

# Sensitivity of National Fire Management Analysis System (NFMAS) Solutions to Changes in Interagency Initial Attack (IIAA) Input Data<sup>1</sup>

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## Abstract

*A sensitivity analysis was conducted of the National Fire Management Analysis System (NFMAS) to better understand the relationship between data input and model output. After consultations with fire managers and researchers, five input variables were selected for sensitization: unit mission costs, average acre costs, net value change, production rates, and escaped fire limits. A random sample of 23 National Forests was selected, according to the distribution of forests within regions and fire frequency classes, on the basis of historical fire data. Database tables were manipulated, with each variable increased and decreased at six levels ( $\pm 25$ ,  $\pm 50$ , and  $+100$  percent). The Interagency Initial Attack Assessment (IIAA) model was run at each successive level, generating a new set of output, cost plus net value change (C+NVC), for each sensitized variable. Results were analyzed statistically, and production rates and average acre costs were found to be the most influential, while unit mission costs was least influential. In general, greater sensitivity changes resulted in greater changes in C+NVC.*

The National Fire Management Analysis System (NFMAS) was designed in the late 1970's by Richard Chase, for use by the USDA Forest Service in strategic fire management and budget planning. It was later adopted by other fire-management agencies, including the USDI's Bureau of Land Management and the National Park Service. The NFMAS simulation model (NARTC 1997) currently consists of two software programs: Personal Computer Historical Analysis (PCHA), which provides historical weather and fire behavior data, and the Interagency Initial Attack Assessment (IIAA). IIAA (COMPUS 1997) is the analytical engine, a tool intended to help analyze various fire-management scenarios or program options that represent various combinations of fire-fighting resources and other budget items. The overriding purpose of IIAA analysis is to help identify the most efficient level (MEL) of funding for a given National Forest, that is, the program option associated with lowest sum of the presuppression budget, emergency fire-suppression costs, and net value change of resources (the sum of positive and negative resource effects). An administrative unit's initial attack organization will use these data in developing budget requests. NFMAS is applied to a sub-forest area, the fire management zone, and results are aggregated to produce Forest, Forest Service Region, and agency-wide totals. This service-wide total is used as the basis for budget proposals.

Management of NFMAS is a major undertaking in the Forest Service. Training sessions are held at the Marana, Arizona, facility. NFMAS training is received by selected Forest Service personnel, ranging from district fire management officers to upper level managers, and by personnel from USDI agencies and various state fire-fighting organizations. A NFMAS "certification" process is implemented at both the regional and forest levels. Certification involves inspection teams reviewing and revising data and procedures used by field personnel to help ensure compliance with national policy, promoting consistency between units. NFMAS-related databases are constructed, calibrated, and analyzed to identify the most efficient initial attack organization for each Forest. The budgets associated with those most-efficient organizations, MEL, become part of the Forest Service appropriations process.

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Because the NFMAS process is a key management tool in the Forest Service and requires a substantial commitment of resources, it is important to understand its analytical workings, including how those workings and related information affect NFMAS solutions. However, surprisingly little formal attention has been paid to this matter. Smith (1985) investigated how changes in output values affected identification of the optimal fire management program, while Dimitrakopoulos (1985) focused on changes in fire behavior data, production rates, initial attack time, and fire size at discovery. Although both studies were limited to the Stanislaus National Forest, expansion would have been very difficult. Until recently, NFMAS software was not conducive to a rigorous sensitivity analysis because the software was extensive and not user-friendly. Indeed, after a quarter century of NFMAS, Bell and others (1995) recognized the need to know more about NFMAS' operations and called for a sensitivity analysis.

This study assesses the sensitivity of NFMAS solutions to changes in input variables, and it measures sensitivity in terms of change in cost plus net value change (C+NVC), the major quantitative output produced by NFMAS.

## Methods

This study used a very straightforward approach. We selected a set of five IIAA variables to evaluate a sample of National Forests. NFMAS databases were obtained, manipulated as appropriate, and several hundred IIAA computer runs conducted. Resulting changes in C+NVC were noted and statistically analyzed to detect differences between variables and the level of sensitization.

