Monitoring the Effects of Partial Cutting and Gap Size on Microclimate and Vegetation Responses in Northern Hardwood Forests in Wisconsin

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Abstract.—Silviculture modifies the environment. Past monitoring of silvicultural practices has been usually limited to vegetation responses, but parallel monitoring of the environment is needed to better predict these responses. In an example of monitoring temperatures in two studies of northern hardwood forests in Wisconsin, we found that different silvicultural practices modified the environment significantly. Temperatures become more extreme as openings in the forest canopy become larger. Temperatures in some cases reached lethal levels. By monitoring the microenviroment along with vegetation responses to different silvicultural practices, we can learn how to grow specific plants or plant communities by adapting the current silvicultural guides.

INTRODUCTION

Silvicultural systems for northern hardwood forests in the upper Great Lakes region include both even- and uneven-age management. The guidelines for tending these forests and the results of their use are well-established (Arbogast 1957; Burns and Honkala 1990; Erdmann 1986; Niese et al. 1995; Strong et al. 1995; Tubbs 1977) and have been used over thousands of acres of public, private and industrial forest lands for several decades. These guidelines cover a continuum of forest overstory conditions from clearcuts to single tree selection.

Because these guidelines have been used extensively and results assessed over many combinations of stand and site conditions, it is now recognized that some adaptations are needed to ensure that tree and other plant species composition, distribution, and growth can be managed to meet timber production, biodiversity, wildlife habitat, aesthetic, and other management objectives. The current guidelines tend to favor the establishment of sugar maple, meeting some management objectives but not others. Furthermore, recent studies in northern hardwoods have substantiated the observation that single and multiple tree gaps created by wind, insects, disease and other factors are of primary importance in maintaining species composition and that incorporating gaps into silvicultural systems for northern hardwoods is important for many management objectives (Canham and Loucks 1984; Erdmann 1986; Frelich and Lorimer 1991; Lorimer and Frelich 1994).

Monitoring the physical environment following silvicultural treatments provides information on the immediate changes in light quantity and quality, soil and air temperature, wind, and other factors. This information describes the immediate change in the availability of resources and the important initial potential for establishment and growth of species with varying requirements for light, water, and nutrients. Longer term monitoring of these variables allows silviculturists to assess change as the forest develops following a prescribed silvicultural treatment and perhaps more importantly to correlate the composition and growth of trees and associated plants with the availability of resources as affected by the treatment.

The objective of the work described in this report, is to describe the effects of a range of different-size, purposefully created canopy gaps and stand level canopy conditions on the temperature regime of managed stands of northern hardwoods in northern Wisconsin. We recognize that temperature interacts with light, water and nutrient availability to provide the resource environment for plant growth. However, temperature—both extreme events (for example frost) and more general growing season conditions—is important in these forests. By itself, temperature affects the physiological processes that result in the phenological and growth patterns that we observe and measure. Compared to the other resources, temperature is relatively inexpensive to measure and thus point-to-point variation is easier to illustrate than similar scale variation in the other resources.

Here we report brief results of two studies to describe how by monitoring microclimate, we can better communicate the values and benefits of silviculture to landowners. Our work builds on the more general work described in Geiger (1965) and earlier work in these forests (Ringger 1972; Ringger and Stearns 1972).

STUDIES

Partial Cutting

We are conducting this study to document meteorological/environmental conditions, and to correlate plant composition and density to the specific conditions rendered by the various partial cutting treatments. The study consists of four 8-ha blocks each thinned to a different overstory density including a clearcut, 50 percent crown cover, 75 percent crown cover and a control.

Meteorological monitoring stations were installed in the center of the clearcut, 50 percent crown cover, and control blocks in 1993. Air and soil temperature profiles are continuously monitored at 10, 2, 1, 0.75, 0.5 and 0.25 m aboveground and 0.05, 0.1, 0.2, 0.5, and 1.0 m belowground.

