Nicholas L. Crookston

Chapter 1 Purpose and Applications

Abstract—The Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS) simulates fuel dynamics and potential fire behavior over time, in the context of stand development and management. This chapter provides an introduction to the model by illustrating its purpose and chronicling some of the applications it has supported.

Keywords: FVS, FFE, forest fire, stand dynamics, FOFEM, BEHAVE, NEXUS, snags, coarse woody debris

1.1 Introduction

Fire is now represented in the Forest Vegetation Simulator's (FVS) predictions of forest stand dynamics. At long last! Al Stage (1973) recognized the importance of including disturbance agents in stand projections when he included mountain pine beetle-caused mortality of lodgepole pine in the first release of the FVS parent model, the Prognosis Model for Stand Development.

Furthermore, long-term stand dynamics are now included in simulations of fires and fire effects. Fuel managers have a tool, the Fire and Fuels Extension to FVS (FFE-FVS), to evaluate the effectiveness of proposed fire and fuel management treatments in the context of potential fire effects on short- and long-term stand dynamics, important to silviculture, wildlife habitat, and fuel hazard.

Adding fire to FVS was accomplished by programming an extension to FVS largely based on existing models of fire behavior (including crowning) and fire effects. New dynamic models that represent snag dynamics and down wood decomposition were constructed to complete the system. The details of these components and their scientific support are the subject of chapter 2, "Model Description." Chapter 3 "User's Guide," presents options and examples of command usage. Chapter 4, "FFE Variants," summarizes the changes made to customize the model for different geographic regions.

FFE-FVS is based on a huge legacy of research, generally dating to the middle of the 20th century. Contemporary contributors include many who attended meetings and workshops where there was a free flow of knowledge, data, and inspiration. Their names are listed in the acknowledgments.

Other papers have been published that introduced the model at various meetings and symposia. Beukema and others (1997) reported the first introduction to the FFE-FVS at the FVS conference held in Ft. Collins, CO, in February 1997. An updated introduction was presented at the Joint Fire Science Conference and Workshop held in Boise, ID, in June 1999 (Beukema and others 2000).

The need for this work and the way that this model fits into the fire-modeling toolbox was the subject of a meeting held in Seattle, WA, in February 1999 (Kurz and Beukema 1999). That meeting led to the development of the research program subsequently funded by the interagency Joint Fire Science Program. Crookston and others (1999) presented a summary of the findings from that meeting and highlighted the workshop methods.

What follows in this paper is an example that demonstrates the kinds of outputs the model produces and the dynamic interactions between the fire, fuel, and tree growth components. Following the example is a summary of some of the applications recorded to date. These document the range of the model's applicability from the stand to regional levels and include the use of the model in conjunction with other FVS extensions that represent insects and diseases.

1.2 An Example

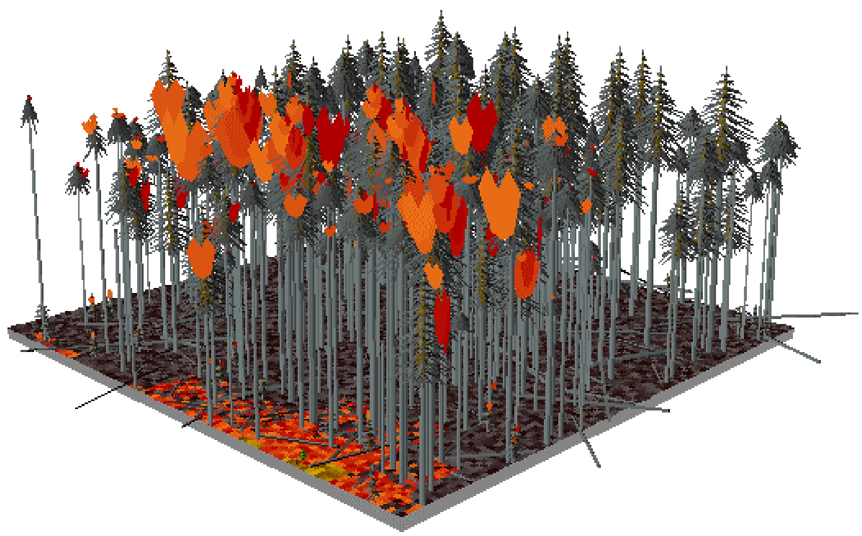
The main use of the FFE-FVS is to support fuel management and postfire treatment decisions in the context of other vegetation management concerns, including wildlife habitat, insect and pathogen hazards, and timber production. FFE-FVS displays measures of fire hazard as they change during the course of stand development and in response to management actions and other disturbances.