## Data Collection

The National Forest was chosen as the sampling unit. There are 156 proclaimed National Forests in the National Forest System, and roughly 116 National Forest administrative units (combinations of proclaimed National Forests) that correspond to the NFMAS concept of a "planning unit." We selected a random sample of 27 administrative Forests nationally, in proportion to their occurrence within Forest Service regions and fire frequency classes (low, medium, and high) based on 1992-96 fire occurrence data (Bunton 1997). However, because of significant differences in the completion status of current-year NFMAS analyses using the new Windows version<sup>3</sup> of NFMAS (COMPUS 1996), several National Forest databases in our sample could not be obtained (to qualify for study use, Forest-level IIAA databases had to have been "calibrated"). Consequently, all Forests in the Pacific Southwest Region (Region 5) were excluded, as well as some Forests in the Rocky Mountain Region (Region 2) and the Pacific Northwest Region (Region 6). The Alaska Region (Region 10) does not use IIAA, because of very low fire frequency, and was not included in this study. Our final sample size was 23 National Forests.

We obtained the appropriate IIAA databases from each sampled Forest and identified the set of program options to use in the sensitivity analysis. We wanted to assess several program options in order to ensure a mix of options representing the range of program choices available to fire managers. Fortunately, most Forest databases we obtained contained this mix. Following national and regional directives for certification, each Forest developed five program options around an option and budget that describes the most efficient use of resources for presuppression activities. This "most efficient" program option, MEL, corresponds to the budget resulting in the lowest combined C+NVC upon natural resources, as a result of fire suppression activities. The remaining five program options are developed by increasing or decreasing the budget associated with the MEL option in increments of 10 percent, with each producing a new C+NVC. We, therefore, worked with six program options: MEL, M10 (MEL minus 10 percent), M20, M30, M40, and P10 (MEL plus 10 percent).

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<sup>3</sup>Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

Although most sampled Forests conformed to the directive of predetermined 10 percent increments, there were a few exceptions. Additionally, only five options were submitted in one sampled Forest, while another contained an M40 presuppression budget about equal to its M10 budget. All databases were acquired from Forest-level personnel who provided valuable assistance with interpretation and questions. Databases obtained were opened by Microsoft Access software (Jennings 1997), and any compatibility problems encountered were resolved before sensitivity analysis proceeded.

### **Variables Sensitized**

The dependent variable in this study was the change in C+NVC resulting from systematic changes in IIAA input variables. The NFMAS program includes software modules, PCHA and IIAA, each with an associated database. Much of the information contained in the PCHA database consists of historical weather and fire information, and these data are used by the IIAA software at the "calibration" stage. Calibration is the process by which outputs from the IIAA model are synchronized with the actual fire history during this predetermined period. All databases received from sampled Forests contained calibrated data. Selection of PCHA variables or IIAA variables affected by the calibration process was avoided, in order not to compromise calibration results.

At the initial stages of variable selection, we identified more than a dozen candidate variables on the basis of interest expressed by study-related personnel and previous studies. For example, several persons were interested in the sensitivity of NFMAS solutions relative to output values at risk; the contention being that IIAA solutions did not vary with changes in timber values. Similarly, we considered some variables that others used in similar analyses. For example, Smith (1985) evaluated both individual and groups of output values, while Dimitrakopoulos (1985) assessed production rates and fire behavior parameters. In the end, five variables were chosen for sensitization: average acre costs (AAC), unit mission costs (UMC), net value change (NVC), production rates (PR), and escaped fire limits (EFL). The escaped fire limits variable was actually two variables working in concert: acres burned (size) and fire duration (time). Conversely, the NVC variable consolidated several individual value-related measures, including stumpage values, into an overall net value per acre.

### **Sensitization Process**

To establish a baseline for comparison, the IIAA model was run for each Forest with the original data and C+NVC results were recorded. Results of these initial IIAA runs were treated as "base" runs, against which all subsequent sensitivity runs were compared. Except for PR and EFL, the base-run values for each variable were sensitized at six levels:  $\pm 25$ ,  $\pm 50$ , and  $\pm 100$  percent. PR and EFL were not sensitized at -100 percent because those levels are not meaningful and C+NVC results were grossly distorted.

Sensitizing variables in IIAA was done through use of the Microsoft Access database management tool. Each variable was sensitized through a series of database queries; we accessed and made changes directly to IIAA database tables, rather than using IIAA data-entry software to effect database changes. To reduce implicit rounding errors, target variable data were set to decimal places of 1/10,000. An update query transformed the target variable by the desired amounts.

