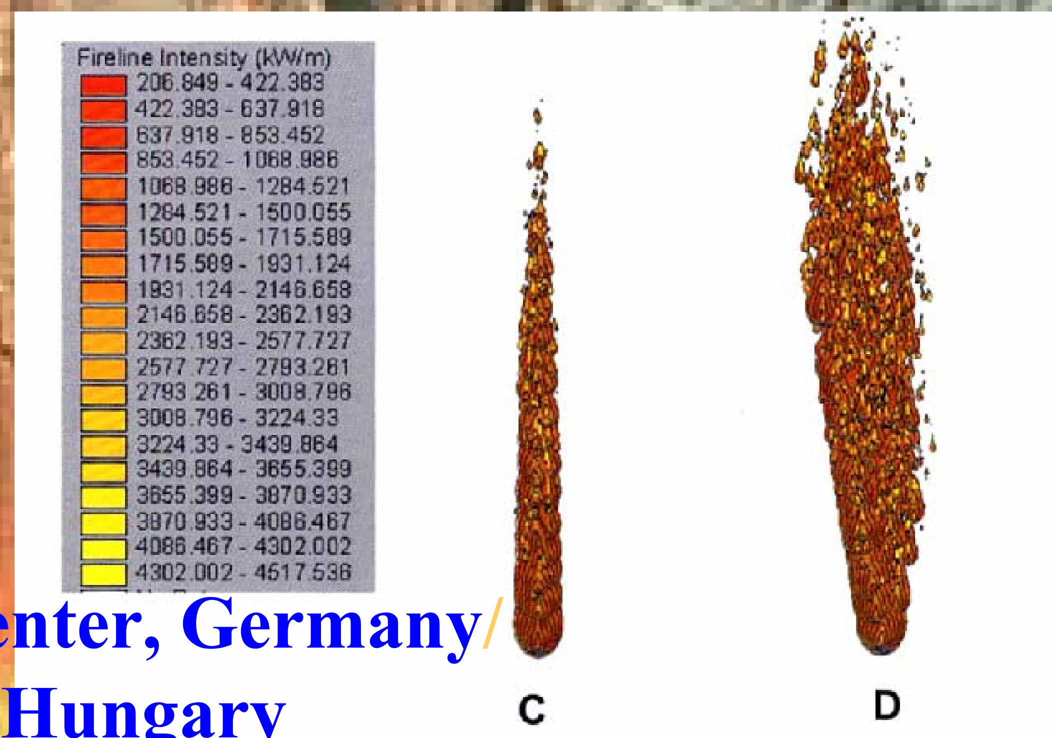
Wildland Fire Simulation by the help of Farsite



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Application area of fire behaviour modelling

- Pre-attack or fire prevention planing
- Planing of large area forest fire fighting operations
- Planing of prescriped burning operation

The minute by minute movement of a fire will probably never be predictable certainly not from weather conditions forecasted many hours before the fire! (Rothermel 1983)

Fire behaviour models

- respectively empirical (or statistical),
- semi-empirical (semi-physical or laboratory models) (BEHAVE , FARSITE,)
- physical (theoretical or analytical).

Forest fire spread models

- **Stochastic models** consisting to predict the more probable fire behaviour from average conditions and accumulating acknowledges obtained from laboratory and outdoor experimental fires,
- **Deterministic models** (Semi-empirical and physical) in which the fire behaviour is deduced from the resolution of the physical conservation laws (mass, energy, momentum…) governing the evolution of the system formed by the flame and its environment,

Modelling of the fire shape:

