An Aid to Streamlining Fire-Weather Station Networks

USDA Forest Service
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Rocky Mountain Forest and
Range Experiment Station
Forest Service
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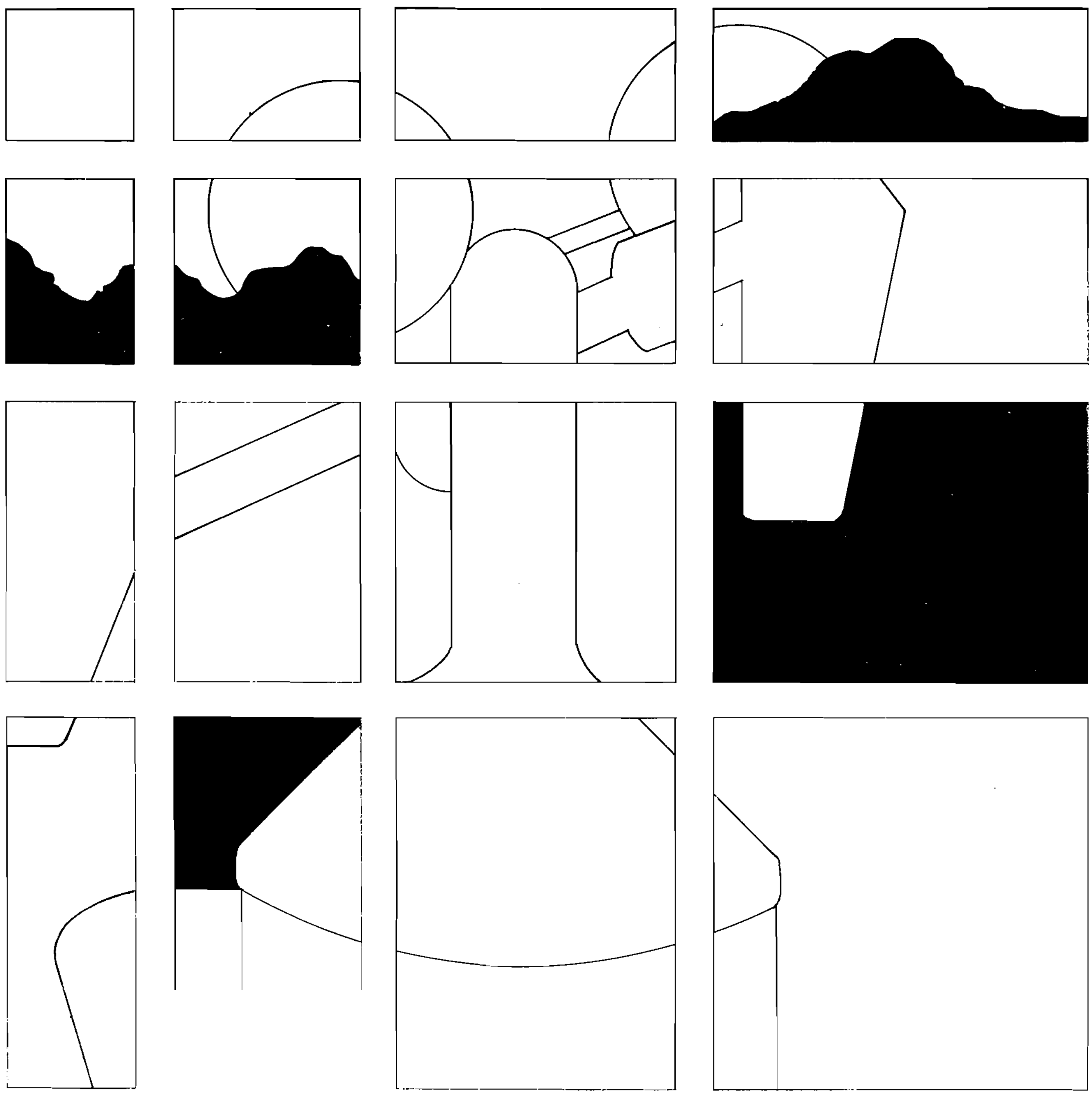
Fort Collins, Colorado 80521



Abstract

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The last paragraph on page 2 of the above publication contains a word transposition error. The words "vertical" and "horizontal" should be transposed in the sixth line from the bottom of the page. The corrected line should read:

horizontal line dividing the "2" vertical box would

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R. William Furman[1]

The Situation

The network of fire-weather stations which supports the National Fire Danger Rating System is changing continuously as new stations are added and existing stations are closed. Studies are currently underway to help the fire manager determine how many observation stations are necessary in his part of the country to adequately monitor the fire danger.