Sometimes, a changed variable would produce unexpected outcomes. For example, we might change a database table, run IIAA, and find no change in output. We learned that IIAA software provides for automatic updating (recalculation) of several key tables after underlying information has been changed. This is accomplished by an auto-recalculate toggle set to "on" or "off," the default setting being "on." The Master Resource Table (MRT) is this type of table and its automatic updating can save the analyst a considerable amount of

work. Data in the MRT, not the underlying information, is used by IIAA in calculations. However, an analyst can edit MRT values to produce the desired information. When IIAA is run, the MRT is recalculated unless the auto-recalculation toggle is set to "off" before run execution. If auto-recalculate is "on," the MRT used in calculations may not be the same as the MRT as sent by the Forest, and the original database would be corrupted. After discovering this problem, and after several discussions with Howard Roose (Lolo National Forest) and Jim Bailey (COMPUS SRVC CORP), we decided no automatic recalculations be performed for either the MRT or the Option Selector Table in the model run. Whether the MRT (as sent to us) was the result of auto-recalculations or manual editing, this approach preserved the integrity of the original data to accurately reflect the unique fire budget situation of each sampled Forest.

IIAA was run for all fire management zones (FMZ's) within selected budget options, yielding a total of 713 computer runs (=23 forests times 5 variables times 6 sensitivity levels plus 23 base runs), with output reports generated for each run. The Option Summary Report format was selected as the primary output report because it contains information regarding C+NVC for the total run group (in this case, six program budget options), summed over all FMZ's. Results were copied into a spreadsheet where calculations of sensitivity and percent change were assessed.

Statistical analyses were at the same time very complicated and very simple. They were complicated because of the way databases were sampled and selected. They were simple because our analytical needs were modest. Analytically, we were interested in hypotheses relating to three questions: are there any differences in sensitivity among the variables tested; does the amount of sensitivity vary with the degree of sensitization; and is there an interaction between variable and the degree of sensitization? To properly test these hypotheses, the error mean square used is that associated with the full or "saturated" model (Neter and others 1990). The full analytical design corresponded to a four-factor analysis of variance, where the factors were: variable (the five variables chosen for sensitization); sensitivity level (the six levels of  $\pm 25$ ,  $\pm 50$ , and  $\pm 100$  percent); fire frequency (the three levels of low, medium, and high); and program option (the six levels of M10, M20, M30, M40, MEL, and P10). After accounting for main effects and all two-, three-, and four-way interactions, we expected about 3,800 "total" degrees of freedom and about 3,300 "error" degrees of freedom.

## Results

This study set out to determine the effect of varying the magnitude of several NFMAS-based variables on the C+NVC portion of IIAA output. Average acre costs (AAC), unit mission costs (UMC), net value change (NVC), production rates (PR), and escaped fire limits (EFL) were selected for analysis. The magnitude of each variable was sensitized  $\pm 25$ ,  $\pm 50$ , and  $\pm 100$  percent, and results were compared to those resulting from the original values (the "base" run). The PR and EFL variables were not sensitized at the -100 percent level because these values have little meaning in IIAA and do not reflect real world situations. C+NVC change results were obtained for a random sample of 23 National Forests.

### ANOVA Results

Although the overriding interest in this study pertained to the sensitivity of C+NVC to changes in the information used in IIAA, our results necessarily reflect other aspects of study design, including the variables chosen for study (factor A-Variables), the historical fire frequency for sampled forests (factor B-Frequency), the sensitivity level (factor C-Levels), and the program options (factor D-Options). Analysis of variance (ANOVA) results were obtained and analyzed (*table 1*).

Table 1—Analysis of variance for NFMAS sensitivity results.

Source	Sum of squares	Degrees of freedom	Mean square	F	P level
Intercept	737	1	737	5.1	0.024
A-Variables	7,598	4	1,900	3.1	<0.001
B-Frequency					0.864
C-Levels	160,346	5	32,069	220.8	<0.001
D-Options	1,335	5	267	1.8	0.102
A x B	528	8	66	0.5	0.888
A x C	582,813	18	32,379	222.9	<0.001
A x D	14,651	20	733	5.0	<0.001
A x B x C					<0.001
A x B x D					0.996
A x C x D	37,040	90	412	2.8	<0.001
A x B x C x D					1.000
Others					
Error	78,822	3,296	145		
<b>Total</b>	<b>1,569,319</b>	<b>3,800</b>			

In the typical factorial design, interpretation of the ANOVA begins with the interaction terms, thereby assessing the prospects of additive main effects. Although the overall four-way interaction (A x B x C x D) is nonsignificant, as are most other interactions involving fire frequency (factor B), the other relevant interactions are all significant (i.e., P level < 0.001). Significant interactions mean that the main effects are not simply additive and must be assessed in light of each other. The statistical significance we found was altogether expected, in light of the substantial degrees of freedom and the error mean square. More unexpected are the nonsignificant interactions involving the fire frequency variable (factor B).

