COMPUTER EVALUATION OF EXISTING AND PROPOSED FIRE LOOKOUTS

Romain M. Mees

Traditionally, the location of fire lookouts is determined by fire history and the areas where fires have been spotted. Fire managers consider the spatial concentration of past fires in an area, and judge the relative portions of an area that a lookout can "see." This procedure for evaluating existing lookouts can be time consuming, and is highly subjective. And the evaluation of potential alternative fire detection sites can require two or three times as much effort as that needed for existing lookout stations (U.S. Forest Service 1971).

This report describes a computer simulation model for evaluating existing lookouts so that alternate locations and detection by aircraft or cooperating agencies can be assessed. The model was tested by using data from the Sequoia National Forest, California. The model is applicable on a forest and regional basis. Its use can contribute toward a uniform interpretation and application of procedures for evaluating fixed lookouts. The primary value of the model is to rank lookouts on a common objective basis. The ability to generate visible seen areas should enable fire managers to consider quickly more efficient flight routes into unseen areas of the lookouts for aircraft detection. Copies of the computer programs are available upon request from the Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian.

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A computer simulation model has been developed for evaluating the fire detection capabilities of existing and proposed lookout stations. The model uses coordinate location of fires and lookouts, tower elevation, and topographic data to judge location of stations, and to determine where a fire can be seen. The model was tested by comparing it with manual detection on a National Forest in California. By using this simulation technique, planners can rank lookouts on a common objective basis, and will be able to plan more efficient flight routes into unseen areas of a lookout for detecting fires by aircraft.

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DATA REQUIRED

The following data are needed in using the model:

1. The longitude and latitude coordinates (degrees, minutes, seconds) of all lightning and man-caused fires for a given number of years. The coordinates can usually be obtained by digitizing existing fire-occurrence maps or by using existing U.S. Forest Service Fire Report forms.
2. The longitude and latitude coordinates of each lookout. These must be specified as accurately as possible (degrees, minutes, seconds, fractions of a second).
3. The elevation of each lookout, i.e., the sum of tower height and the elevation at the lookout position.
4. Elevation data described on a grid system for the area covered by the lookouts. One source of elevation data is TOPOCOM (digital terrain data), available on a 208.333-ft. grid for the continental United States (U.S. Army 1973). However, these data should be carefully checked against existing topographic maps before they are used. For technical information concerning the elevation data, contact the U.S. Geological Survey, User Services, 507 National Center, Reston, Virginia 22092.

The acquisition of data requires a substantial amount of effort and some cost. However, most of the data need to be collected only once and can have substantial uses in other types of planning work.

DETECTION PROGRAM

Lookouts are evaluated on the basis of intersecting geometries between seen areas of the lookout and fire intensity areas of the planning unit (*fig. 1*). The intensity factor for each of these areas is computed

