A Fire Danger Rating System for Hawaii

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Extremes in rainfall on the Hawaiian Islands make it difficult to judge forest fire danger conditions. The use of an automatic data collection and computer processing system helps to monitor the problem.

UNTIL recently, fire protection agencies in Hawaii have always relied on past experience to estimate fire danger.[1] This subjective judgment is being replaced by a more objective method — a computerized system for rating relative fire potential based on indexes derived from weather and fuel conditions.

The problem of forest fires in the Hawaiian Islands differs greatly within short distances. Rainfall ranges from more than 200 inches on the windward side to less than 25 inches on the leeward side, a distance of about 10 miles. Amount of precipitation can change drastically with changes in elevation. For example, Hilo, on the island of Hawaii, has nearly 150 inches of rainfall annually, while the forests above Hilo receive more than 200 inches. Even so, fires often break out during the short periods of drought common to the Hilo area.

Vegetation grows rapidly in Hawaii's subtropical climate, but also dries rapidly during periods of drought. The buildup in fuels may be considerable. Such plants as fountaingrass, false staghorn fern, and broomsedge provide excellent fuel beds for ignition and quick fire spread.

Fires occur more often on Oahu than on the other islands. The number of forest and brushland fires on Oahu ranged from 400 in 1967 to 1200 in 1972. In February 1970, one fire burned 4200 acres. The largest fires, however, have occurred on the island of Hawaii.[2] A fire in September 1969 burned vegetation on 37,000 acres. In recent years, the area burned annually on state-protected forest and brushlands has averaged 14,000 acres, ranging from 3100 to 45,800 acres.

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Most wildfires are caused by human carelessness. These include debris burning, children playing with matches, and military maneuvers. Fires occasionally result from volcanic activity. Only one case of lightning-caused fire has been documented.

NATIONAL FIRE DANGER RATING SYSTEM

The U.S. Forest Service's National Fire Danger Rating System[3] provides the basic means for rating forest fire danger in Hawaii. It produces six indexes — ignition, spread, energy release, occurrence, burning, and fire load — for estimating fire potential. Mathematical models used in the System incorporate the effects of a wide variety of weather conditions, fuel types, and topography. Nine different models for wildland fuels are available.

The fine fuel model was selected for application in Hawaii because it is the simplest to implement and because it characterizes much of the local wildland fuel situation; much of the local fuels comprise living and dead herbaceous plants and dead woody plant materials less than one-fourth inch in diameter.

Fire Danger Zones

Because fire danger and occurrence differ greatly in various parts of Hawaii, it was necessary to define danger zones. Maps on vegetation type, rainfall, and fire occurrence provided the basic information for delineating the zones for the five largest islands (Figure 1). Some areas were not rated because of very high annual rainfall or lack of vegetation there.

The zone boundaries delineate areas having significantly different fire problems or potentials. As more is learned about fire danger and occurrence, zone boundaries may be revised.

Weather Data

To monitor the weather, it was necessary to set up a network of weather stations on the major islands. The National Weather Service maintains an extensive network of stations throughout the island chain. These stations are a primary source of the fire weather data. Several stations were added to provide information from data-scarce areas (Table 1).

Weather observations are recorded daily, between noon and 2 P.M. Each station observes cloudiness, dew point, wind speed, 24-hour precipitation, past weather, and maximum and minimum temperature.

Computer Facilities

To compute indexes of fire danger, a computer processes the weather data. We were able to fully automate the computations largely through the cooperation of the U.S. Navy, which has provided its CDC 3100 computer at Pearl Harbor for our daily use. The computer program we use is FIRDAT, a FORTRAN IV program that calculates National Fire