Before dealing with the complications resulting from the interaction of factors, we set the stage by first dealing with the main issue: which variable is most influential? The average of the percent changes (labeled "normal") and the average of the absolute value of the percent changes were determined:

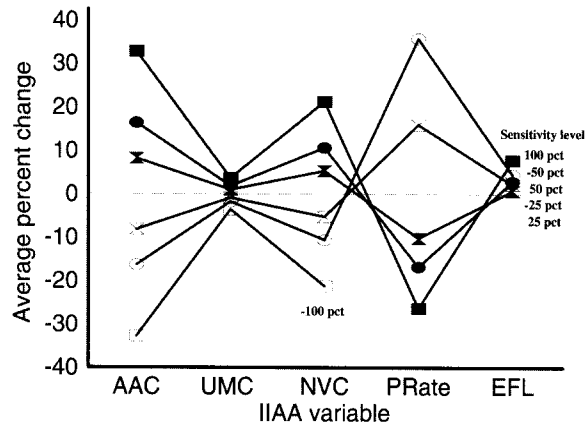
	Average Percent Change	
	Normal	Absolute
Unit mission cost	0.00033	2.1
Average acre cost	0.00024	19.1
Net value change	0.00081	12.4
Production rate	-0.334	21.0
Escaped fire limits	3.5	7.8

The "normal" percent change is simply the difference between a base C+NVC and that resulting from a sensitized variable, expressed as a percent of the base. The "absolute" percent change is simply the absolute value of the "normal" percent change. The distinction is important. Because we sensitized variables to ±25, ±50, and ±100 percent and some of the variables were very symmetrical in their response, their average change was close to zero. Although that average concealed the sensitivity issue, the average of the absolute changes correctly revealed sensitivity. The average change produced by AAC, NVC, and UMC was nearly zero, while the other variables did not show that type of symmetry. However, as reflected by the absolute average percentage change, PR and AAC are the most influential, the NVC variable is next most influential, followed by EFL and UMC, in that order.

**Variable by Sensitivity Level Interaction**

Because of the significant interactions (table 1), the influence of the Variables (factor A) on changes in C+NVC should be interpreted in light of the other factors. In the case of the level of sensitization (factor C-Levels), the interaction with the target variable (factor A-Variables) helps clarify the importance of that

**Figure 1**  
Average percent change in C+NVC, by IIAA variable and sensitivity level.



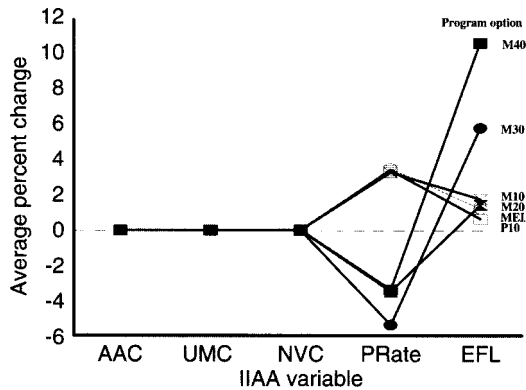
factor. The average percentage change was determined from the base C+NVC for each variable as it is sensitized to  $\pm 25$ ,  $\pm 50$ , and  $\pm 100$  percent (*fig. 1*). The general size of the range of outcomes for each variable is quite compatible with the magnitude of the absolute average percent change. For example, the ranges shown for AAC and PR are the largest, as are the absolute percent changes. The ranges for UMC and EFL are the smallest, as are the absolute percent changes.

The symmetrical nature of changes for AAC, UMC, and NVC explains why their "normal" average percent change (in the listing) is nearly zero. For these variables, a change of -25, -50, and -100 percent has an equal but opposite effect on C+NVC compared to their positive counterparts. Consequently, the average percent changes for the six sensitivity levels, is close to zero. On the other hand, results for PR and EFL show no such symmetry. Results for PR are positive and negative, but skewed toward the positive. Results for all EFL variations are positive. The statistically significant A x C (Variables by Levels) interaction (*table 1*) result from the converging and diverging lines for AAC, UMC, and NVC, the reversal for PR, and the positive-only results for EFL.