In the meantime, however, economic factors must be considered along with fire danger in determining the number of stations needed in a protection area. If it becomes necessary to reduce the number of observation sites on a protection unit, the task should be done in a manner that will minimize the impact on the ability of the fire manager to accurately assess the overall fire danger. A step toward this objective is to determine which stations monitor similar fire climates. Candidates for elimination may include those stations that duplicate effort.

Any reduction in the number of observation stations in an area will result in a decrease in the amount of information available to assess fire danger. Factors other than complete knowledge of fire danger must sometimes be considered, however. A method is needed that will provide guidance for deciding if—and where—there is duplication of effort in monitoring some components of fire weather. It is the intent of this paper to propose a technique to determine the location and degree of similarities of some elements of fire danger being monitored.

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What is Fire Climate?

Fuel moisture content controls fuel ignition and strongly influences fire behavior. Moisture content is determined by the ambient and sometimes prior environmental temperature and humidity. Since ignition takes place in the fine fuels (1-hour timelag), and since fine fuels are common to all fuel models in the National Fire Danger Rating System, we will focus on the relationships between fire climate and the moisture content of the 1-hour timelag fuels. Although wind is a major weather input into NFDRS calculations, it is so variable that we did not include it in these similarity comparisons. It is a factor that would have to be considered, however, in any final decision to eliminate any stations.

The moisture content of fine fuels was related to their equilibrium moisture content (EMC) by Fosberg and Deeming (1971). The EMC is the moisture content a fuel particle will reach if left in constant environment for an infinitely long time. EMC has been related to temperature and humidity by Simard (1968). The moisture content of the smaller fuels reaches equilibrium with the environment very quickly. For this reason, it is not a bad first approximation to assume that the smaller fuels are constantly in equilibrium with their environment, and have a moisture content specified by the ambient temperature and humidity. Therefore, as a first effort at a quantitative definition of fire climate, we will consider the properties of the EMC.

The fire climate at a point is determined by an array of attributes. Properties of the fire climate at a site that should be measured include:

(1) An estimate of the mean value of the minimum (which normallv occurs dailv at 1400 hours).

(2) An estimate of the dispersion of the 1400h EMC about the mean. This is represented by the coefficient of variation, the ratio of the standard deviation to the mean.

(3) The day-to-day persistence of EMC represented by the 1-day lag autocorrelation of the daily EMC's.

(4) An estimate of the mean diurnal variation of EMC. The diurnal variation was computed by subtracting the minimum EMC from the maximum EMC for a 24-hour period. These maximum and minimum EMC's can be computed from minimum temperatures and maximum relative humidities, and from maximum temperatures and minimum relative humidities, respectively.

(5) The coefficient of variation about the mean daily variation.

(6) The day-to-day persistence of the daily variation.

These six statistics of the EMC define fire climate. The first three are fairly good discriminators of aspect effects while the latter three tend to discriminate elevation effects (Furman 1974).

A Brief Resume of the Method

For completeness, a brief but technical description of the similarity analysis methodology is given. If the reader is not interested in the technical aspects, he may go to the next section for an example of how the method is used, and the results.

The analysis is performed for the fire season or a portion of it. So as not to eliminate any seasonal trend by averaging, the season is divided into consecutive 10-day periods. There is nothing special about intervals of 10 days; it is just a convenient period over which to sample the fire climate. If an observation is taken each day, the amount of data in each period is 10 days per year times the number of years of data. All six variables are then determined from the data in each of the periods, and collectively are considered as defining the fire climate. If a fire season were 40 days long, for example, then the number of variables for each station used in the analysis would be 6 per period times 4 periods equals 24 variables. Principal component analysis is then used to reduce this large number of variables to a few meaningful combinations.

Principal component analysis is a multivariable statistical method that can be used to express the original variation in terms of a few variables that are linear combinations of the original variables (Morrison 1967). The method has been used in many forestry applications such as taxonomic research (Jeffers 1966), site classification (Fourt et al. 1971), and climate regionalization as related to tree species distribution (Newnham 1968).