Canopy Gap Study

We are conducting this study to understand the function and dynamics of canopy gaps in northern hardwood ecosystems,

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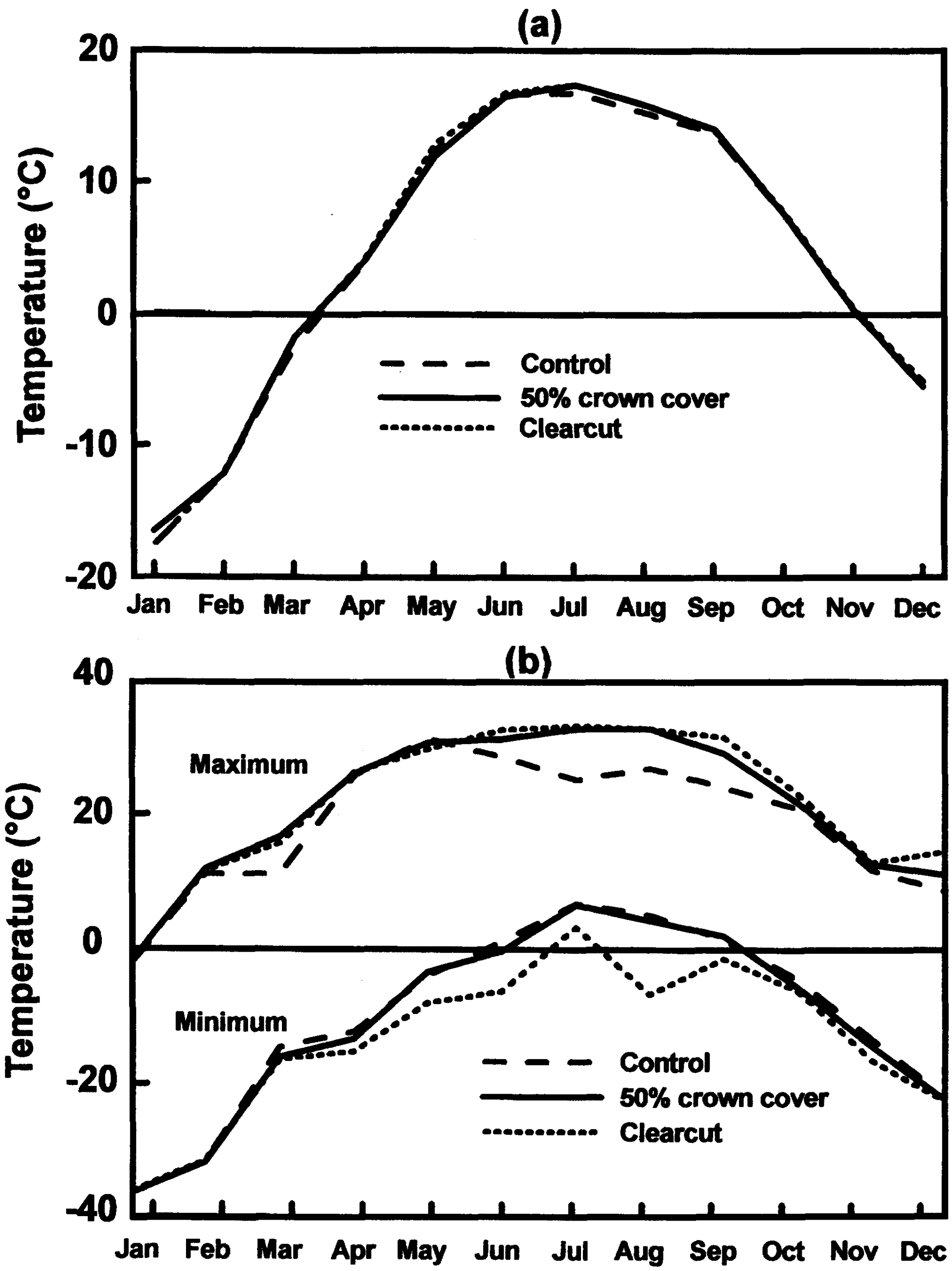

Figure 1.—Average (a) and maximum and minimum (b) monthly temperatures for the control, 50 percent crown cover, and clearcut treatments in the partial cutting study 1.0 m above the ground, 1994.

and the response of the biotic community—flora and fauna—to the changes in microclimate resulting from canopy gaps of different sizes. Gap sizes being studied are: 5.5, 10, 20, 30, and 45-m in diameter, and a control.