**Variable by Program Option Interaction**

The ANOVA shown indicates a statistically significant interaction between Variables (factor A) and program Options (factor D) (*table 1*). The basis for that interaction is shown in *figure 2*. For example, the average percent change for AAC for each program option (i.e., M40-P10) is about zero, portrayed by all program option labels being stacked on each other. The same is true for UMC and NVC, again because of the symmetrical response to sensitization.

The major sources for the interaction between Variables and program Options (A x D) resides with the PR and EFL variables. In the case of PR, the overall averages are not 0 because changes in production rates have a differential effect on C+NVC. Specifically, for a pair of equal and opposites changes (e.g.,  $\pm 25$  percent), the negative change (-25 percent) has a larger positive effect on C+NVC than the negative effect resulting from a positive change (25 percent), and the amount of that differential changes as program Option goes from M40 to P10. This results in negative average percent changes for M20, M30, and M40 and positive average changes for M10, MEL, and P10. All average percent changes for EFL are positive, regardless of whether the escape limits were increased or decreased (*fig. 1*). The overall consequence of these changes is most pronounced in the M40 program option and generally decreases to the P10 option (*fig. 2*; these results are affected by the fact that PR and EFL were sensitized +100 percent, but not -100 percent). If sensitization were restricted to  $\pm 25$  and  $\pm 50$  percent, PR results would all be positive and EFL results would remain positive but compressed.



**Figure 2**  
Average percent change in C+NVC, by IIAA variable and program option.

**Individual Variables**

More than interaction between variables and sensitivity levels or program options, the study was concerned with how changes in individual variables affected C+NVC. Unit mission costs had the smallest effect and production rates had the largest effect.

**Unit Mission Costs**

In addition to AAC, UMC constitute total emergency fire suppression costs. UMCs are intended to represent the typical average, emergency fire suppression costs of **containing** smaller, non-escaped fires. UMC are specified on a "per fire" basis for each producer line item (units that fight fires) and budget line item (types of money represented in program option budgets). For initial attack units, UMC represents the average cost per trip for use of that unit on contained fires. UMC only reflects costs paid out of emergency fire suppression funds, not budgeted costs or pay.

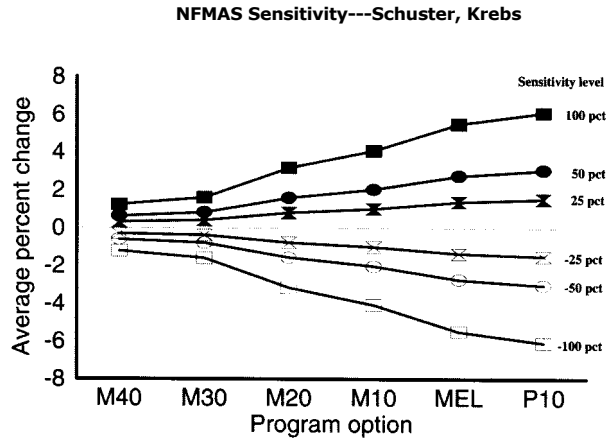
The user enters several bits of UMC-related information in several, IIAA data-entry screens. Data entry begins with identifying and describing producer types, but mainly involves editing several data fields in a series of line-item screens. Through these screens, IIAA collects information on equipment, personnel, supplies, rent, and other costs. Information is stored in various database tables, most notably the LineItems table. Then, in the process of running IIAA, the UMC values in the MRT are updated for final calculations. We sensitized the UMC variable in the MRT database table. In order to preserve the integrity of our newly sensitized UMC values, the toggle for automatic recalculation of the MRT was set to off before IIAA was run.

As shown earlier, changes in the UMC variable had the smallest effect on C+NVC, with an absolute average change of about 2 percent. C+NVC changed under all sensitivity levels and program options (*fig. 3*). If the absolute value of all points in *figure 3* were summed and divided by 36, the average would be about 2 percent. C+NVC responses to changes in UMC are symmetrical. In other words, changes above the zero line are mirror images of those below. However, the magnitude of C+NVC change varies with the program option level. The smallest responses are associated with the least costly program option, M40, a program option that is 40 percent less expensive than the MEL option. The largest C+NVC responses are for the P10 program option. If program options were funded at the MEL level, variations in UMC would have about the biggest effects possible.