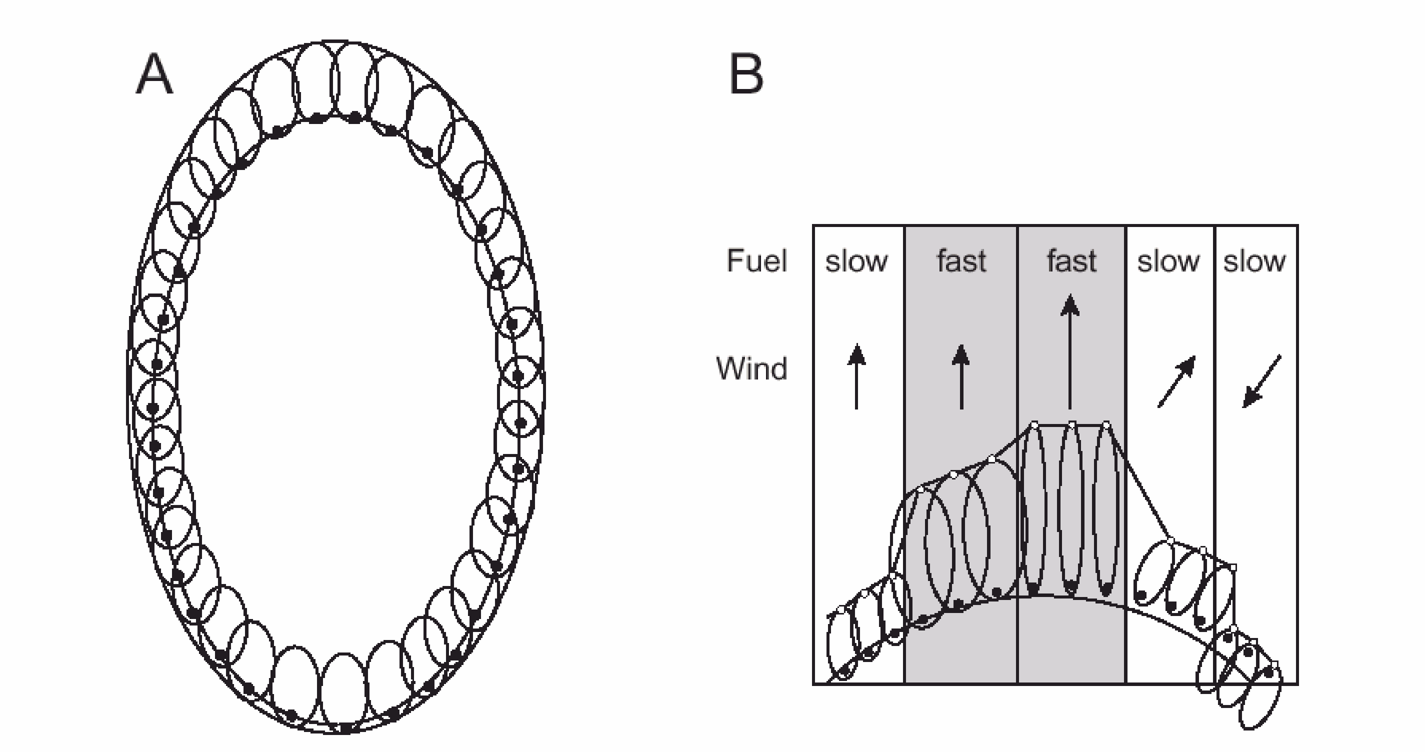
- •simple ellipse /van Wagner 1969/
- •rughly egg (Anderson 1980, Peet)
- •fan (Byram 1959)

The reliance on an assumed fire shape, in this case an ellipse, is necessary because the spread rate of only the heading portion of a fire is predicted by the present fire spread model (Rothermel 1972). Fire spread in all other directions is inferred from the forward spread rate using the mathematical properties of the ellipse.

Computerized fire models:

- *eight neighboring cells modell* (by Kourtz and O'Regan,1971) The model computed the time for fire to travel between the eight neighboring cells or nodes on a rectangular grid.
- *Other cellulars modell*
- Stochastic percolation techniques (Beer and Enting 1990; Von Niessen and Blumen 1988)
- Fractal algorithms (Clarke and others 1994) to reflect uncertainty in spread though a regular landscape matrix.