The following example displays a few of the many FFE-FVS outputs. It is taken from a Forest Inventory Analysis (FIA) plot on the Flathead National Forest in western Montana. The forest type is Douglas-fir, although the potential type is classified as subalpine fir. While there is little species diversity, there is a great deal of variation in tree size, ranging from seedlings to trees over 30 inches in diameter.

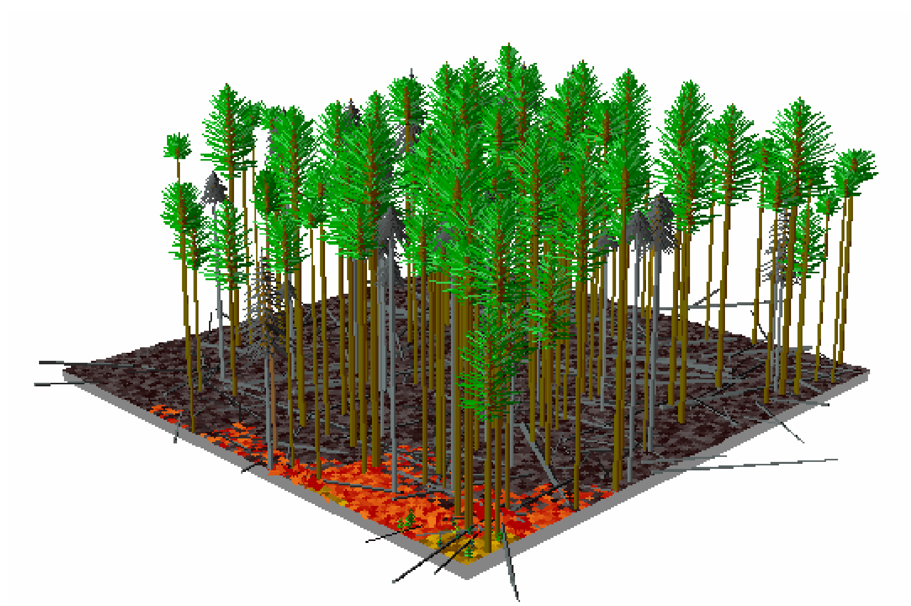
Two simulation scenarios are offered. The first, named *Wildfire only*, includes a simulated wildfire in the year 2065 and was run with no other management actions. The second is like the first except that a series of prescribed fires was simulated prior to the wildfire and is therefore named *With prescribed fire*. A series of figures show the results of running these two scenarios. The variables were chosen to illustrate the relevance of the model outputs to various disciplines and to demonstrate the dynamic interactions between fire, fuel, and tree dynamics. There are many more variables that could be displayed, and many more scenarios on many more stands could be run.

1.2.1 Output for Everyone: Stand Visualization

The Stand Visualization System (SVS, McGaughey 1997) can create images like the ones illustrated in figure 1.1. The images (reproduced in color on the cover) show how the fire behavior differs during the wildfire under the two scenarios. In the *Wildfire only* case, the fire is burning in the crown, while the *With prescribed fire* case exhibits some torching. Images like these can be made for each time period of a simulation and viewed on computers as a time-lapse sequence showing the dynamic changes that take place in a stand. The software needed to construct these sequences is freely available and includes linkages to FVS.



Wildfire only



With prescribed fire

Figure 1.1—Stand Visualization System (McGaughey 1997) images show how the fire behavior is different during the 2065 wildfire under the two scenarios. In the *Wildfire only* case (top), the fire is burning in the crown, while in the *With prescribed fire* case only a surface fire is burning (bottom).

1.2.2 Outputs for Fire and Fuel Managers

The potential flame length indicates the expected fire intensity if a fire were to burn. It is computed over the duration of the simulation period using the same logic as used to simulate a fire except that no fire effects are included. Figure 1.2 illustrates that the *Wildfire only* case provides a rather static potential flame length until the year 2060 when it increases dramatically. This is due to a reduction in canopy base height and other factors that result in the FFE predicting that fuels would support an active crown fire. Consequently, the wildfire simulated in year 2065 is classified as a crown fire and results in 100 percent tree mortality. Following the fire, the potential flame length dips sharply due to fuel consumption, and then increases because of the increase of dead surface fuels that accumulate immediately after the fire as a result of fire-caused tree mortality. In the *With prescribed fire* scenario, a pattern of reduction and increase in potential flame length follows the prescribed fires.