**Average Acre Costs**

AAC are one of two costs comprising total emergency fire suppression costs, the other being UMC. AAC are specified for each fire size class, for each fire management zone. For size classes at or below the escaped fire size limit, AAC include **after-containment**

**Figure 3**  
Average percent change in C+NVC for UMC, by program option and sensitivity level.



suppression costs that are not specific to the initial attack unit; that is, these AAC do not include UMC. For size classes above the escaped fire size limit, AAC includes all suppression costs (with UMC).

The user directly enters AAC information on the Average Acre Cost data-entry screen of IIAA. These costs are entered for the upper boundary of each fire size class within each fire management zone. HAA takes these data and stores them as the Cost variable in the AAC database table. To sensitize AAC, we varied the Cost variable and ran the IIAA model.

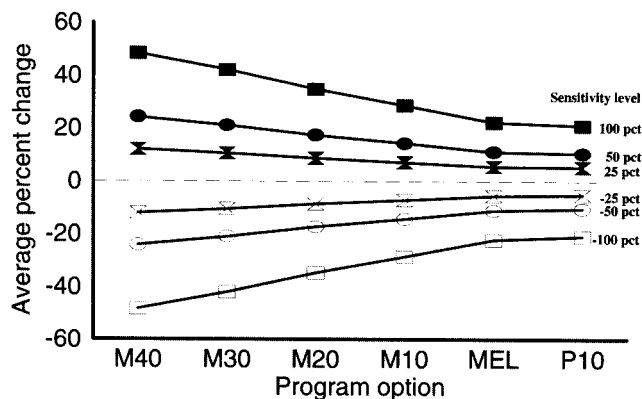
The AAC variable was shown earlier to have the second largest effect on changes in C+NVC, with an absolute average change of about 19 percent. C+NVC changed under all sensitivity levels and program options (*fig. 4*). If the absolute value of all points in *figure 4* were summed and divided by 36, the average would be about 19 percent. As with UMC, C+NVC responses to changes in AAC are symmetrical. In other words, changes above the zero line are mirror images of those below. However, the magnitude of C+NVC change also varies with the program option level. But the direction of change is opposite of UMC. The smallest responses are associated with the most costly program option, P10, a program option that is 10 percent more expensive than the MEL option. The largest C+NVC responses are for the M40 program option. If program options were funded at the MEL level, variations in AAC would have about the smallest effects possible.

**Net Value Change**

NFMAS uses the concept of "net value change" in two ways. First, it is used as a component of IIAA output, as in C+NVC. In that sense, net value change refers to the sum of positive and negative changes in outputs resulting from fires, over a geographical area such as an FMZ. Second, net value change is a variable (NVC) used in the IIAA model to measure the economic impact (per acre) of fire on resource outputs, both positive or negative effects. We focus on the NVC variable. Outputs can be market-valued or valued outside markets.

The user enters NVC-related information through several data-entry screens in IIAA. For example, the unit value of recreation or forage can be entered in the Setup NVC Tables screen, which also accepts pre- and post-fire output

**Figure 4**  
Average percent change in C+NVC for AAC, by program option and sensitivity level.



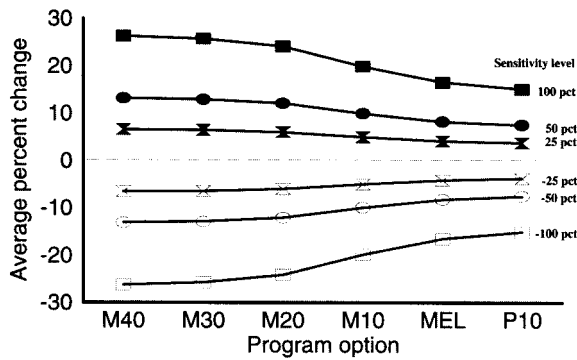


Figure 5

Average percent change in C+NVC for NVC, by program option and sensitivity level.

information. A series of data-entry screens are also used to collect timber-related information, including stumpage values and volumes, as well as fire mortality and salvage rates. IIAA stores NVC-related information in several database tables. It also performs numerous calculations on these data, all intended to portray the net (pre- versus post-fire) consequences to resource output values resulting from fires. These net values are expressed on a per-acre basis, and are stored as the WPANRVCBF variable in the NVCTable database. Used in all IIAA calculations, we accessed the WPANRVCBF variable, sensitized it, and executed the IIAA model.