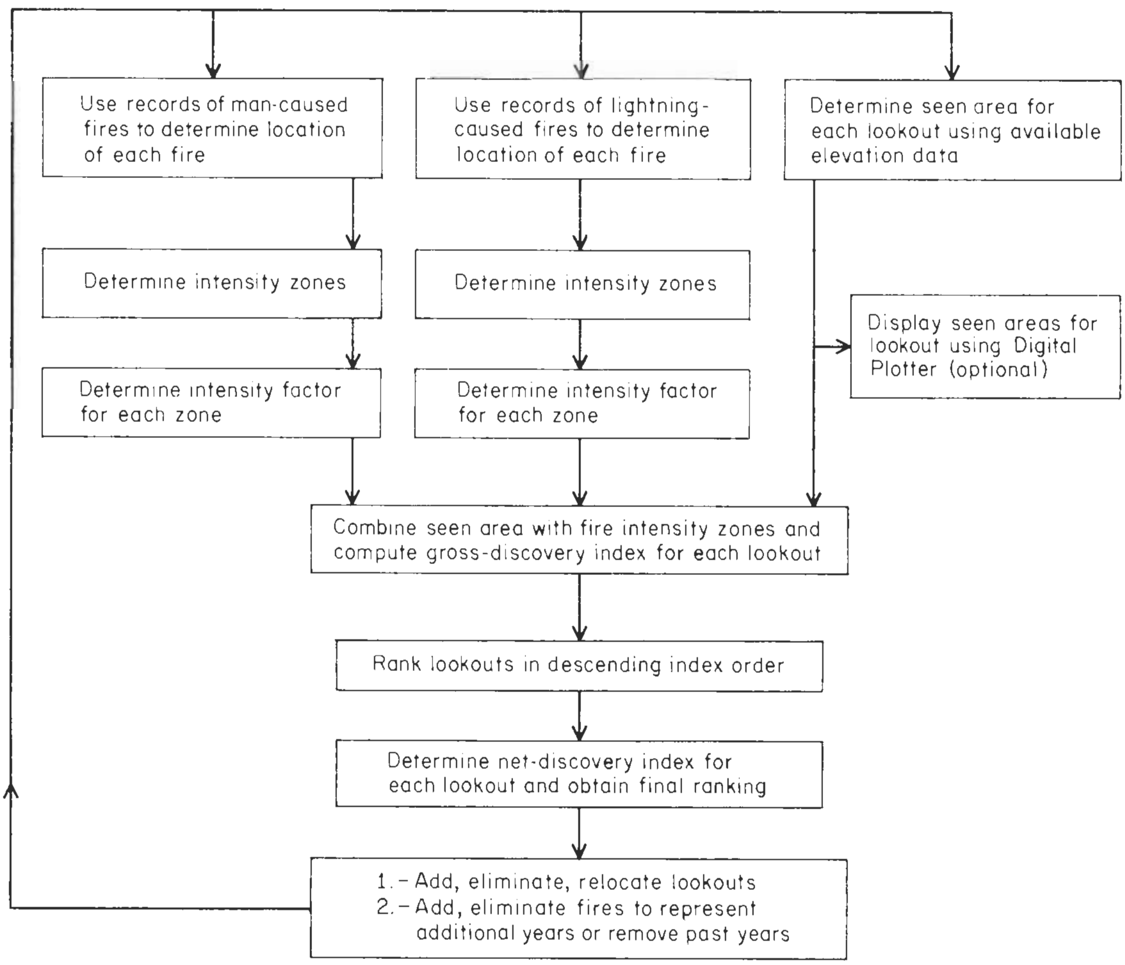

Figure 1—The evaluation and ranking of fire lookouts are functions of seen areas and fire-intensity zones.

by

$$I_a = 1000 \times \frac{\text{Number of fires}}{\text{Number of acres}}$$

in which the coefficient 1000 is used as a scaling factor to improve computational accuracy.

The area of interest can be divided into a square mile grid so that each fire falls into one of the squares (*fig. 2*). The total acreage associated with each intensity area will, therefore, be an exact multiple of the area of the basic square.

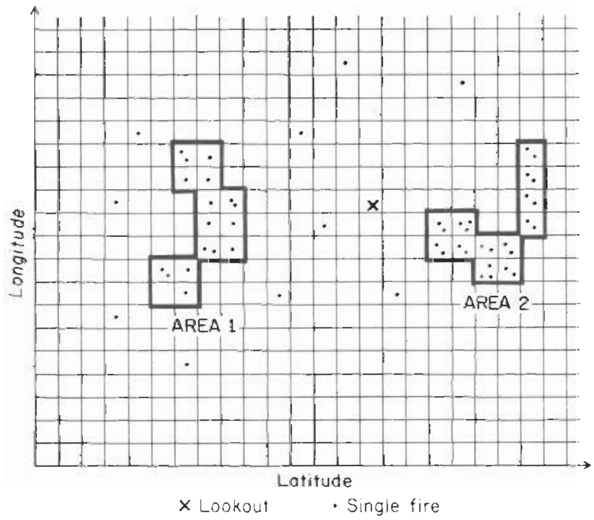

Figure 2—These two fire-intensity areas have a minimum of three fire starts within each area. Each square represents 1 square mile, and each dot a single fire.

The evaluation of fire intensity areas and associated fire-start counts within each seen area ignores the local effects of weather, visibility, existing fuels, and fuel conditions which existed at the time of each specific fire. Therefore, it is important that an adequate number of fire occurrences be considered. This consideration will tend to average out local conditions over a long period of time and will result in a reasonable estimate of the value of a lookout usually designed to last many years.

