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CFES--The California Fire Economics Simulator: A Computerized System for Wildland Fire Protection Planning[1]

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Abstract: The University of California's Department of Forestry and Resource Management, under contract with the California Department of Forestry and Fire Protection, has developed and released the first version of the California Fire Economics Simulator (CFES). The current release is adapted from the Initial Action Assessment component of the USFS's National Fire Management Analysis System and features a greatly enhanced user interface. Research priorities include exploring alternatives to per acre net value change to better account for localized values at risk, addressing the issue of determining final sizes of escaped fires and developing enhancements to the Initial Attack Module to improve its realism.

The University of California, Berkeley, in cooperation with the California Department of Forestry and Fire Protection (CDF), is developing the California Fire Economics Simulator (CFES), it is a package of computer programs designed to evaluate the CDF's wildland fire protection organization and alternative protection strategies. The first component of this simulator, the Initial Attack Module (CFES-IAM version 1.11), has been released and is outlined in this paper. Some improvements envisioned for the next version of CFES-IAM and an outline of proposed large fire and economics modules are also presented.

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THE PROBLEM

With the annual cost of wildland fire control in California exceeding $200 million, those with fiduciary responsibility have sought to introduce systematic economic criteria into the CDF budget allocation process. In 1985, the Board of Forestry formally charged the CDF with conducting a rational analysis of the CDF's fire protection program and reporting preliminary results in August 1987. Initially, the CDF considered the possibility of adopting the Forest Service's Initial Action Assessment (IAA) model of the Forest Service. U.S. Department of Agriculture, as the vehicle for this analysis; however, a pilot program revealed several problems with IAA's assumptions and operational characteristics.

One problem intrinsic to IAA's design is its heavy reliance on the cost plus net value change (C+NVC) statistic for comparing fire protection alternatives. Although the C+NVC criterion is an established concept in fire economics, and may be entirely appropriate for a land management agency like the Forest Service its applicability is questionable for wildland and urban-wildland intermix zones characterized by private ownership and public fire protection. Reliance on the C+NVC criterion to determine the "optimal" level of protection fails to address the important equity questions inherent in a situation where costs are borne publicly and losses privately (and by only a portion of the tax-paying public).

Reliance on per acre net value change calculated over extensive areas with similar fuels seems inappropriate for California, given its extremely heterogeneous wildlands where localized habitation developments dominate net value change calculations. Net value change on Forest Service lands is usually dominated by timber losses which may, in fact, be spread homogeneously over the analysis area. However, the concept of an expected per acre NVC becomes less meaningful in the context of California's problem.

Another problem with C+NVC calculations in IAA is the reliance on an exogenous determination of the final size of escaped fires. When the acreage attributed to these non-modeled "escaped" fires drives the C+NVC criterion, the assertion that IAA "models" or "simulates" fire protection "economics" becomes somewhat questionable.

CDF recognized the potential of an enhanced IAA-style analysis, but was cognizant of the program's limitations for their specific needs. Consequently, CDF contracted with the Department of Forestry and Resource Management at the University of California, Berkeley, to develop an alternative computerized system for wildland fire protection planning--the California Fire Economics Simulator (CFES)--with the assistance of the CDF planning staff.

Because of the magnitude of the CDF fire protection organization and the extensive data requirements and local expertise that would be needed for a realistic evaluation of it, it was immediately obvious that a workable system would need to operate in a distributed fashion, with analyses conducted at the ranger unit level, and contain provisions for aggregating results statewide. It was also apparent that the system would have to account for the random nature and special considerations of structure losses, and incorporate more realistic assumptions about fire behavior and protection strategies than those contained in IAA. Finally, an overriding consideration was ease of use by field personnel with varying degrees of computer experience. Because CDF cannot afford the luxury of hiring expert analysts to run this model, but does have a distributed network of MS-DOS compatible computers installed at all ranger unit command centers, creating an interactive, micro-computer based enhancement of the IAA program appeared to be the best choice.

CURRENT STATUS

After carefully examining of the IAA FORTRAN code provided by the Forest Service, the authors decided to rewrite the physical simulation component of IAA in Turbo Pascal[3] to facilitate future enhancements and to permit development of a more sophisticated, interactive user interface.