Of the five variables we evaluated, changes in the NVC variable had the middle effect on C+NVC, with an absolute average change of about 12 percent. C+NVC changed under all sensitivity levels and program options (fig. 5). If the absolute value of all points in figure 5 were summed and divided by 36, the average would be about 12 percent. C+NVC responses to changes in the NVC variable are symmetric. That is, changes above the zero line are mirror images of those below. However, as with AAC, the magnitude of C+NVC change varies with the program option level. The largest responses are associated with the least costly program option, M40, a program option that is 40 percent less expensive than the MEL option. The smallest C+NVC responses are for the P10 program option. If program options were funded at the MEL level, variations in NVC would have some of the smallest effects possible.

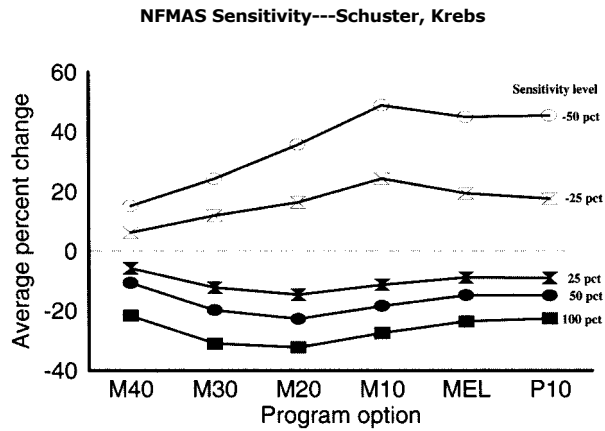
**Production Rates**

The rate at which fireline is produced by initial attack units are called "production rates" (PR). Rates are measured in chains per hour for ground forces and gallons per 100 feet of fireline for aerial-delivery forces. PR are specified for each initial attack unit, and reflect fire perimeter containment capabilities, not capabilities for sustained fireline construction. "Standard" rates have been developed for various types of initial attack units.

Production rates are specified in two ways. First, they can be entered directly into the default production rates screen in IIAA. This screen is normally accessed when national, standard production rates are used in conjunction with IIAA's automatic calculation of the MRT. Second, the user can edit these production rates in the user-viewable MRT that were created by using the auto-MRT provision of IIAA. Regardless, production rates found in the PRate variable of the MRT database table are used in IIAA calculations. We sensitized PRate (our PR variable), set the auto-MRT toggle to "off," and ran IIAA.

Changes in the PR variable had the largest effect on C+NVC of any variable studied, with an absolute average change of about 21 percent. C+NVC changed under all sensitivity levels and program options, except the -100 percent level (fig. 6). If the absolute value of all points in figure 6 were summed and divided by 30, the average would be about 21 percent. C+NVC responses to changes in PR are not symmetrical. Negative change to PR has a larger effect on C+NVC changes

**Figure 6**  
Average percent change in C+NVC for PR, by program option and sensitivity level.



than do equivalent, positive changes. Moreover, that differential is smallest at the M40 program option and generally increases with more costly options. At the same time, the overall magnitude of C+NVC change varies with the program option level, but C+NVC responds to positive changes differently than to negative changes. In both cases, the smallest responses are associated with the least costly program option, M40. The largest C+NVC responses for positive changes in PR are at the M20 program option, while the M10 option shows the largest responses to negative changes. If program options were funded at the MEL level, variations in PR would have relatively large effects in C+NVC.

**Escaped Fire Limits**

The point at which a fire is declared "escaped" is specified in IIAA by a fire size or duration limit. Escape "acres" is the fire size limit, in acres, after which a fire is assumed to have escaped initial attack; escape "hours" is the time limit equivalent. When a fire escapes, the ultimate size the fire achieves, in Forest Service analyses, is determined by the Escaped Fire Table in IIAA. Specified for each fire management zone, final fire sizes are listed for combinations of fire intensity levels and representative locations. Once the final size has been determined, the Average Acre Cost database table is used to specify the per-acre suppression costs.