The following procedure demonstrates how the program works: select a square with at least one fire start in it, examine its eight neighboring squares (nine squares make up a neighborhood in this case), and check if any of these squares contain at least one fire start. Continue the process until all neighboring squares which contain at least one fire are exhausted.

In *Figure 2,* area number 1 has intensity

$$I_a = 1000 * \frac{17}{14 \quad * \quad 640} = 1.8973$$

and area number 2 has intensity

$$I_a = 1000 * \frac{26}{12 \quad * \quad 640} = 3.3854$$

Each square having two or more fire starts is absorbed into the intensity area where each square must contain at least two or more fire starts (area number 2, *fig. 2*). This condition allows the setup of high intensity areas by the program. Furthermore, a neighborhood can be defined as the aggregation of squares within a 2, 3, 4, . . ., mile vertical and horizontal distance of the initial square. The requirement that each intensity area must contain a minimum of fire starts has been included.

The computer program can be directed to create a basic square grid, sort the fire starts as to location, and create the intensity areas. If a fire in a given square has no neighbor, it becomes a single fire with an individually assigned area of 1000 acres and intensity constant $I_a = 1$. If an intensity area contains less than the required minimum number of fires per area, all fires involved will be considered single fires.

The program has been set up so that the user can specify the minimum number of fires (NMIN) per unit square to delineate the high-intensity areas. These areas will be established first followed by the areas in which each square contains 1, 2, 3, . . ., NMIN fires.

With the intensity areas established, the program accumulates the intensity areas of like intensity into five possible fire intensity zones.

The overall fire intensity for each zone is computed by:

$$I_z = 1000 * \frac{\Sigma \text{ No. of fires in area i}}{\Sigma \text{ Acreage in area i}}$$

in which each intensity area belongs to one of these zones:

1 if $I_a < 0.1$
2 if $0.1 \leqslant I_a \leqslant 1$
3 if $1 < I_a \leqslant 3$
4 if $3 < I_a \leqslant 10$
5 if $10 < I_a$

The model develops the seen areas by using the position and height of each lookout and the elevation data provided. The model was tested by using data from the Sequoia National Forest and TOPOCOM elevation data. Any efficient line of sight computer subroutine can be used to generate the seen areas based on the available elevation data. Use of the program as described here, however, is recommended. The program was designed to handle large amounts of elevation data efficiently at reasonable cost of machine time and computer core and storage costs. Another advantage of this program is that the seen areas generated to evaluate the lookouts are permanently recorded on existing computer storage devices and can be displayed by means of a plotting device at the users convenience.

To evaluate each lookout independently, the model estimates the area overlap between each zone and the seen area for the lookout. It sums all squares (1 square mile) partially or completely in the seen area of a lookout and computes the gross-discovery index. This index is the sum of total acreage seen multiplied by the intensity factor (number of fires/acre) of each zone. The equation is . . .

$$G_d = \Sigma \text{ (acreage per unit square) } * I_z$$

in which I_z is the appropriate zone-intensity index for each square.

To establish the relative value of each lookout, the program lists the lookouts in decreasing order as to gross-discovery index. The highest ranking lookout is left at full value.

The net-discovery index for the second-ranked lookout is computed with any seen area already covered by the first lookout removed. The net-discovery index, then, is the sum of total acreage seen (and not covered by higher-ranking lookouts) multiplied by the intensity factor (number of fires per acre) of each zone. The remaining lookouts are evaluated in a similar fashion with overlapping seen-areas credited to the higher ranking lookouts.

The model developed gross-discovery indexes (*table 1*) by using data on fire occurrences (man-caused and lightning) from 1960-1967, the TOPOCOM elevation data, and the elevation and position of 11 lookouts on the Sequoia National Forest. The gross-discovery index, the number of fires in each seen area, and the acreage for each intensity zone were developed for both lightning and man-caused fires.