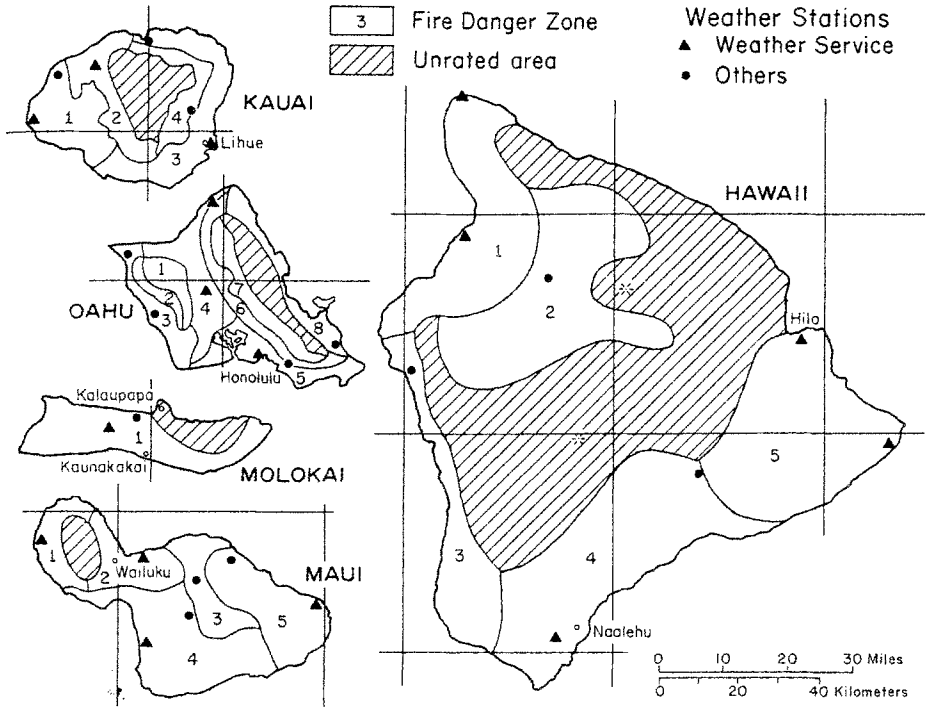

Figure 1. Hawaii Fire Danger Rating System — fire danger zones and weather station maps.

Danger Rating System indexes from historical fire weather records.[4] We developed a simplified version of FIRDAT, tailored to the fine fuel model. Calculations not relating to this model were omitted entirely. The modified program can be executed in about one-third of the time required by the original FIRDAT program. Speed is achieved at the expense of flexibility, however, and the proper balance will vary with application.

Communication Procedures

The task of collecting input and disseminating output through a network comprising insular stations spanning some 300 miles might have been formidable, except for the combined efforts of federal and state agencies that have a common concern in forest fires. The National Weather Service, the U.S. Navy, and the Hawaii State Civil Defense have played a large role in establishing a Hawaii Fire Danger Rating System.

The 2 P.M. weather observations are telephoned daily to the local National Weather Service Office on each major island (Figure 2). Each office, in turn, encodes the data and incorporates them into the 2 P.M. synoptic report. The report is teletyped to the National Weather Service Forecast Office at the Honolulu International Airport, and also to the U.S. Navy's Fleet Weather Central. National Weather Service forecasters then use the current day's observations in developing 24-hour forecasts. The predicted weather parameters are then teletyped directly to Fleet

TABLE 1. *Weather Stations and Weather Observers in the Hawaii Fire Danger Rating System*

Island and Station	*Observer or Agency*
Kauai:	
Hanalei	Kauai County Fire Department
Makaha Ridge	Dynalectron
Kokee*	Hawaii Air National Guard
Barking Sands*	National Weather Service
Lihue Airport*	National Weather Service
Wailua Mauka	University of Hawaii
Oahu:	
Waialee*	University of Hawaii
Kaena Point*	U.S. Air Force
Lualualei	U. S. Navy
Wheeler AFB*	U. S. Air Force
Honolulu Airport*	National Weather Service
Waimanalo	University of Hawaii
Molokai:	
Molokai Airport*	Aloha Airlines
Palaau	Hawaii State Parks
Maui:	
Kaanapali*	Amfac Properties, Inc.
Keawakapu*	A. L. Corell
Kahului Airport*	National Weather Service
Kula	University of Hawaii
Kailua	East Maui Irrigation Company
Hana*	Royal Hawaiian Airlines
Hawaii:	
Upolu Point*	U. S. Coast Guard
Puako*	Erwin Rapp
Kona	Hawaii County Fire Department
Halemaumau	Geological Survey
Kapoho*	Genevieve Arruda
Hilo*	National Weather Service
Waikii	Parker Ranch

* A first- or second-order National Weather Service station.