Figure 1.3 shows changes in crowning index, the wind speed necessary to sustain crown fire. The series of prescribed fires in the *With prescribed fire* scenario increased the crowning index from 15 to 20 miles per hour until after the severe fire simulated at 2065. The huge increase in the crowning index under the *Wildfire only* scenario is due to the lack of overstory trees in which the fire can burn.

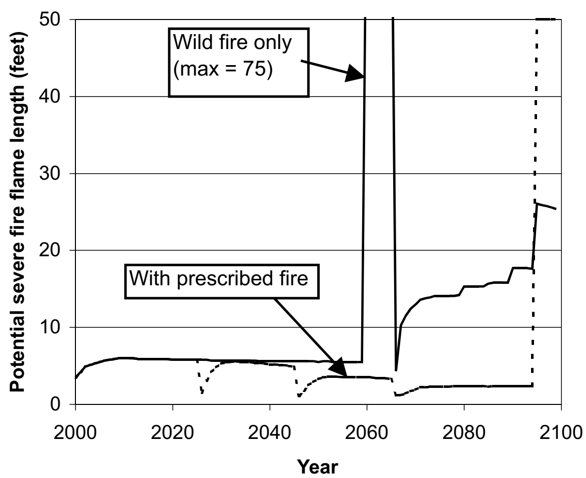


Figure 1.2—The potential fire flame length for severe burning conditions is illustrated for both scenarios. The *With prescribed fire* scenario has a much lower potential flame length in this example until the end of the simulation when it jumps up to 50 feet.

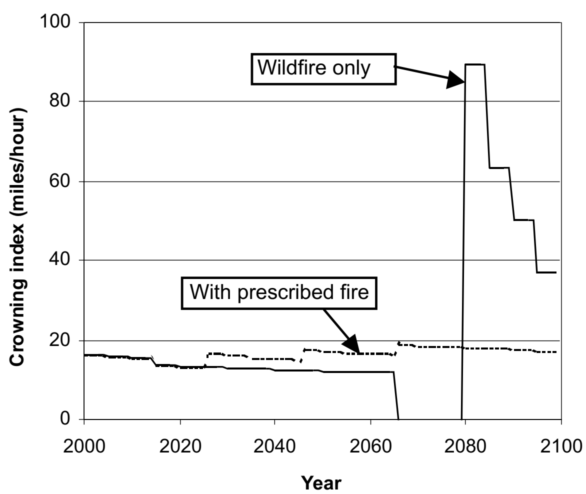


Figure 1.3—Crowning index is the wind speed necessary to cause a fire that is torching trees to become a running crown fire.

1.2.3 Outputs for Silviculturists and Fuel and Wildlife Managers

The surface fuel load in tons per acre is an indicator for fuel managers because generally, the more there is, the greater the fuel hazard. Figure 1.4 shows total weight of woody fuels summed over all size classes. To wildlife and vegetation managers, this fuel is considered coarse woody debris, and that is often a valuable resource. The *Wildfire only* scenario shows consistently high fuel loads while the *With prescribed fire* scenario shows that surface fuels are reduced by the prescribed fires. In general, however, the reductions are short lived as the trees killed by the prescribed fires create surface dead material soon after each prescribed fire.

Snags are less important to fire behavior than down fuel yet can be important to wildlife habitat management (fig. 1.5). The *Wildfire only* scenario shows a slow, steady, increase in snag numbers with a peak after the wild fire. The *With prescribed fire* scenario shows an early increase and a smaller spike after the fires of 2065.