The new variables (or combinations) for each station are then used in a clustering program called ISODATA (Ball and Hall 1965), to group the stations into any desired number of clusters. The result is an arrangement of stations into groups or clusters with a minimum of variation among stations within each cluster, and a maximum amount of variation among clusters.

If constraints are such that the existing station network must be reduced by a certain number of stations, then the approach should be to minimize duplication by removing the stations which are most similar to others. These stations will show up as occupants of the same cluster. It makes little difference which station(s) in a cluster are eliminated.

As an indication of how the removal of a station or stations affects the accuracy of the observing network, we can compare the sums of squared deviations from the original sample means, before and after the removal of the station(s). As stations are removed from the sampling network, the ratio of these sums will decrease from one toward zero.

When the decision has been made as to which stations will be eliminated, the sums of squares ratio with those stations removed will indicate the extent to which the information received from the new network is reduced compared to the original. No criterion is available on what constitutes an optimum, acceptable, or maximum permissible level of reduction. This decision must be based on other factors.

An Example of Station Similarity Analysis: The Boise National Forest

From 1964 to 1970, 12 fire weather stations were operated on the Boise National Forest in Idaho (fig. 1). A decision was made to terminate operations of 3 of the 12 stations after the 1970 fire season. Stations 2, 4, and 8 were closed on the basis of best judgment available. Subsequently, however, we used similarity analysis to determine which three stations could have been closed with least impact on fire climate evaluations throughout the Forest.

The season used in the analysis—the months of July and August—was divided into six, 10-day periods. All 36 variables were determined from the 7 years of record. The cluster pattern resulting from the analysis is shown in figure 2. This figure shows the groups of stations, or cluster memberships, for the specified number of clusters on the bottom. One cluster would obviously include all the stations. If we want to separate the 12 stations into 2 clusters, the stations (down the left) which fall above the horizontal ~~vertical~~ line dividing the "2" vertical ~~horizontal~~ box would constitute a cluster, and those which fall below would constitute the second cluster. The same process applies for any number of clusters determined by the horizontal partitions of the vertical box corresponding to the number of clusters desired.

Figure 1.—Fire-danger stations with contours and drainages on the Boise National Forest, Idaho.