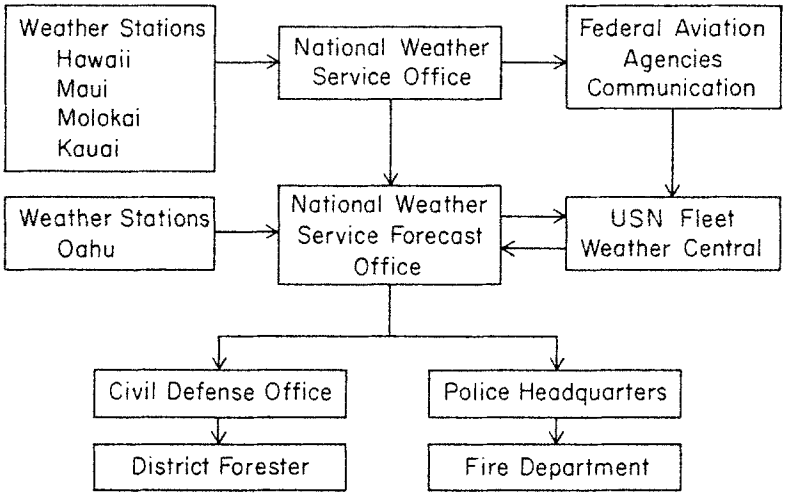

Figure 2. Current and predicted indexes of fire danger are sent to the field by the National Weather Service Forecast Office after it receives computer-processed weather data.

Weather Central, and processed along with the current day's weather data on the computer.

The computer produces a punched paper tape that is used to transmit both the current day's fire danger indexes and the 24-hour forecast indexes to the Weather Service Forecast Office (Figure 3). From there, the indexes are entered directly into the Hawaii State Civil Defense teletype network. The indexes are received at both the State Civil Defense Office and the Police Headquarters on Kauai, Oahu, Maui, and Hawaii, and also at the Honolulu Fire Department's Alarm Bureau on Oahu. The District Foresters obtain the indexes from those offices.

Collection and Processing of Weather Data

Weather data from locations throughout the Pacific are teletyped to Fleet Weather Central on six circuits and are recorded on magnetic tape for subsequent scanning. Fire weather data are received in World Meteorological Organization synoptic format, grouped under a specific collective heading. A data preparation subprogram searches for this collective heading and extracts the data group upon finding it. A sorting subprogram arranges the randomly stored data into a sequence ordered by station number. Since duplication of station data is possible up to this point, the sorting subprogram checks for duplicates and deletes any encountered.

After sorting is completed, the computer utilizes the weather data

FOR HAWAII CIVIL DEFENSE
HAWAII FIRE DANGER INDEXES FOR 00Z 29 JAN 74

STATION	T	RH	FF	PPP	FFM	IC	SC	ERC	OI	BI	FLI
KOKEE (161)	57	93	2	0	23.4	0	1	0	0	0	0
BARK SANDS (162)	78	57	6	.04	8.2	37	7	9	37	2	1
LIHUE (165)	78	65	8	.31	31.0	0	0	0	0	0	0
WAIALEE (169)	77	69	4	0	9.9	28	3	8	28	1	0
WHEELER (170)	78	54	8	.07	7.8	39	7	10	39	3	1
HONOLULU (182)	75	64	8	0	31.0	0	0	0	0	0	0

FOR HAWAII CIVIL DEFENSE
FORECAST FOR HAWAII FIRE DANGER INDEXES

(EFFECTIVE 24 HOURS FROM 00Z 29 JAN 74)

STATION	T	RH	FF		FFM	IC	SC	ERC	OI	BI	FLI
KOKEE (161)	60	82	5	0	11.5	19	5	7	19	2	0
LIHUE (165)	78	65	10	0	9.2	31	9	9	31	3	1
WAIALEE (169)	77	73	10	0	10.2	26	8	8	26	2	1
HONOLULU (182)	77	65	10	0	9.2	31	11	9	31	3	1
MOLOKAI AP (186)	78	69	10	0	12.8	14	7	6	14	2	0

Figure 3. Printouts of current and predicted fire danger indexes list dry bulb temperature (T), relative humidity (RH), wind speed (FF), 24-hour rainfall amount (PPO), fine fuel moisture (FFM), ignition component (IC), spread component (SC), energy release component (ERC), fire occurrence index (OI), burning index (BI) and fire load index (FLI).

in executing the modified FIRDAT program. Flow of execution is essentially the same as in the original FIRDAT.