The first component of the CFES system, CFES-IAM version 1.11, has been released. Since the simulation mechanics of this version and IAA are essentially the same, some IAA analysts may find CFES-IAM to be an attractive alternative to IAA. Several enhancements have been identified and proposed for future releases of CFES-IAM. In addition, large fire and economic evaluation modules of CFES will be developed in the coming months.

OPERATION AND CONTENT OF CFES-IAM VERSION 1.11

CFES, will eventually consist of three modules: initial attack, large fire, and economic evaluation. CFES-IAM, the first module, facilitates the comparison of alternative initial attack dispatching and deployment systems with respect to expected annual frequencies of escaped and contained fires, total area burned by contained fires and the distribution of this area by fire size and dispatch level, and firefighting costs for contained fires. While the simulation component of the first version of CFES-IAM is essentially identical to that of the Forest Service's IAA, CFES-IAM features a more sophisticated user interface, truly interactive operation, more detailed reporting on "escaped" fires, more flexible reporting of simulation results and enhancements to the treatment of air attack and helicopter water drops.

CFES-IAM program operation consists of three phases: a data entry/editing phase, a simulation phase, and an output presentation phase. For an initial analysis, the user enters information describing a fire management analysis zone (FMAZ) and representative fire locations within that FMAZ, fire history,

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[3]Borland International, Turbo Pascal version 3.0 Reference Manual, 1985, available from Borland International Inc., 4585 Scotts Valley Drive, Scotts Valley, CA 95066.

simulation limits, size class limits for reporting simulation outcomes and costs, and fireline production rates, response times and dispatch criteria for up to 50 firefighting resources. Data entry is accomplished via error-trapped, interactive screens, and data can be saved to disk files for later simulations. Once a data set has been entered or loaded from disk, it can be modified as needed using these same interactive screens. Pressing a function key initiates the simulation phase, which lasts 1-15 seconds on an IBM PC or compatible, depending on the number of representative locations modeled and the specified simulation limits. The program then proceeds to the third phase, output presentation, where the outcome of each simulated fire, the fire frequency and acreage burned by size class and fire dispatch level for the expected value fire year, and expected equipment usage frequencies and projected containment success by fire dispatch level and location are reported. Any of these outputs can be printed, if desired, before cycling back to the data entry/editing phase or quitting the program. All screens in a particular phase can be accessed directly or sequentially via function and cursor movement keys. On-line, screen-specific help can always be summoned by a function key. The data entry/editing phase (Figure 1) and the output presentation phase (Figure 2) together comprise a significantly enhanced user interface over current versions of IAA.

When the simulation phase is invoked, CFES-IAM constructs a dispatch list for each representative fire location with the firefighting resources ordered by increasing arrival time. Then, six representative fires are simulated at each location: one at the 50th and one at the 90th percentile rate of spread for each of three CDF dispatch levels--low,

