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Influence of forest openings on climate

Diane Ringger
University of Wisconsin-Milwaukee

Forest Stearns
University of Wisconsin-Milwaukee

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INFLUENCE OF FOREST OPENINGS ON CLIMATE

Grasslands, marshes and forests become established and survive because the initial invading species are adapted to the prevailing climate and soils. As it matures, each plant community alters its internal environment. For example, as a forest develops and tree crowns grow together, the surface where solar radiation is received and from which long wave radiation is dispersed shifts from ground level to the treetops. Within the forest, temperature fluctuations are greatly reduced, moisture in the air is stabilized, and movement of air is reduced. Even after the maple, birch, ash and basswood of the deciduous forest lose their leaves, the bare mass of limbs, twigs and tree trunks influences the internal climate. Not all forests are alike. During the summer, in a vigorous oldgrowth hardwood forest, one may be almost unaware of the external climate. Light rain does not penetrate the forest, the moisture is held in the crowns. Cloud cover has little effect on the understory; even in full sun, less than 5% of the total radiation reaches the ground. Strong winds only ruffle the upper crowns. In contrast, the canopy of a second growth aspen-birch stand is thinner and less regular, much light penetrates to the forest floor and relatively light showers soak through rapidly. Open aspen stands support more vigorous undergrowth than hardwood stands and are more suitable summer habitat for deer. Even so, the aspen canopy influences air temperature and humidity beneath it. Young white pine growing under an open canopy will show less infection by white pine blister rust than trees in the open (Van Arsdel, 1961). This results largely because less dew condenses on the pine under the aspen, in turn reducing rust spore germination.

In the old growth forest, openings were often created by the death of a single tree whose massive crown may have spread 75 to 100 feet. Occasionally, a tree was lost to lightening; more frequently old age and decay were responsible for death. Such openings provided light, stimulating growth and encouraging tree reproduction. Openings soon filled with vigorous young saplings. The old growth forest maintained itself largely through this spot replacement. Openings are also found in the second growth and successional communities of aspen, birch or pine. Occasionally, following fire or logging, a solid grass sod would develop in the absence of tree reproduction. As aspen ages, disease also increases and the death of one or several stems soon creates openings. Wind and ice may also influence second growth stands drastically.

The forester and ecologist have long been aware of the general conditions in forest openings (Geiger, 1965), but only recently have they begun to document the effects of opening size on solar radiation, temperature, and snow accumulation (Brown and Merritt, 1970). Knowledge of the microclimate of forest openings is essential from the viewpoint of forest growth and reproduction

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and also contributes to understanding the relationships of openings to disease, insect abundance, wildlife behavior and water production.

Data presented in this paper were obtained during a five year study by the U.S. Forest Service (Ringger, 1972). This study, done in a hardwood stand in Forest County, Wisconsin sought to determine the effect of opening size upon temperature and moisture. Stations were chosen under a complete forest canopy and in openings ranging from single tree size to those large enough to behave as open fields. Hygrothermographs provided continuous records of temperature and humidity.

Opening size cannot be defined adequately by surface acreage alone. Effective opening size depends upon the height of the surrounding trees; the best measure of opening size is the ratio between the opening diameter and crown height, i.e., the DH ratio (Fig. 1). Our openings ranged from 0.5:1 to 15:1 DH.

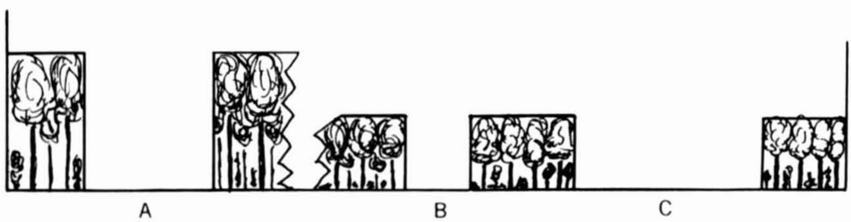

Fig. 1. Diagram illustrating the diameter: height ratio with two crown heights.
A. 1:1 Opening B. 1:1 Opening C. 3:1 Opening

The influence of opening size on temperature (at the center of the opening) is illustrated by temperature patterns from openings of sizes DH 1:1 and 4:1 (Fig. 2). In the small openings (and in narrow east - west strips) the sun reaches the ground only for a short period during the middle of the day and temperatures rise abruptly and fall quickly. In larger openings the ground is warmed for a much longer period and temperature rise and fall are more gradual. In small openings, the abrupt temperature change frequently results in a long period of high humidity which in turn contributes to the larger insect population of small openings and to a greater potential for fungus spore germination. Humidity in small openings is often greater than in the forest interior.

Wind barely penetrates into small or medium openings, (i.e. less than 3:1 or 4:1). For openings of 1:1 or smaller, the wind moves over the surface of crowns with little if any downward mixing. Thinning a forest stand to leave only 50% of the total area covered by crowns, has little effect on wind movement. The effective surface remains at the crown level.