Temperatures are recorded from 13 locations within each of three of the gap sizes (control, 20 m, and 45 m diameter gaps). These are located at the center, midway between center and canopy edge, the canopy edge, and 5 m beyond the edge and beneath the canopy along an east-west and north-south transect of each gap. At each sampling point, temperatures are recorded at 1.0 and 0.1 m aboveground and at 0.03 and 0.15 m belowground.

RESULTS

Average Monthly Temperature

Average daily or monthly temperatures differed among treatments in the partial cut study (Figure 1). However differences were distinct in the temperature range (maximum to minimum variation) in both studies (Figures 1 and 2). This variation was more evident during the growing season than during the dormant season. Temperatures were cooler at night and warmer during the day in the clearcut and 45-m gap treatments than in the control. Average maximum temperatures were warmer and average minimum

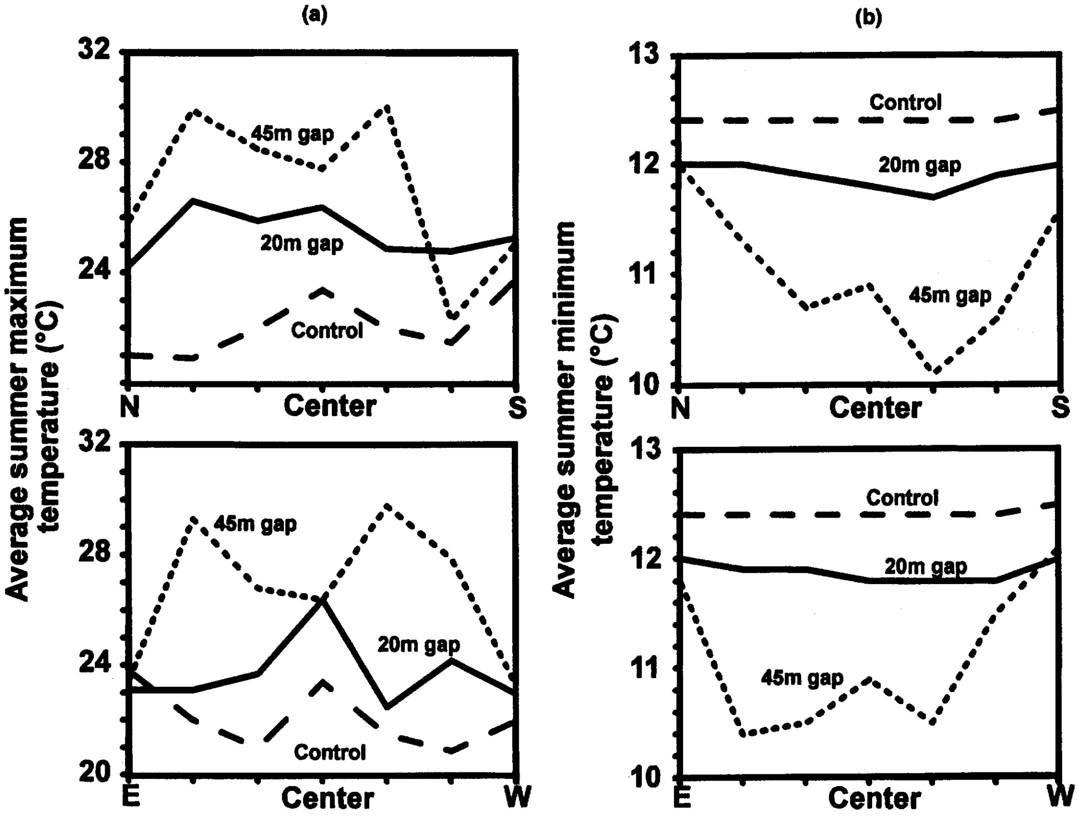

Figure 2.—Average summer maximum (a) and minimum (b) temperatures for the control, 20-m gap, and 45-m gap treatments in the canopy gap study 0.1 m above the ground, 1995.