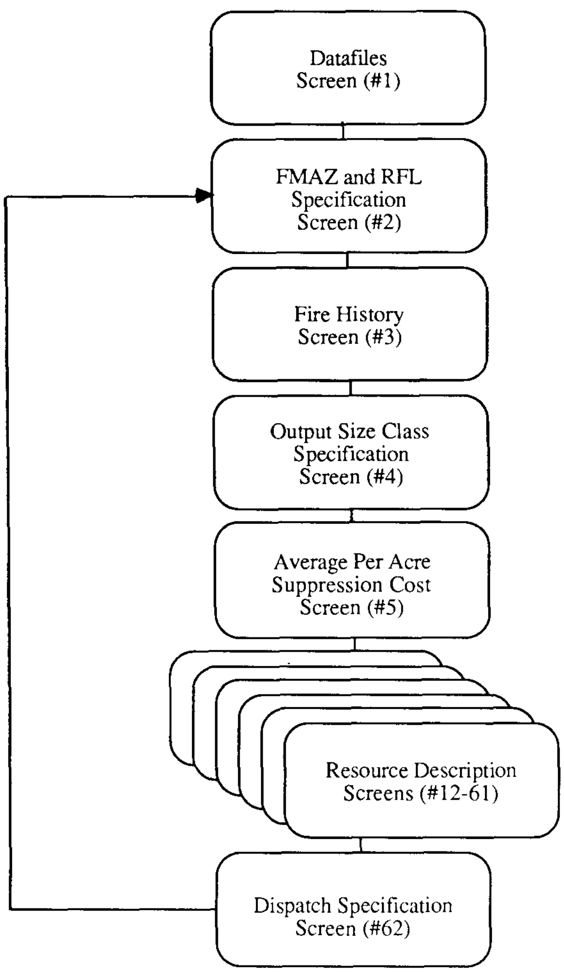

Figure 1--The sequence of screens in the data entry/editing phase of CFES-IAM.

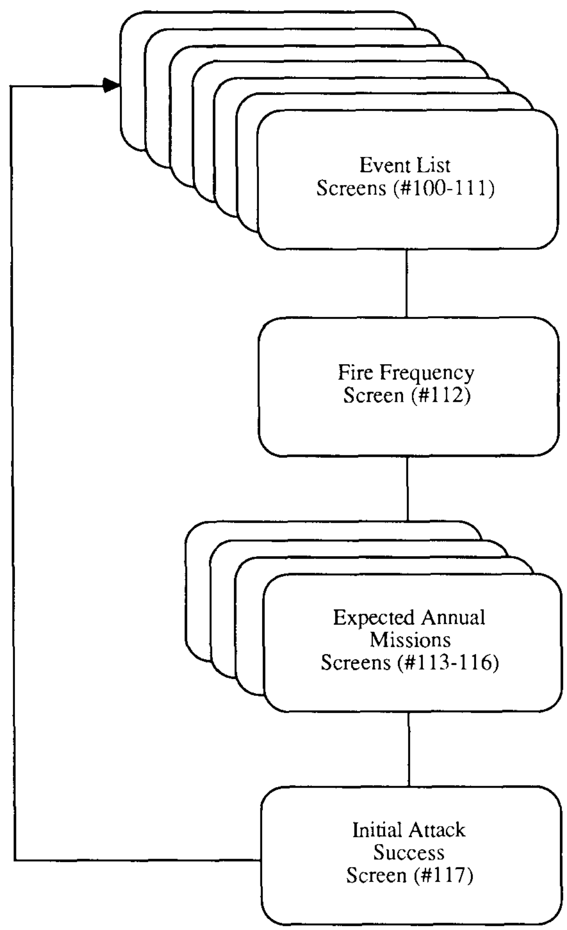

Figure 2--The sequence of screens in the output presentation phase of CFES-IAM.

medium and high. The simulation mechanics are summarized in Figure 3. A more complete description of CFES-IAM and its operation can be found in the CFES-IAM User's Manual (Fried and Gilless 1987).

ANALYSIS CAPABILITIES OF CFES-IAM VERSION 1.11

CFES-IAM was conceived as an interactive, "what-if" simulation tool for California's Ranger Units and Contract Counties. It is intended to be used in conjunction with the judgment of CDF's experienced fire managers, not as a replacement for it. Several types of analyses can be conducted using this version of the program. CFES-IAM can be used to:

1. Evaluate alternative initial attack dispatch policies by simulating the effect of varying the number and type of firefighting resources typically dispatched to different areas under different conditions.