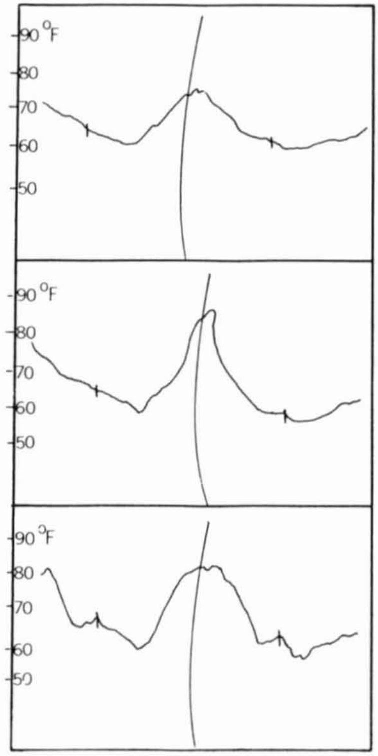

Fig. 2. Temperature record in the forest and at opening centers on a clear day, July 23, 1967. Top: Under the hardwood canopy, Center: In a 1:1 opening; and Bottom: In a 4:1 opening. The central vertical line indicates noon and the short lines - 6 A.M. and 6 P.M.

Cloud cover influences the temperature relationships of openings since incoming solar radiation is a major factor driving the temperature changes. If one plots the maximum and minimum temperatures within each of several openings (Fig. 3), the effect of size is evident. Minimum temperatures are little affected in openings smaller than 1:1, but as the opening is enlarged, there is increased opportunity for outgoing radiation during the night. In the large opening, there is also proportionately less heat radiating from tree trunks and crowns to warm the opening. Maximum temperatures remain low in openings smaller in size than DH 1:1, but there is a rapid increase with size and the highest maximum temperatures are reached in openings of approximately 1.5:1 to 2:1. Maximum temperatures decrease somewhat as the openings become larger. The 1.5:1 or 2:1 opening permits sufficient solar radiation to reach the ground to raise temperatures rapidly with a minimum of wind movement and of convective transfer of heat. Specific relationships between opening size and temperature and other climatic factors vary with season and latitude; the position of the sun obviously influences the energy received in the opening.

After autumn leaf-fall and before spring green-up, differences between openings are greatly reduced (Fig. 3). The solar energy accumulated in tree trunks and radiated out as heat helps to maintain somewhat higher minimum temperatures in the forest and in small openings as compared to open fields.

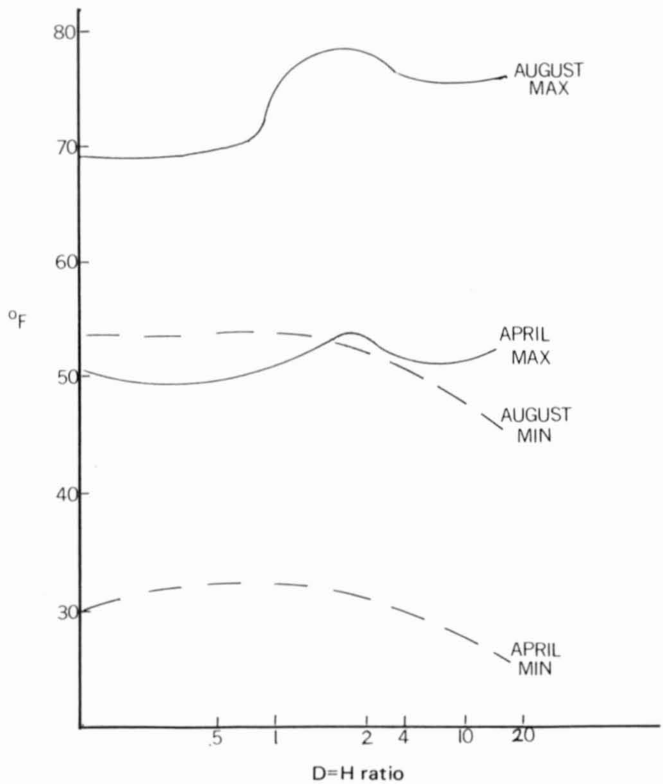

Fig. 3. April and August average maximum and minimum temperatures for openings of different sizes.

DISCUSSION

The evident effect of opening size on temperatures as well as the differences in relative humidity and wind have numerous implications for forest management. Growth of understory plants and forest reproduction are influenced by average temperatures as well as by extremes. Smaller openings are likely to have a longer frost free period, in contrast to larger openings (over 6:1 or 10:1) which in northern Wisconsin may experience frost every month of the summer.

Mosquitoes and deerflies were more abundant in the small and medium size openings (below 6:1) than in the large ones. This is partly a function of higher humidities in the small openings and of increased wind and greater temperature extremes in the larger openings. We originally assumed that deer would avoid smaller openings with high insect populations and might escape into large openings during the peak of the insect season. This does not appear to be true. Apparently factors other than opening size or insects cause deer to prefer medium size openings (McCaffery and Creed, 1969).

For human comfort, desirable opening size varies with forest type and recreational activity. Small openings, receiving sun for only a brief period, are poor places to camp. Likewise, large openings should be avoided in colder weather when minimum temperatures may fall far below those in the forest. For maximum human comfort, openings should provide a relatively long period of solar radiation at the campsite. Usually shading from afternoon sun and sufficient clearing to permit good air circulation are desirable.

Within large openings, temperature regimes vary from site to site and also influence plants and animals. Many specific questions remain concerning plant reproduction and animal activity that must be resolved if forest openings are to be successfully managed.

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Diane Ringger and Forest Stearns
Department of Botany
The University of Wisconsin–Milwaukee