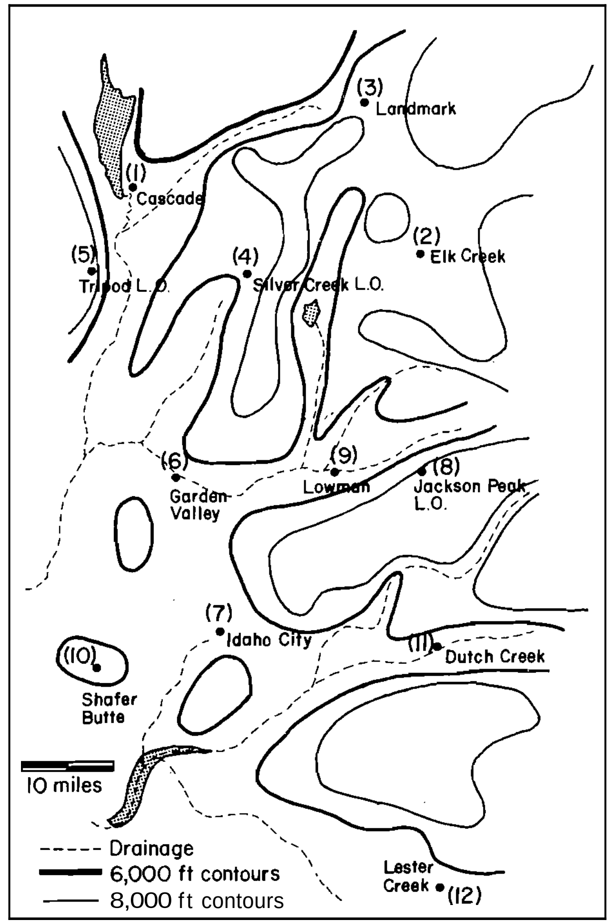
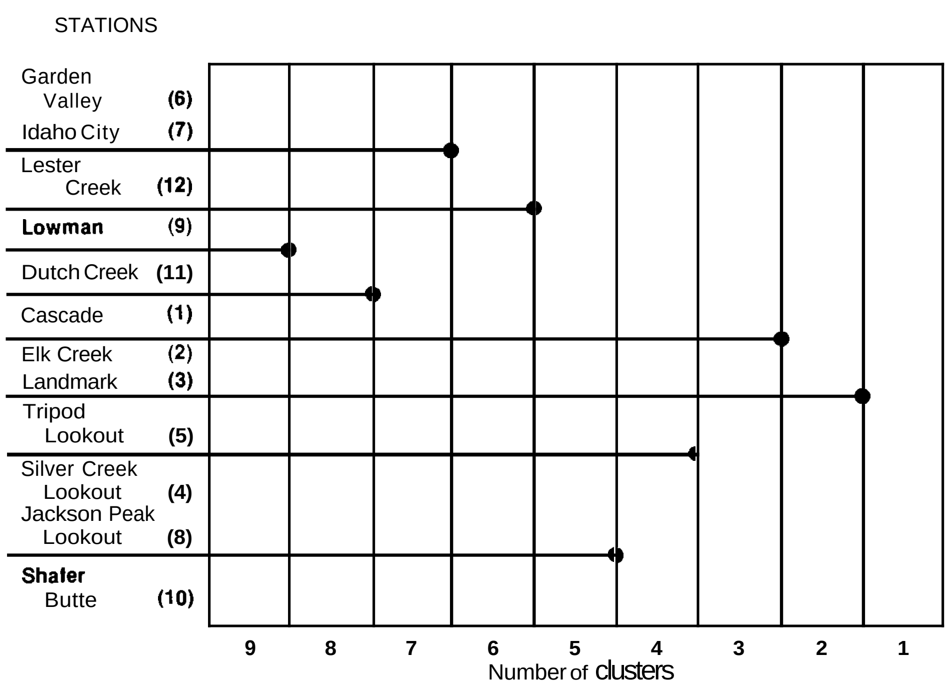


Figure 2.—Clusters of stations based on increasing levels of climate discrimination. Horizontal lines separate the stations (in the left margin) into the number of clusters indicated at the bottom of the figure. Cluster membership is determined by how the stations are grouped by the horizontal lines.



Since our problem was to reduce the network of 12 stations to 9, we were interested in how the stations could be arranged into 9 clusters. Looking at the divided box for nine clusters in figure 2, we see that three of the clusters are pairs of stations: (1) Garden Valley—Idaho City; (2) Elk Creek—Landmark; and (3) Silver Creek Lookout—Jackson Peak Lookout. This indicates that the two stations in each pair have fire climates that, according to our definition, are very similar. Therefore, one of each of these pairs should be considered for elimination. The remaining station of the pair would be a sufficient indicator of the climate at both locations. If three stations were to be eliminated, the loss of these three should minimize the loss of fuel-moisture information assessing fire danger on the Boise National Forest. One should keep in mind that wind must be considered separately, however.

The stations that have minimum impact on the sum-of-squares ratio (sum of squares final/sum of squares initial) are Landmark, Garden Valley, and Jackson Peak Lookout. They would be primary candidates for closure. Removing these stations from sampling network gives a sum-of-squares ratio of 0.83. This may be interpreted as meaning that the remaining 9 stations would monitor 83 percent of the variation that the original 12 stations monitored

Our technique suggests that all of the actually eliminated stations—2, 4, and 8—were among those to be considered for closure. However, stations 4 and 8 formed a pair that monitored a climate different from the rest down to the four-cluster level. Thus, current information about the areal distribution of fire danger is not as complete as if one of the pair 4,8 were still operational and one of the pair 6,7 had been removed.

Summary

The purpose of fire weather observation networks is to monitor the "average worst" fire danger conditions. In the mountainous West, this condition normally exists at midelevation on a south to west aspect. Thus the purpose specifies the location of fire weather stations. A second but no less important consideration for locating an observation station is that it monitor a climate representative of that which exists in the protection area. In other words, the weather measured at the local airport most likely does not monitor the "average worst" conditions on a nearby protection unit, and may not even be representative of the "average" weather conditions on that unit. These factors must be considered when evaluating the effectiveness of a fire weather station. Also, any reduction in the number of fire weather stations in an area reduces the information available to evaluate fire danger in that area.