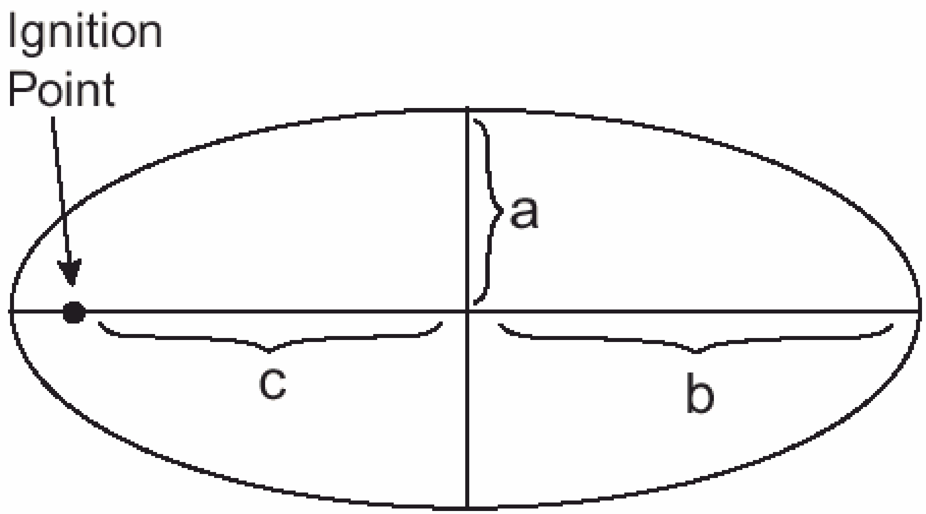
Huygens' principle



Implementation of Huygens' principle as a fire growth model

$$X_t = \frac{a^2\cos\theta(x_s\sin\theta + y_s\cos\theta) - b^2\sin\theta(x_s\cos\theta - y_s\sin\theta)}{(b^2(x_s\cos\theta + y_s\sin\theta)^2 - a^2(x_s\sin\theta - y_s\cos\theta)^2)^{1/2}} + c\sin\theta \quad [1]$$

$$Y_t = \frac{-a^2\sin\theta(x_s\sin\theta + y_s\cos\theta) - b^2\cos\theta(x_s\cos\theta - y_s\sin\theta)}{(b^2(x_s\cos\theta + y_s\sin\theta)^2 - a^2(x_s\sin\theta - y_s\cos\theta)^2)^{1/2}} + c\cos\theta \quad [2]$$



Implementation of Huygens' principle as a fire growth model

The information required at each vertex includes

(1) the orientation of the vertex on the fire front in terms of component differentials (m) xs, ys,

(2) the direction of maximum fire spread rate q (the resultant wind-slope vector, radians azimuth)

(3) the shape of an elliptical fire determined from the conditions local to that vertex in terms of dimensions a, b, *c* (m/min). From these inputs, Richards'(1990) equation computes the orthogonal spread rate differentials (m min –1) *Xt* and *Yt* for a given vertex:

Other equations:

1. Transformations for Sloping Terrain
2. Vektoring Wind and slope

Farsite

The simulator incorporates

- existing fire behavior models of surface fire spread,
- crown fire spread,
- spotting,
- point-source fire acceleration,
- and fuel moisture.

It demonstrates the linkages between existing fire behavior models and the consequences to spatial patterns of fire growth and behavior.

The surface fire model equations of the FARSITE

$$R = \frac{I_R \xi (1 + \Phi_w + \Phi_s)}{\rho_b \varepsilon Q_{ig}}$$

R =heading fire steady state spread rate (m min –1)
IR = reaction intensity (kJ min –1 m –2)
ξ =the propagating flux ratio
rb = ovendry bulk density, kg m –3
ε = effective heating number, dimensionless
Qig =heat of pre-ignition, kJ kg –1

Wind and slope coefficients are accounted for by the additive terms *Fw* and *Fs* , respectively. Fuel bed characteristics are specified according to the format of fire behavior fuel models used in BEHAVE (Albini 1976; Anderson 1982; Andrews 1986; Burgan and Rothermel 1984).

$$Ib = h\ w\ R/60$$

Fireline intensity *Ib* (Byram 1959) describes the rate of energy release per unit length of the fire front (kW m –1):

***h* represents the heat yield of the fuel (kJ kg –1 , total heat less the energy required for vaporizing moisture), *w* the weight of the fuel per unit area (kg m –2) burned in the flaming front, *R/60* is fire spread rate converted to units of (m s –1).**

$$I_b = \frac{I_R}{60}\frac{12.6R}{\sigma}$$

σ characteristic surface area to volume ratio of the fuel bed (m –1). The frontal fire characteristics (spread rate, fireline intensity, and so forth) calculated for a steady-state fire are dependent on the current environmental conditions such as fuel characteristics and moisture, windspeed and direc-tion, and topographic slope and aspect. All of these parameters must be available or computable at any point on the landscape at any time.