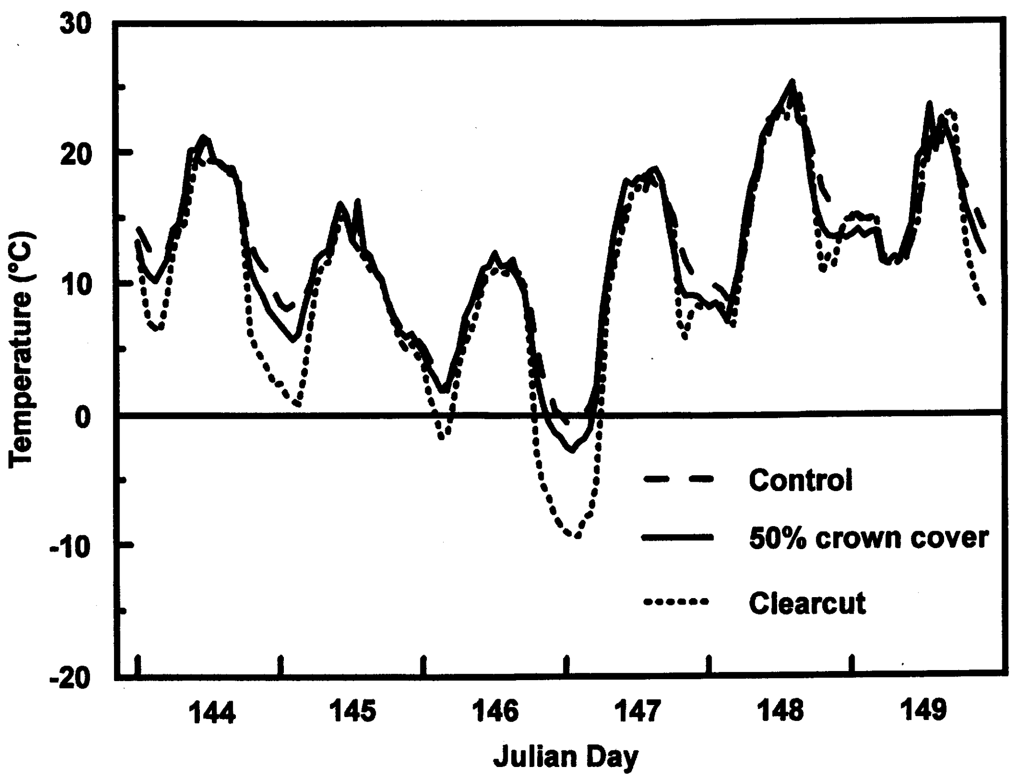

Figure 3.—Minimum temperatures in the partial cutting study for the control, 50 percent crown cover, and clearcut treatments, May 26-27, 1994.

temperatures were cooler in the center of the gaps than in the control and under the canopy beyond the edge of the gaps.

Temperature Profiles

Temperature differences among treatments at each measurement height at the center position of the canopy gap study did not vary during the winter (Table 1). However, temperature differences did occur among treatments at each measurement height during the summer, warmer in the 45-m gap than in the control. During the winter, temperatures are warmer in the soil and at 0.1 m above the soil surface than at 1.0 m above because of snow cover. Temperature patterns reversed during the summer: cooler in the soil and the warmest temperatures 0.1 m above the soil surface. Similar trends were found in the partial cutting study.