The purpose of this paper is to present an analysis technique to aid fire managers if it becomes necessary for them to reduce the size of their fire weather observation networks. The variables used are related more to fire climate than to fire danger, and the variability of wind was not considered in the method.

The result of the data analysis technique proposed is information on the similarity structure of fire climates monitored in a protection area. Such information, in conjunction with other considerations, may be useful in streamlining fire weather monitoring networks.

Literature Cited

Ball, Geoffrey H., and David J. Hall.
1965. ISODATA, A novel method of data analysis and pattern classification. Tech. Rep. Stanford Res. Inst. Menlo Park, Calif.

Fosberg, Michael A., and R. William Furman.
1973. Fire climates in the Southwest. Agric. Meteor. 12:27-34.

Fosberg, Michael A., and John E. Deeming.
1971. Derivation of the 1- and 10-hour timelag fuel moisture calculations for fire danger rating. USDA For. Serv. Res. Note RM-207, 8 p., Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Fourt, D. F., and D. G. M. Donald, J. N. R. Jeffers, and W. O. Binns.
1971. Corsican pine. (*Pinus nigra* var. *maritima* (Ait.) Melville) in Southern Britain. A study of growth and site factors. Forestry, XLIV, 189-207.

Furman, R. William.
1974. A study of the regionalization of wildfire climates. Ph.D. Diss. Colo. State Univ., Ft. Collins, Colo.

Jeffers, J. N. R.
1966. Principal component analysis in taxonomic research. Int. Adv. Group Forest Statist. IUFRO. Rapp. Uppsatser. Inst. Skoglig. Mat. Statist., Skogshogskolan, Stockholm, 9:138-159.

Morrison, Donald F.
1967. Multivariate Statistical Methods. McGraw Hill Book Co., New York, 338 p.

Newnham, R. M.
1968. A classification of climate by principal component analysis and its relationships to tree species distribution. For. Sci. 14:254-264.

Simard, A. J.
1968. The moisture content of forest fuels. I. A review of basic concept. Inf. Rep. FFX-14, 46 p. For. Fire Res. Inst., Ottawa, Ont.

Agriculture—CSU, Ft. Collins

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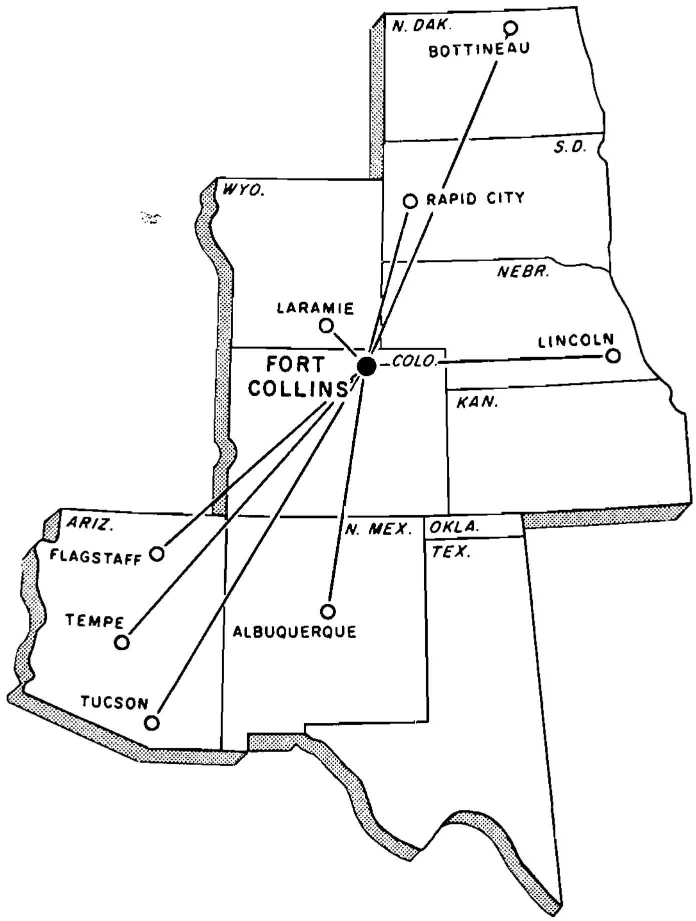
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