Crown Fire Model

The crown fire model used in *FARSITE* was developed by Van Wagner (1977, 1993) and is similar to its implementation in the Canadian Forest Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992)

The model assumes that the threshold for transition to crown fire *Io* (kW m–1) is dependent

- on the crown foliar moisture content *M* (percent on dry weight basis: determines crown ignition energy)
- and the height to crown base *CBH* (m) (Van Wagner 1989):

$$Io = (0.010\ CBH\ (460 + 25.9M))^{3/2}$$

The “type” of crown fire depends on the threshold for active crown fire spread rate *RAC* (Alexander 1988):

RAC = 3.0/CBD

where *CBD* is the crown bulk density (kg m–3) and 3.0 is the product of an
empirical constant defining the critical mass flow rate through the crown
layer for continuous flame (0.05 kg m–2 s–1) and a conversion factor (60 s min–1).
Van Wagner (1977) identifies three types of crown fire determined by the *Io*
and *RAC*:
1. Passive Crown Fire (*Ib*> = *Io* but *RCactual*<*RAC*),
2. Active Crown Fire (*Ib*> = *Io*, *RCactual*> = *RAC*, *E*<*Eo*)
3. Independent Crown Fire (*Ib*>*Io*, *RCactual*> = *RAC*, *E*>*Eo*)
where *E* and *Eo* represent the actual and critical energy flux, respectively in

The spread rate of a passive crown fire is assumed equal to that of the surface fire. The actual active crown fire spread rate at the *ith* vertex $R_{Cactual}$ (m min–1) is determined from the maximum crown fire spread rate (R_{Cmax}) as:

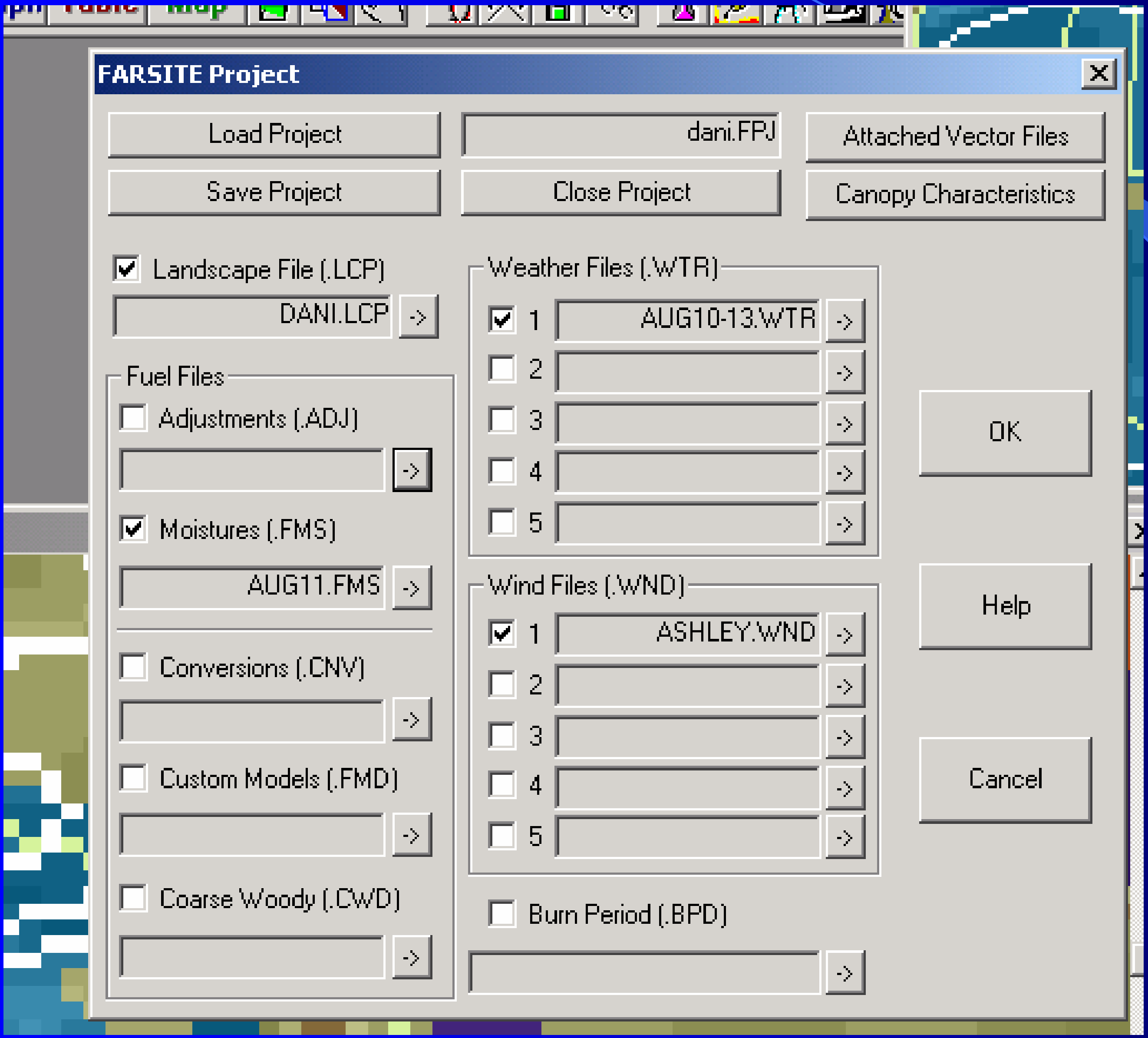
$$R_{Cactual} = R + CFB\,(R_{Cmax} - R)$$