Table 1—*Acreage in each of five fire-intensity zones (I_z), number of fires in each seen area and the gross discovery index*[1] *for lightning and man-caused fires, by lookout*

Lookout	Name	Fire intensity zones (acres)					Fire incidence	Gross discovery index
		$I_z \leq 0.1$	$I_z \leq 1$	$I_z \leq 3$	$I_z \leq 10$	$I_z > 10$		
				Lightning fires				
1	Baker	0.	1000.	11520.	4480.	0.	36	37.
2	Jordan	0.	0.	21120.	16000.	0.	93	96.
3	Needles	0.	0.	21120.	18560.	0.	102	106.
4	Buck Rock	0.	0.	11520.	4480.	0.	45	36.
5	Bald Mtn.	0.	0.	26240.	17920.	0.	112	112.
6	Mule Pk.	0.	0.	16000.	6400.	0.	48	51.
7	Tobias	0.	1000.	21120.	3200.	0.	54	47.
8	Oak Flat	0.	0.	9600.	0.	0.	17	15.
9	Blue Mtn.	0.	0.	7040.	640.	0.	16	14.
10	Delilah	0.	0.	640.	1280.	0.	5	6.
11	Breckrdg.	0.	0.	8960.	2560.	0.	24	24.
				Man-caused fires				
1	Baker	0.	0.	10240.	3840.	0.	38	35.
2	Jordan	0.	1000.	8960.	0.	0.	17	17.
3	Needles	0.	3000.	7040.	640.	0.	20	18.
4	Buck Rock	0.	1000.	4480.	640.	0.	16	12.
5	Bald Mtn.	0.	2000.	3200.	0.	0.	7	8.
6	Mule Pk.	0.	0.	1280.	1280.	0.	6	8.
7	Tobias	0.	0.	8960.	1280.	0.	31	22.
8	Oak Flat	0.	2000.	3840.	2560.	0.	17	20.
9	Blue Mtn.	0.	0.	4480.	640.	0.	13	11.
10	Delilah	0.	1000.	2560.	0.	0.	6	6.
11	Breckrdg.	0.	0.	1280.	0.	0.	2	2.

[1] Sum of the total acreage seen multiplied by the fire intensity factor (number of fires/acre) of each zone.

Table 2–*Acreage in each of the fire intensity zones (I_z), total acreages within each seen area, net discovery index*[1] *for man-caused and lightning fires, by lookout*

Lookout	Name	Fire Intensity Zones (acres) $I_z \leq 0.1$	$I_z \leq 1.$	$I_z \leq 3$	$I_z \leq 10$	$I_z > 10$	Total	Net discovery index
					Lightning fires			
3	Needles	0.	0.	21120.	18560.	0.	39680.	119.
5	Bald Mtn.	0.	0.	24320.	17920.	0.	42240.	122.
2	Jordan	0.	0.	17920.	11520.	0.	29440.	83.
1	Baker	0.	0.	10240.	4480.	0.	14720.	38.
7	Tobias	0.	0.	14720.	1280.	0.	16000.	32.
6	Mule Pk.	0.	0.	5120.	4480.	0.	9600.	29.
4	Buck Rock	0.	0.	16000.	0.	0.	16000.	28.
8	Oak Flat	0.	0.	9600.	0.	0.	9600.	17.
11	Breckrdg.	0.	0.	6400.	2560.	0.	8960.	23.
9	Blue Mtn.	0.	0.	3840.	0.	0.	3840.	7.
10	Delilah	0.	0.	1920.	0.	0.	1920.	3.
					Man-caused fires			
3	Needles	0.	3000.	7040.	640.	0.	10680.	18.
5	Bald Mtn.	0.	2000.	3200.	0.	0.	5200.	8.
2	Jordan	0.	1000.	7040.	0.	0.	8040.	14.
1	Baker	0.	0.	8320.	3840.	0.	12160.	32.
7	Tobias	0.	0.	5760.	1280.	0.	7040.	16.
6	Mule Pk.	0.	0.	0.	1280.	0.	1280.	6.
4	Buck Rock	0.	1000.	4480.	640.	0.	6120.	12.
8	Oak Flat	0.	2000.	3840.	2560.	0.	8400.	20.
11	Breckrdg.	0.	0.	640.	0.	0.	640.	1.
9	Blue Mtn.	0.	0.	3200.	640.	0.	3840.	9.
10	Delilah	0.	1000.	2560.	0.	0.	3560.	6.