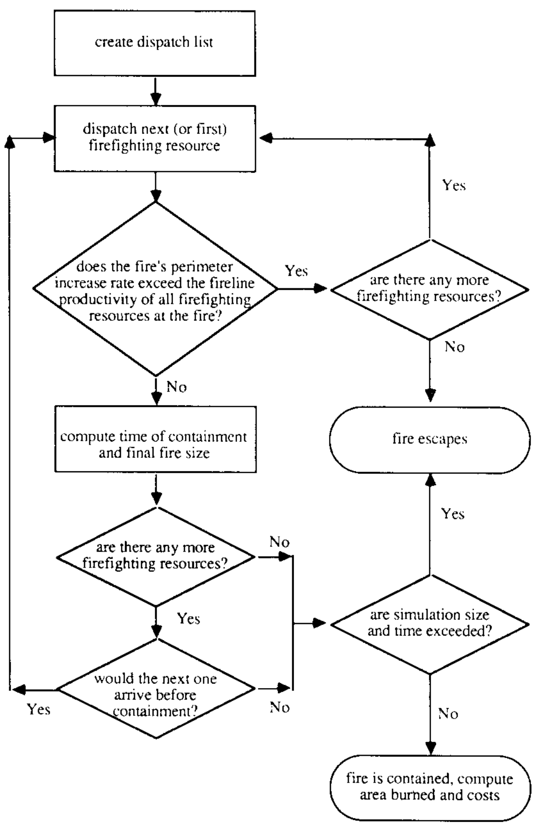

Figure 3--Flow Chart of the mechanics of CFES-IAM simulation of initial attack on one fire.

2. Evaluate alternative stationing of existing firefighting resources by simulating the effect of altering the stationing of existing firefighting resources.

3. Evaluate alternative move up and cover policies and determine critical draw-down points by simulating initial attack only during some critical portion of the fire season.

4. Determine the most effective stationing and utilization of additional firefighting resources by simulating the marginal impact of such resources.

5. Determine how to minimize the damage done to an initial attack organization by the removal of specific firefighting resources by simulating the marginal impact of withdrawing these resources, and by altering stationing and dispatch policies accordingly for the remaining resources.

6. Evaluate the relative effectiveness and contributions of cooperative initial attack forces.

PLANNED ENHANCEMENTS AND IMPROVEMENTS

For effective integration of economic efficiency criteria into CFES a better treatment of large fires and localized zones of high economic risk is essential. The realism of the simulation mechanics should also be improved. The planned enhancements outlined below address these problems.

Instead of utilizing only the expected values (averages) of all parameters, frequency distributions for some could be developed, and CFES-IAM could then be adapted to run in a Monte Carlo mode using these distributions. CFES-IAM would then run repeatedly, sampling randomly from these distributions to assemble the parameters for each run. The expected values of all CFES-IAM outputs would then be revised after each Monte Carlo simulation. When these expected values and their variances stabilized, confidence intervals bracketing the estimates would be calculated and a report printed or displayed. The most likely candidates for stochastic treatment are spread rate, burning index, annual fire frequency, fire size at reporting, fire shape, availability of firefighting resources, productivity of firefighting resources and response times of firefighting resources. This enhancement would improve model realism by ensuring that some of the simulations consider "unusual" events. It would also increase the value of the analysis by explicitly reporting confidence intervals that reveal the level of risk inherent in the alternatives.

An operationally useful, geographic information system approach to defining planning zones is also being considered. Using the CDF's wildland response areas (WRA's: areas of 1 to 50 square miles areas within which the same initial attack forces are dispatched to any fire) as building blocks, WRA's with similar fuels, slopes and habitation densities could be grouped, possibly using an automated cluster analysis technique, to form more homogeneous FMAZ's. This approach could streamline the process of updating CFES inputs to reflect changes resulting from fuel management efforts or residential development. It would also help ensure consistency in the degree of heterogeneity within FMAZ's.

Several enhancements are anticipated for the CFES-IAM to improve the realism of the initial attack simulation. Ideally, CFES-IAM would utilize better fire behavior models. Parallel research (i.e., by a non-economist) is needed to develop improved fuel models that account for the interaction of slope and wind with fuel type in determining fire spread, that more accurately reflect the underlying physical/chemical processes of wildfires, and that better portray the burning behavior of live fuels such as chaparral.

More realistic fireline production rates need to be assembled from the literature, unpublished data, or developed from new data collected in the field. These new values need to reflect how firefighting resources are actually used, and how differences in fuel types, burning conditions and terrain affect production rates. An assumption of the current model is that fireline construction has no effect on the fire shape or spread rate until the fire has been completely encompassed. The fire spread rate could be modified to reflect decreases in the rate of perimeter growth over the duration of the fire where appropriate, based upon field observation of firefighting operations and expert opinion.

The simulation mechanics could also be modified to reflect variation in deployment strategies for ground-based resources under different fire behavior conditions. Ideally, CFES-IAM would match firefighting tactics to the fuel model, burning conditions, topography, resource availability and threats to human life and structures. Initial attack might then be simulated as a direct attack on the head of a fire (or its flanks), or an indirect attack, depending on these factors.