if $R_{Cactual}$ meets or exceeds RAC, where:

$$R_{Cmax} = 3.34 R_{10} E_i$$

and *3.34R10* is the active crown fire spread rate (m min–1) determined from a correlation with the forward surface fire spread rate for U.S. fuel model 10 using a 0.4 wind reduction factor (Rothermel 1991). Although intended to represent the average crown fire spread rate (Rothermel 1991), the coefficient
3.34 was used here to determine the maximum crown fire spread rate. Nevertheless, this correlation remains independent of crown structure, and the uncertainties in predicting crown fire spread rates are not likely resolved through simple adjustment of the coefficient

Farsite required Input Data's

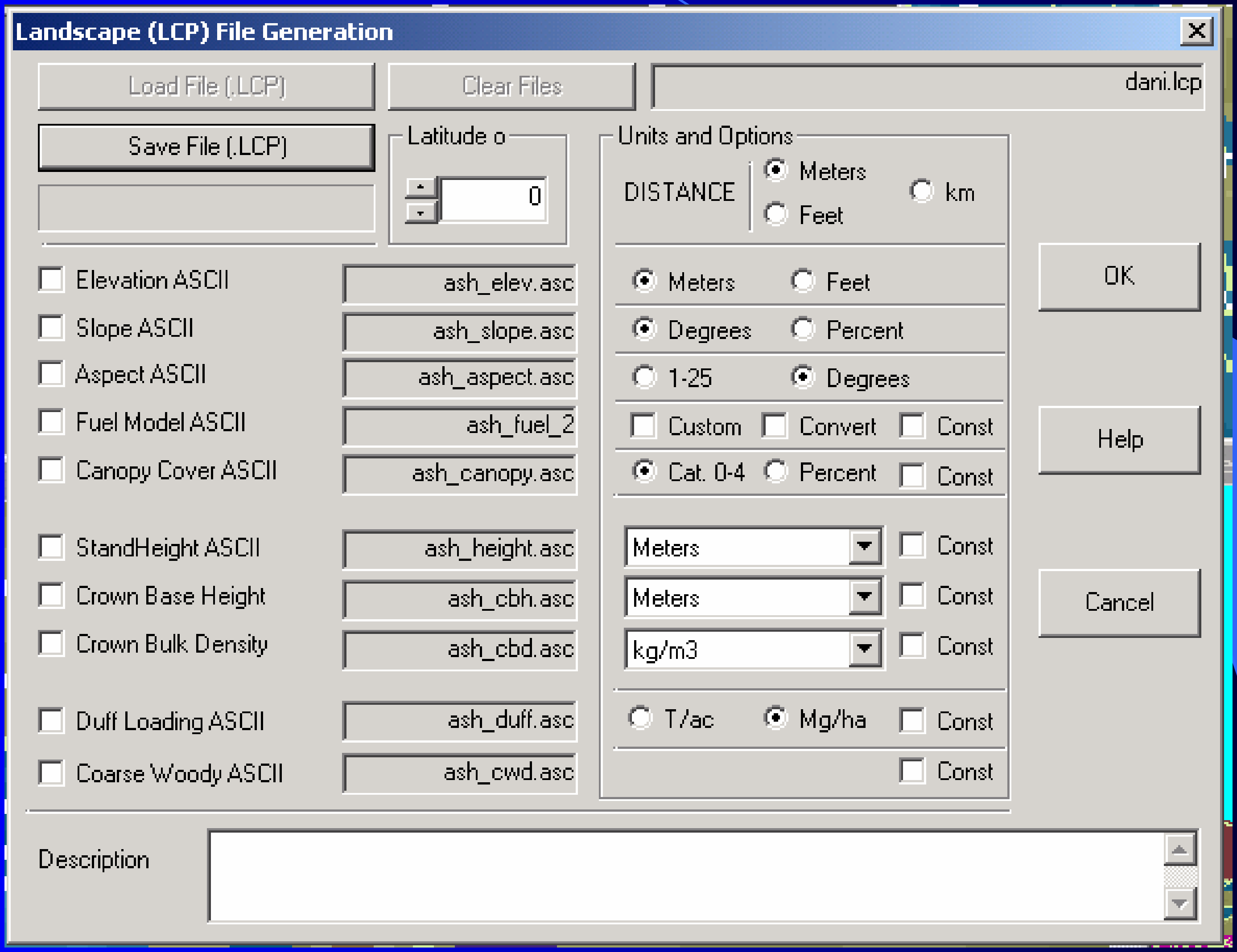



FARSITE
Fire Area Simulator
Systems for Environmental Management
P. O. Box 8089, Missoula, MT 59807 ◆ www.farsite.org
version 4.02 © Mark A. Finney 1994, '95, '96, '97, 2000, '02, '03

File Name	File Ext.	File Type	Required	Optional
Landscape	.LCP	Raster	Fuel Model, Slope, Aspect, Elevation, Canopy Cover	Crown Bulk Density, Crown Base Height, Stand Height, Duff Loading, and Coarse Woody themes
Weather	.WTR	Text	At least one file	*FARSITE* can use up to 5 .WTR files in a simulation