[1] Sum of total acreage seen (and not covered by higher-ranking lookouts) multiplied by the fire intensity factor (number of fires/acre) of each zone.

SAMPLE PROBLEM

The net discovery index and net acreage within each seen area are shown for both man-caused and lightning fires in *table 2.*

The sum of the net-discovery indexes for lightning and man-caused fires are shown in *table 3.* Columns 1 and 2 show the results of the computerized method and the Sequoia National Forest work respectively. The third column shows the actual number of fires within a 15-mile radius of each lookout.

If we assume a net discovery index of 50 as a cutoff value (U.S. Forest Service 1971) for acceptable lookouts, we need to consider eliminating two additional lookouts. The evaluation of the Tobias lookout by the Sequoia National Forest included 180,000 acres of low intensity acreage in the seen area of the Tobias lookout. Inclusion of this amount of acreage on the basis of 345 fires within the 15-mile radius and 85 fires within its seen area is subjective and tends to overcredit lookouts. Further differences in net discovery indexes between the two methods can be attributed to the seen areas, definition of intensity zones, and computational techniques.

One program option is the visual display of seen areas by means of a digital plotter. The seen area generated for the Baker Mountain lookout by the program is compared to the seen area used by the Sequoia National Forest for the Baker mountain lookout (*fig. 3*).

The difference in seen areas in the comparison may be due to both the difference in methods used to generate the seen area and the accuracy of the data used. Any seen area generated by an office procedure or a computer should be carefully checked out in the field for accuracy. Any method used to generate seen areas will present unique problems and differences in actual seen areas generated from other existing procedures.

The purpose of the model is to facilitate fire

Table 3—*Net discovery index*[1] *values obtained by computer and manual analyses, and number of fires within 15 miles of each lookout*

Lookout	Computer analysis	Manual analysis by the Sequoia National Forest	Fires within 15-mile radius
Needles	137	135	612
Bald Mountain	130	127	487
Jordan	97	76	451
Baker	70	80	417
Tobias	48	136	345
Buck Rock	40	65	211
Oak Flat	37	18	426
Mule Peak	35	18	426
Breckenridge	24	23	149
Blue Mountain	16	14	164
Delilah	9	14	117

[1] Sum of total acreage seen (and not covered by higher-ranking lookouts) multiplied by the fire intensity factor (number of fires/acre) of each zone.

detection *planning* and to generate a relative ranking of lookouts by using the geometry of the seen areas and intensity zones. In long-range fixed detection and aerial detection planning, a small consistent percentage error in seen areas will have an insignificant effect.

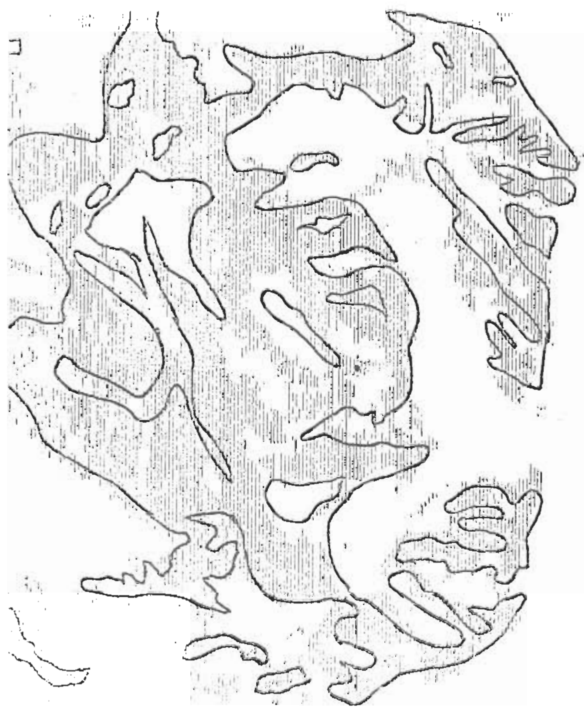

Figure 3—A comparison shows the seen area (parallel vertical lines) generated by computer for the Baker Mountain forest fire lookout, and the seen areas (solid lines) used by the Sequoia National Forest for lookout.

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The Author

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