The user directly specifies escaped fire limits for each fire management zone through the Fire Management Zones data-entry screen of IIAA, but much more information needs to be synchronized. First, the escaped fire acre limits need to be reflected both in the upper acre limit boundaries in the Average Acre Cost data-entry screen and in the costs per acre entered. Specifically, costs per acre up to the escaped fire limits do not include unit mission costs while costs per acre above the limit include UMC. Second, the escaped fire acres limit must be reflected in the acre boundaries in the Escaped Fire Table in IIAA. We had to synchronize these items every time it was changed. Accordingly, we modified the EscAcres and EscHours variables in the FMZ database table; the UpAcres variable in the AAC database table; and the Acres50 and Acres90 variables in the EFT database table. In the process of making these changes to databases from sampled Forests, we encountered a range of questionable situations, including size-class boundaries not synchronized with escaped fire limits and average acre costs that always increased, always decreased, decreased and increased, and increased and decreased.

Overall, the EFL variable had relatively little effect on C+NVC, with an absolute average change of about 8 percent. C+NVC changed under all sensitivity levels and program options, except the -100 percent level (fig. 7). If the absolute value of all points in figure 7 were summed and divided by 30, the average would be about 8 percent. C+NVC responses to changes in EFL is not only not symmetrical, but it is almost random. The largest effects take place at the M40 and M30 program levels, where a plausible ordering of effect is shown: +100, +50, +25, -25, and -50 percent. Beyond the M30 program option, several

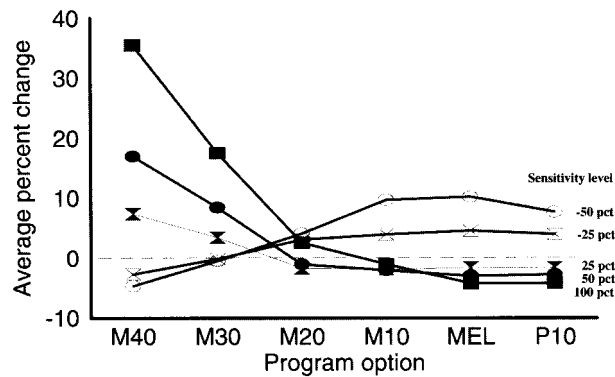


Figure 7

Average percent change in C+NVC for EFL, by program option and sensitivity level.

crossovers occur, such that the ordering at P10 is the total opposite of before: -50, -25, +25, +50, and +100 percent. We cannot interpret the meaning of these reversals but believe it is related to the questionable information we encountered.

## Discussion

This study set out to determine which IIAA-based variable and what amount of change in the variable would have the greatest effect on IIAA results, as measured by C+NVC. In terms of the variables we examined, the answer is clear: PR and AAC are most influential; EFL and UMC are least influential; and the NVC variable is in the middle. In terms of the level of variable change, the more the change (positive or negative), the bigger the effect, generally. However, there was no consistent pattern of program option effect. Sometimes changes in the variables had a large effect on C+NVC with costly program options such as MEL and P10; sometimes the largest effects occurred at the least costly levels of M40 or M30.

The most immediate application of these results is probably in training and research. NFMAS training sessions should use these results to guide instruction. Students could be made more aware of how errors in information can influence IIAA results. Instructors could concentrate more on influential variables and spend less time discussing variables that have little effect on C+NVC. These results could also influence research by emphasizing the need to improve information about variables that influence IIAA outcomes. Similarly, forest planners could concentrate efforts on compiling more refined values for those variables that have the greatest effect on C+NVC outcomes.

Future investigations into the operation of IIAA and its sensitivity to changes in variables could focus on several options. First, we could continue the current study in order to collect and complete IIAA runs on the original sampled forests. Because sampled forests did not have their IIAA databases completed when needed in this study, Region 5 was completely excluded, and Regions 2 and 6 under-represented. Second, we could expand the study to include more observations, by increasing the number of sampled forests beyond the original study plan. This would give a more adequate sample from which to better confirm the relationships now found and delve more deeply into cause-effect issues. Third, we could add additional variables and measure C+NVC sensitivity to systematic changes in them. When we originally selected variables, we identified more than a dozen candidates. Some were eventually discarded or combined with other variables. If desired, we could disaggregate these aggregate variables and investigate the component variables, we could add new variables from those discarded, or we could identify new variables. Fourth, we could expand the study to involve other agencies that use NFMAS, such as the USDI-BLM and Bureau of Indian Affairs. Because NFMAS is used by several Federal and State agencies in addition to the Forest Service, our results should be tested against procedures and budget allocation processes for other NFMAS users. Fifth, we could expand the orientation of this study to focus on how budget allocations and/or the MEL program option changes with changes in IIAA variables.

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