Wind	.WND	Text	At least one file	*FARSITE* can use up to 5 .WND files in a simulation
Adjustment	.ADJ	Text	Although required, this file can consist of all zeros	Adjustment factors other than zero are optional
Initial Fuel Moisture	.FMS	Text	*FARSITE* needs moistures at least one day before the beginning of the simulation	none

File Name	File Ext.	File Type	Required	Optional
Fuel Model Conversion	.CNV	Text	none	yes
Custom Fuel Models	.FMD	Text	none	For fuel models other than the 13 standard NFFL models
Fire Acceleration	.ACL	Text	none	yes
Air Attack Resources	.AIR	Text	none	needed to implement the air attack functions
Coarse Woody Profiles	.CWD	Text	none	specifies > 3" fuels for the Coarse Woody GIS theme used by Post Frontal Combustion Model.
Burn Period	.BPD	Text	none	specifies a daily burn period by date
Gridded Weather and Winds	.ATM	Text	none	uses gridded weather files if a weather model to provide them is available
Ground Attack Resources	.CRW	Text	none	needed to implement the air attack functions

Landscape file

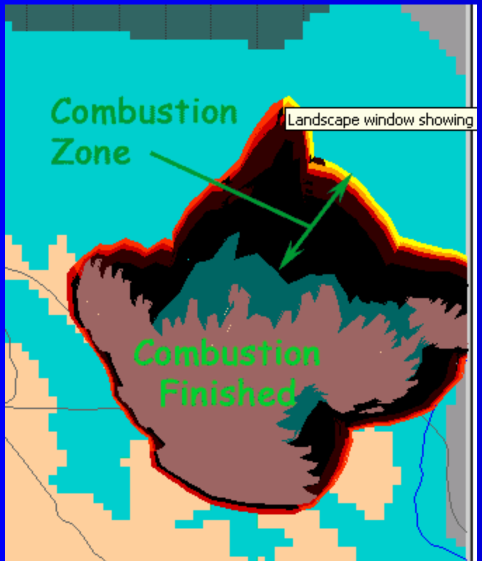


Surface fire modelling

Required Themes	*Unit*
Elevation	Meter
Aspect	1-25/degree
Slope	Degree/percent
Fuel Model	NFFL 13/custom, const
Canopy Cover	Cat 0-4/const/ percent