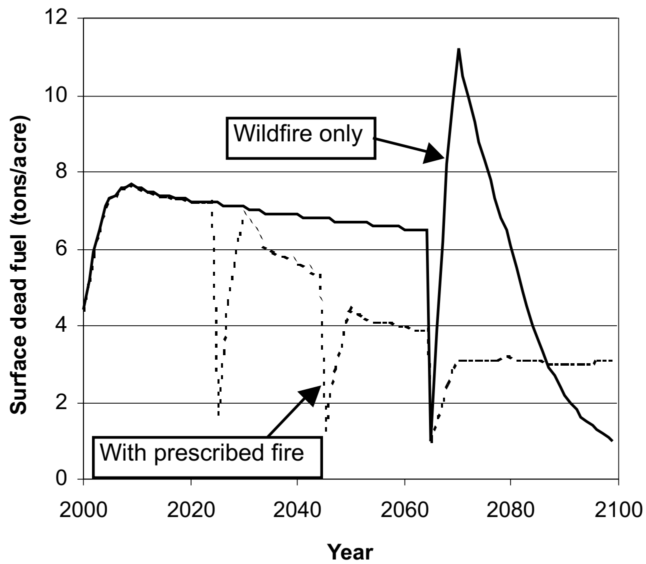


Figure 1.4—Surface fuel loads are of interest to fuel managers. To wildlife and vegetation managers this variable measures coarse woody debris. For the *Wildfire only* scenario, the model predicts surface fuel decomposition exceeds accumulation after the initial accumulation.

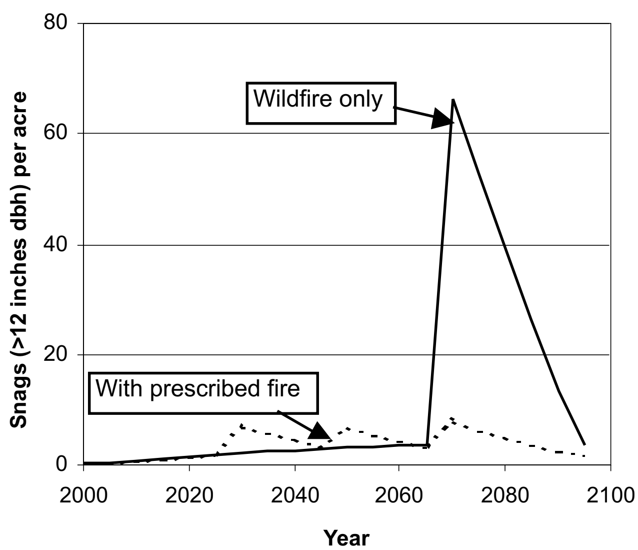


Figure 1.5—The number of large snags per acre for the two scenarios.

1.2.4 Outputs For Wildlife Managers and Silviculturists

Percent canopy cover for each of the scenarios is shown in figure 1.6. Wildlife habitat managers and silviculturists use this variable to evaluate management alternatives. Thomas and others (1979) say that 70 percent canopy cover is an important level with respect to deer and elk habitat needs. While neither of the scenarios demonstrate 70 percent cover, it is clear that the *Wildfire only* scenario shows high cover values for the simulated period up to the wildfire of 2065. In contrast, the *With prescribed fire* scenario shows reduced canopy cover, leaving the stand relatively open for most of the simulation period.

Fire is a major disturbance agent and can change the successional pathways of forest stands. FVS classifies the successional stage at each time step into one of the classes shown in figure 1.7 (O'Hara and others 1998, Crookston and Stage 1999). In both scenarios, fire acted to modify succession on this stand. A third scenario, without any fire, showed that the stand would be classified an old forest in 250 years.

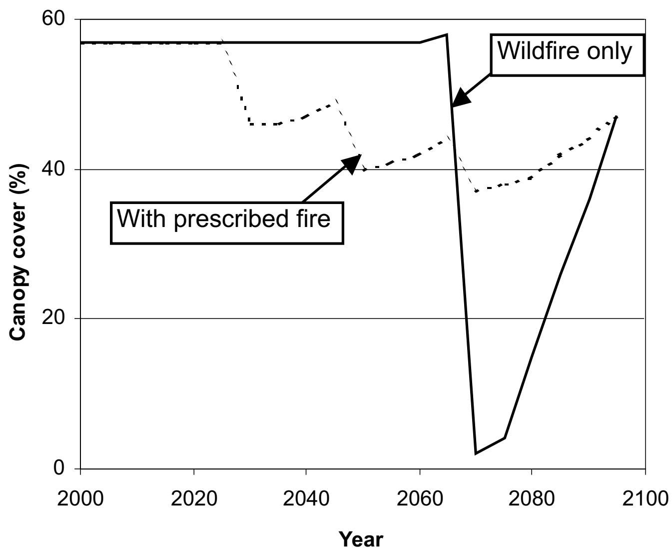


Figure 1.6—Canopy cover is a key variable used in habitat assessments. The prescribed fires caused a steady reduction of this variable while the *Wildfire only* scenario provided significant cover until the wildfire of 2065.

