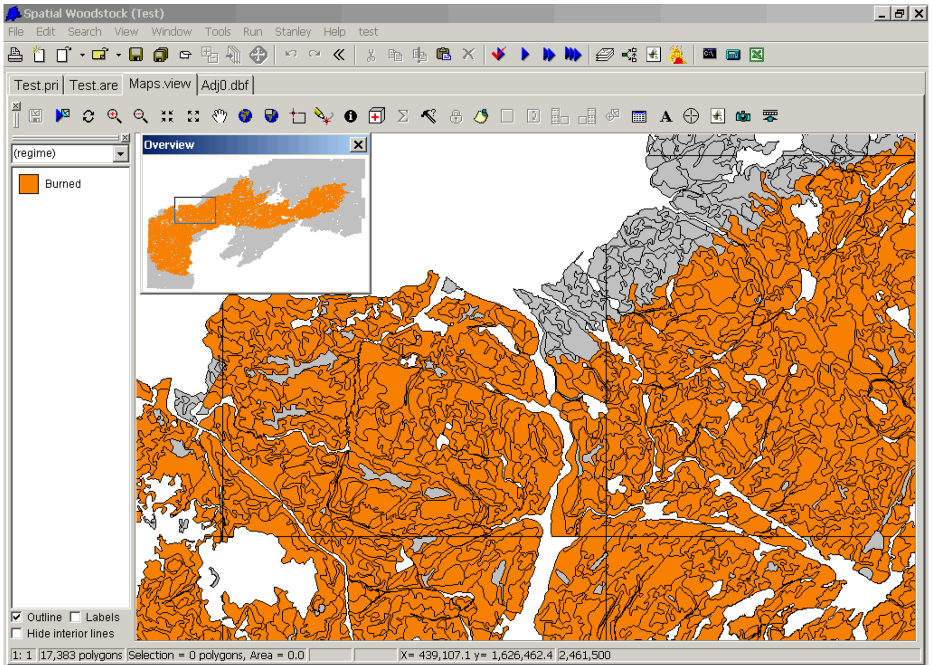
Sample Results

The following image illustrates the perimeter of a simulated fire at various time periods. The image is composed by overlaying the raster image (fire perimeter) over the shapefile polygon layer.



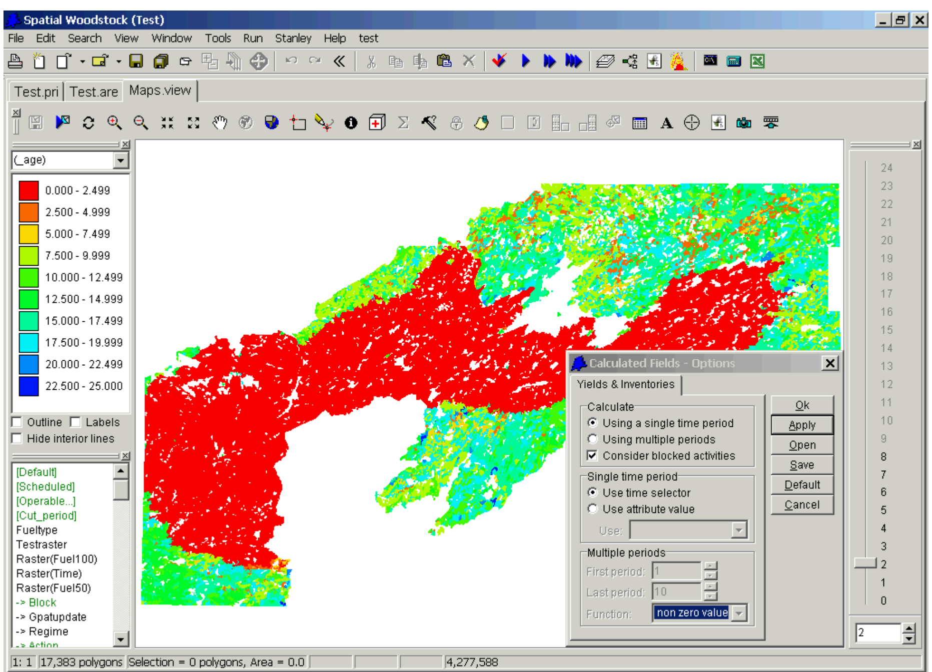
Projected fire location after burning for 100 hours from 3 ignition points. Red represents the early portion of the fire while blue the most recently burned.

In this screen, we see the results of the polygon update. The polygons colored orange were designated as burned since at least half of the associated raster cells burned in the fire simulation.



Shapefile representation of the fire burned as a raster layer. Note: the raster layer was used to determine fire shape, and determine which polygons were burned.

Finally, because we updated the field named "action" we can use the time selector to project development types and/or any other "virtual field" into the future in the presence of this large fire.



Forest age in periods 2 (10 years) assuming a large fire occurs in the first period.

Conclusion

The preceding discussion has been written to generate comments and/or suggestions. Most of the coding to date has been developed around integrating the fire spread model within the RSPS in such a way the existing users of the system.

The potential benefits of this integration are numerous, from the design of "fire smart" landscapes all the way through to the evaluation of a particular strategy.

Stay tuned for updates as we continue with this work.

Comments

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Selected Remsoft Research

Over the years Ugo Feunekes has researched and written widely on the topics of fire spread, fire weather and fire behaviour. The results of this research have been used for both consulting and products development purposes by Remsoft. A selected list of papers is presented below.

A century of fire and weather in Banff National Park. Ugo Feunekes and C. E. Van Wagner. March, 1995.

Fire games for park managers: exploring the effect of fire on landscape vegetation patterns. Methven, I. R., and U. Feunekes. 1987. Pp. 101-110 In, Landscape Ecology and Management, Proc., First Symposium of the Canadian Society of Landscape Ecology and Management, Univ. of Guelph, Guelph, Ont., Polyscience Publications, Montréal Que.

Simulation error in fire growth under heterogeneous conditions. Feunekes, U., and I.R. Methven. 1993. In Proc. International Symposium on System Analysis and Management Decisions in Forestry. Valdivia, Chile. March 9-12, 1993.

The effect of hourly weather on fire area in the FBP system. Ugo Feunekes and Ian R. Methven. Pp. 333-336 in D.C. McIver, H. Auld, and R. Whitewood Eds., Proc. 10th International Conference on Fire and Forest Meteorology, Environment Canada, Ottawa.

Simulating process interactions on landscape attributes; fire and spruce budworm in Pukaskwa National Park. Methven, I.R., and U. Feunekes. 1991. In, Proc. International Conference on Science and Management of Protected Areas. Acadia University, Wolfville, Nova Scotia. May 14-19, 1991.

Landscape disturbance modeling. Rogeau, M.P., P.M. Woodard, and U. Feunekes. 1996. Presented at the 13th Conference on Fire and Forest Meteorology, Lorne, Australia. October 27-31, 1996.

A cellular fire growth model to predict altered landscape patterns. U. Feunekes and I.R. Methvan. 1987.

Application of a PC-based fire management information system in New Brunswick. W.G. Clowater, U. Feunekes and I.R. Methvan. Presented at the 10th International Conference on Fire and Forest Meteorology. Ottawa, Ontario. April 17-21, 1989.

Decision aids for controlling landscape patterns with fire. Ugo Feunekes and I.R. Methvan. Presented at the Landscape Ecology and Management Symposium. University of Guelph. Guelph, Ontario. May 19 -22, 1987.