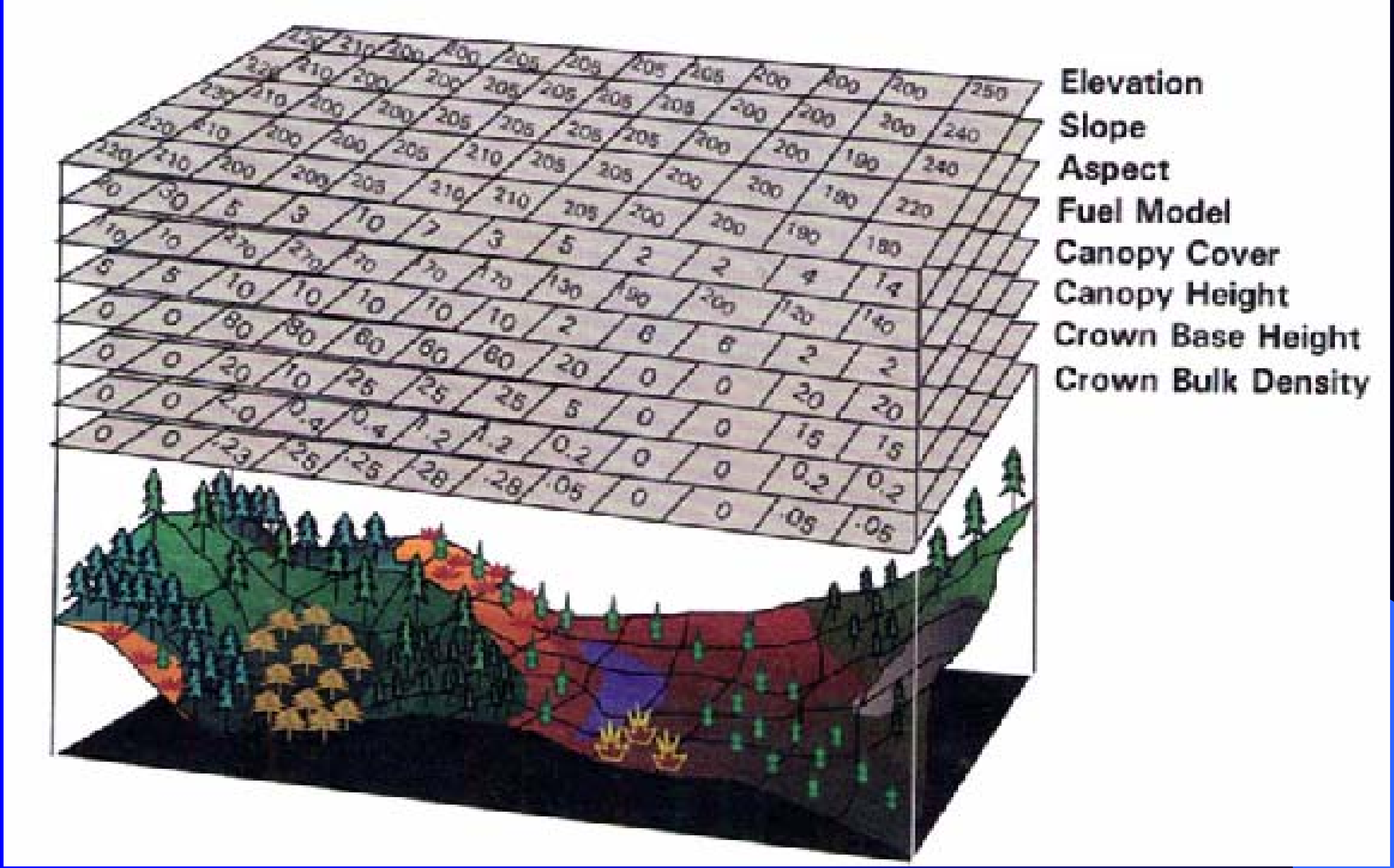
Crown fire modelling

Optional Themes	*Unit*
Crown Base Height	Meter, const
Stand Height	Meter, const
Crown Bulk Density	Kg/m^3, const