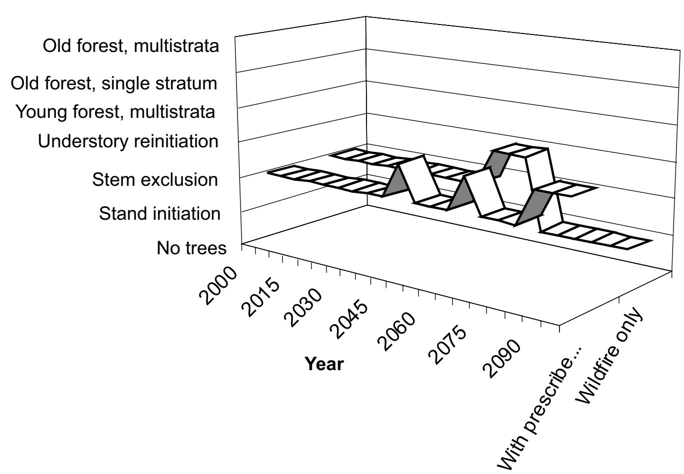


Figure 1.7—Stand structure is classified by FVS (Crookston and Stage 1999) and plotted here for each scenario. After the 2065 wildfire, the *With prescribed fire* scenario maintains later successional stages compared to *Wildfire only*.

1.2.5 Outputs for Silviculturists, Wildlife Managers, and Foresters

Top height (fig. 1.8) and volume (fig. 1.9) are key indicators for silviculturists and foresters. The simulations show that the average height of the largest trees is not greatly affected under the *With prescribed fire* scenario. The sequence of prescribed fires protects this vertical component of the stand from destruction by the wildfire of 2065. On the other hand, the prescribed fires cause a great deal of mortality and reduction in stocking resulting in a great loss in timber production. A plot of cubic volume over time (fig. 1.9) shows the model's ability to integrate growth, mortality, and fire processes showing how these processes affect productivity. There is no doubt that the *Wildfire only* scenario leads to the destruction of the timber in this stand in the 2065 wildfire while the *With prescribed fire* scenario left the stand capable of escaping the complete loss of timber.

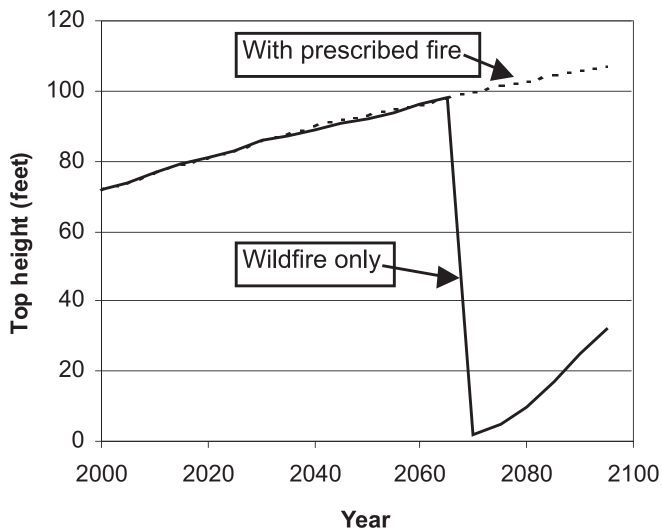


Figure 1.8—Top height is the average height of the largest 40 trees per acre. The scenarios provide similar top heights until the wildfire.