The contributions of air resources to fire containment could also be improved to better reflect the differential effectiveness of air-delivered retardants and water. Of particular concern to the CDF is the current assumption that air resources contribute nothing to containment on fires that spread faster than 40 chains per hour. The authors anticipate analyzing the latest information, collecting some additional data and surveying expert opinion to arrive at more realistic productivity functions for air resources.

Another potential enhancement to CFES-IAM's simulation mechanics concerns fire shape assumptions. Currently, CFES-IAM contains the assumption of an elliptical fire shape for all fires where a longitudinal axis is twice the length of the minor axis. While the length of fireline required to encircle a simulated fire is moderately sensitive to fire shape, the area burned (crucial to the assignment of economic damages and the determination of escapes) is very sensitive to the length-to-width ratio. The BEHAVE model and Rothermel's equations might be used along with the fuel type, wind and slope parameters of simulated fires to endogenously determine more appropriate fire shapes.

Another fire behavior assumption of the current model which could be improved is the length of the build-up phase during which fire spread rates grow to the quasi-steady states predicted by Rothermal's equations. Fire spread rate is currently assumed to start at zero, increase linearly with time and plateau at the predicted steady-state value in between 10 and 60 minutes, depending on the fuel type and burning conditions being simulated. As this seems rather protracted, available data and expert opinions will probably be used to modify build-up phase duration for California conditions.

As part of the CFES analysis process, the economic impacts of large fires (i.e., those that escape initial attack efforts) must somehow be accounted for, both the suppression costs of fighting such fires and the loss of natural resources and property. A first step is to develop California specific estimates of final sizes for fires that are deemed escapes by the initial attack module. One possible approach would be to develop probability distributions of the final sizes of historical fires, and randomly sample from appropriate portions of these distributions to select a final fire size. This way, the final size of escaped fires could be anchored to some extent by fire behavior conditions, and be made independent of the frequency with which fires at a particular intensity level occurred. A paucity of large fire data for individual fire management analysis zones likely would prevent assignment of escaped fire sizes from FMAZ specific distributions. The distributions would probably have to be formed by pooling large fire records statewide from FMAZ's with similar average fire size by dispatch level, fuels, slope, habitation density and historical protection force levels. Presumably, this approach would yield enough data points for any combination of fire behavior conditions to permit the stochastic approach. Other possible approaches would involve gaming techniques and expert opinion. It is unlikely that we will ever be able to simulate large fires, given their complexity and the enormous data requirements that this would entail.

We anticipate that the most influential economic phenomenon in CDF's analysis will be structure loss and that the types and numbers of structures in a management zone, not the vegetation, will determine the efficient level of fire protection. Therefore, we anticipate concentrating our efforts on improving the treatment of localized zones of high economic value at risk within an FMAZ, a concept that must encompass subdivisions, reservoirs and endangered species habitat. To some extent, this can be accomplished through the automation of FMAZ designation and the creation of FMAZ's small enough to be relatively homogeneous with respect to these localized values. In addition, we plan to collect data to help estimate the likelihood of structure loss, given the presence of fire, and to identify the changes in fire protection effectiveness that accompany changes in firefighting strategy related to the presence of structures in the path of a wildfire.

Finally, we anticipate that CFES will never reduce its analysis to a single criterion, like C+NVC, because even the most carefully executed simulation is so distant from reality and the components of NVC that treat nonmarket goods are of such questionable value that an integrative statistic becomes more of a distraction than a tool. CFES outputs will include both costs and value changes, but it will be up to the CDF, and the public to decide whether 20-30 houses saved from destruction justifies a $2 million increase in the fire protection funding level, or whether $100 thousand per annum constitutes a sound investment in preventing the destruction of an endangered species' critical habitat. The authors share the philosophy that when the trade-offs are between apples and oranges, a person makes the decision better than a computer.

REFERENCES

Fried, J.S.; Gilless. J. K. 1987. California Fire Economics Simulator: Initial Attack Module (CFES-IAM) User's Manual version 1.11. Sacramento: California Dept. of Forestry and Fire Protection: Special Publication.