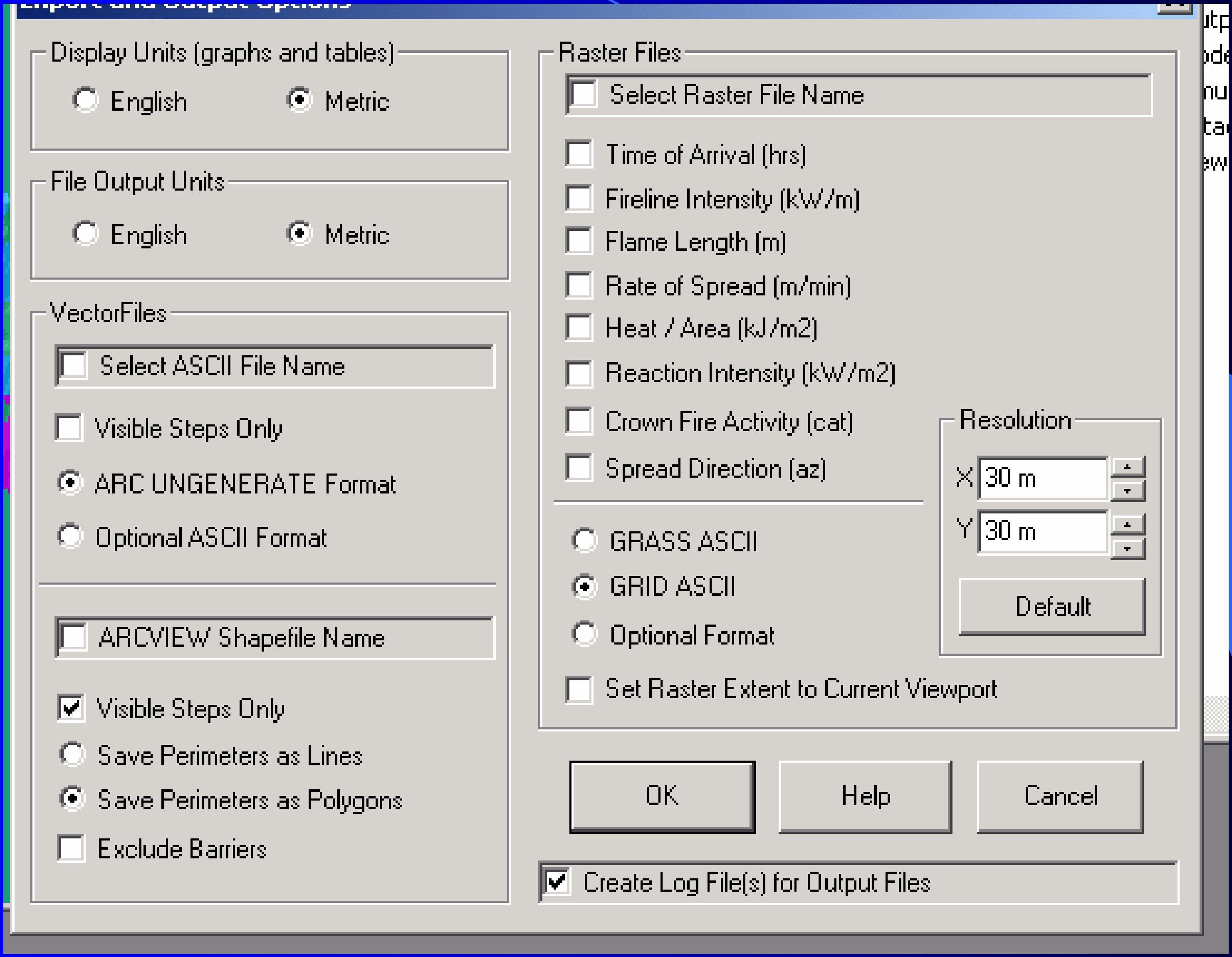
Post frontal combustion

Duff Loading	T/ha, const
Course Woody	const



- co-registered (e.g. have the same reference point, projection, and units)
- identical resolution (e.g. cell size must be the same for all themes)
- same extent (the corners of the rectangular spatial region must be the same)

Export and Outputs optoins



Switch over on the FARSITE!

Limitation and problems at the use of farsite

- Missing input dates,
- The needs of digital data gathering under the prevention planing
- Other fire fighting structure that in use in USA or in Canada
- Missing funktion in practice for professional moddeling personal (FBAN)

Dziekuje za uwage!

Thanks for your patience!

References:
***FARSITE*: Fire Area Simulator—Model Development and Evaluation, USDA Forest Service 1998**
EUFIRELAB: Behaviour Modelling of Wildland Fires: a State of the Art

Photo: GFMC