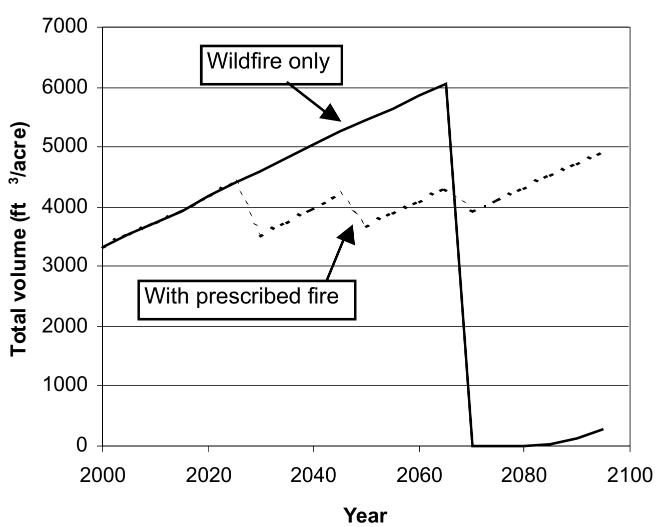


Figure 1.9—The series of prescribed fires seriously reduced timber production as seen by this graph of cubic volume over time; this trend is similar when board foot volume over time is plotted.

1.2.6 Summary of the Example

Structure, function, and composition of forest stands can be assessed for each management alternative using FFE-FVS. The base FVS model and the FFE calculate many variables besides those shown in figures 1.1 through 1.9. The dynamic interactions between the model components are evident.

Different, perhaps better, management options could be run as well. The FFE-FVS system provides several options to manage the trees, snags, and simulate fuel treatments. The "User's Guide" (chapter 3) lists them all.

1.3 Applications

The FFE-FVS has proven useful in several situations. The first involved the evaluation of fuel treatments in an urban forest interface zone near Coeur D'Alene, ID. Simulations demonstrated to the National Forest managers and interested members of the public that post thinning fuel treatments were needed in addition to proposed thinning to meet fire hazard reduction goals. The simulation period was a few decades, and the analysis was done at the stand level.

Later, FFE-FVS was used to evaluate alternatives for managing forests and fuels in the wake of a Douglas-fir beetle out break on the Idaho Panhandle National Forests. The model was used to show the changes in potential flame length (using such figures as fig. 1.2) given different infestation and management scenarios, over a 150-year simulation period. The analysis was done in support of an environmental impact statement prepared while deciding what actions should be taken in response to the outbreak (IPNF 1999). How the outbreak affected long-term fuel loading and subsequent fire intensity was a key question. The results of the analysis were used to support a related environmental assessment (IPNF 2001).

During the summer 2000 fire season, FFE-FVS was used to confirm satellite-based data to predict future fire perimeter. Fire managers were using the spatially explicit model, FARSITE (Finney 1998), to predict fire spread. The FFE-FVS choice of fire behavior fuel model and estimates of canopy base height and bulk density were used to provide inputs to FARSITE. This application had a large spatial scope and 1-year time horizon. Since 2000, FFE-FVS has often been used as a step in generating fuel maps for use in FARSITE and, more recently, FlamMap (Hayes and others, in review).

The Northern Region of the Forest Service (Atkins and Lundberg 2002) used FFE-FVS to characterize forest structure, fuel loads, potential fire hazard, and forest health conditions in Montana. The analysis units are the Forest Inventory Analysis (FIA) plots on public and private lands. The work will be extended to Utah.

Christensen and others (2002) used the FFE-FVS to determine the effectiveness of several stand treatment options designed to reduce fire hazard both now and into the future. Long-term effects are reported in terms of the stocking, size, and species mix of stands and the size and species mix of trees and logs that might be removed for wood products.

FFE-FVS, coupled with SVS, was used to build the "Living with Fire" educational computer game intended for use by the general public. The game Web site is: http://www.fs.fed.us/rm/fire_game.

FFE-FVS is part of Prognosis EI (Greenough and others 1999), a detailed watershed-level environmental indicators model developed and used in

British Columbia. It is capable of representing several disturbance agents besides fire, represents the dynamic interactions of agents in space within the landscape, and directly outputs or links to scores of indicators measuring stand structural attributes, species-specific wildlife habitat quality for birds, bats, ungulates, and bears, patch size, old growth, 23 measures of water quality, visual quality, and timber. It is based on the Parallel Processing Extension of FVS (Crookston and Stage 1991), western root disease model (Frankel 1998), and is linked to a geographic information system. Its spatial scope is several thousand stands, and its time scope is over one generation of trees, about 300 years.

1.4 Conclusions

FFE-FVS is a rich model that provides outputs of interest to several disciplines, has been successfully used in a number of applications, and can be linked to other models and tools. The science on which it is based and its limitations are the subjects of the next paper in this volume. A user's guide follows outlining how to apply it to your needs. Differences between regional variants are outlined in the fourth paper.