An output subprogram provides fire indexes that fill these needs: (a) the immediate dissemination of the computed values; (b) hard-copy for quality checks and future reference; and (c) a data bank on magnetic tape for archiving and subsequent statistical analysis. This computer processing routine is performed once daily at about 3 P.M. Execution time takes 1 to 2 minutes, and data transmission at least 3 more minutes. The entire computer program requires 11,000 locations — 7000 for instructions and the remainder for storage of observation data and program constants.

FIRE WEATHER FORECASTS

The National Weather Service Forecast Office at Honolulu prepares a 24-hour forecast every midafternoon, covering dry bulb temperature, cloudiness, wind speed, and amount of precipitation. Currently, these forecasts cover nine of the twenty-five operating fire weather stations. Forecast confidence is highest for Hilo Airport, Kahului Airport, Honolulu Airport, and Lihue Airport, these being the only first-order stations in the network and the stations with which the forecasters have had the most experience. Forecasting will begin for the other fire weather stations when a sufficient data base is built.

DROUGHT INDEX

In addition to indexes provided by the National Fire Danger Rating System, one other index is being used in Hawaii — the drought index developed by Keetch and Byram.[5] They defined the index as "a number representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff or upper soil layers." The drought index is a measure of long-term accumulative drying, which generally relates to the flammability of organic material in the ground. Drought index values range from 0, a condition in which the soil and duff are fully wet, to 800, which indicates soil moisture is not available for plant growth.

The drought index is being used to provide a scale for estimating drying conditions over large areas. In the future it may provide an objective means of evaluating the herbaceous stage of grasses or flushes of plant growth and also provide estimates of brush fuel moisture contents.

As with differences in precipitation, drought patterns vary widely from place to place in Hawaii. Figure 4 shows the drought index curves for Wheeler Air Force Base on Oahu and for Hilo Airport on Hawaii, for the years 1968–1970.

The drought index is computed manually each day because core storage is not available on the Navy computer to retain the previous day's drought index and precipitation data for each weather station in the network.

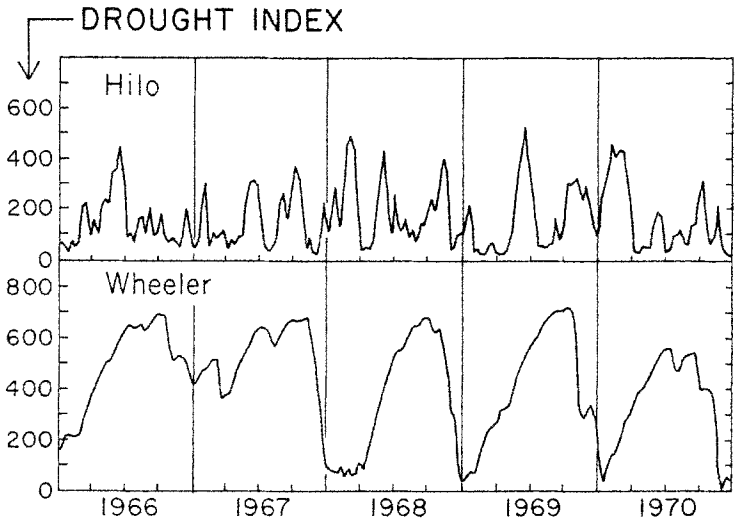

Figure 4. Drought index curves — July 1968 to December 1970.

The Hawaii State Division of Forestry has been the primary user of the system to date. It has used the system to determine when to cancel burning permits, when to adjust preparedness levels, to develop guidelines for helicopter use, and for pre-attack planning.

Various county fire departments have also expressed an interest in utilizing the system.

Future work on the system should include studies to develop basic data for fuels that are unique to Hawaii. Other mathematical models in the National Fire Danger Rating System will need to be incorporated in the State's system. The use of a single model — fine fuel — to represent all the fuel types in Hawaii is an obvious oversimplification. The 24-hour forecast of fire danger indexes, now being prepared for only nine stations, should be expanded to cover all other stations in the network.

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ACKNOWLEDGMENTS: The authors thank the following agencies and individuals for their contributions to this study: Hawaii Division of Forestry; U. S. National Weather Service; U. S. Navy; Hawaii State Civil Defense Office; Walter Yee, University of Hawaii Computer Center; Myron Kerner, William Taliaferro, and Saul Price, National Weather Service; Mark J. Schroeder; and Robert E. Nelson, U. S. Forest Service.