Table 1.—Profiles of average maximum temperatures (° C) for the center of the control and 45-m gap in January and July, 1996

Measurement location (m)	January		July	
	Control	45-m gap	Control	45-m gap
1.00	-8.0	-7.7	23.7	27.5
0.10	-1.8	-1.4	24.2	30.5
-0.03	0.4	0.4	16.6	23.0
-0.15	1.3	1.0	15.8	20.1

Temperature Extremes

Frost. Late spring frosts occur frequently in northern Wisconsin. Some are severe enough to kill newly expanding foliage and may kill the plant. Examples of several frost events are shown in Figures 3 and 4. Frosts were most severe in the clearcut treatment of the partial cutting study and in and around the center of the 45-m gap in the canopy gap study. Temperatures below freezing also occurred in the intermediate treatments but were not as low. Temperatures in the clearcut fell to nearly -10°C the morning of May 27, 1994. New growth on oak seedlings and saplings was killed. The seedlings and saplings did recover, but growth for the season was less in the clearcuts than in the control and 50 percent crown cover treatments.

High Temperatures. Extreme high temperatures not only can kill trees but also can dry the upper soil due to high evaporation from the soil surface limiting moisture to newly germinating seedlings. High temperatures are most critical at or near the soil surface. In the canopy gap study, the highest temperatures occurred in the center of the 45-m gap and clearcut

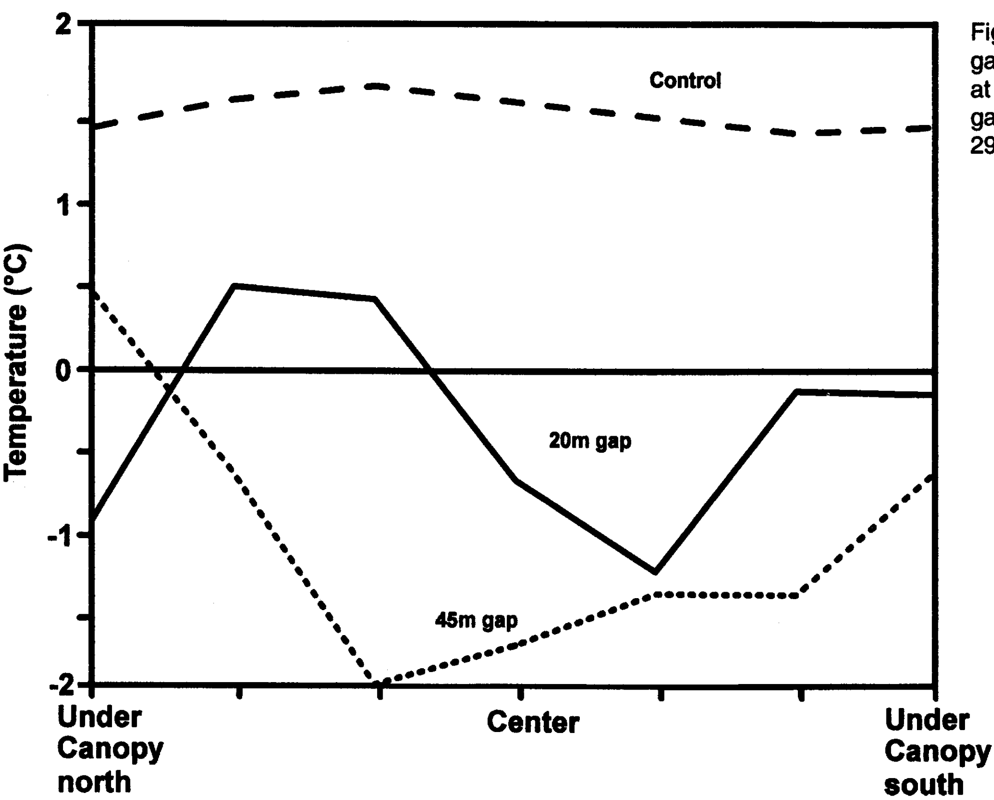

Figure 4.—Frost event in the canopy gap study 0.1 m above the ground at the center of the control, 20-m gap, and 45-m gap treatments, May 29, 1995.

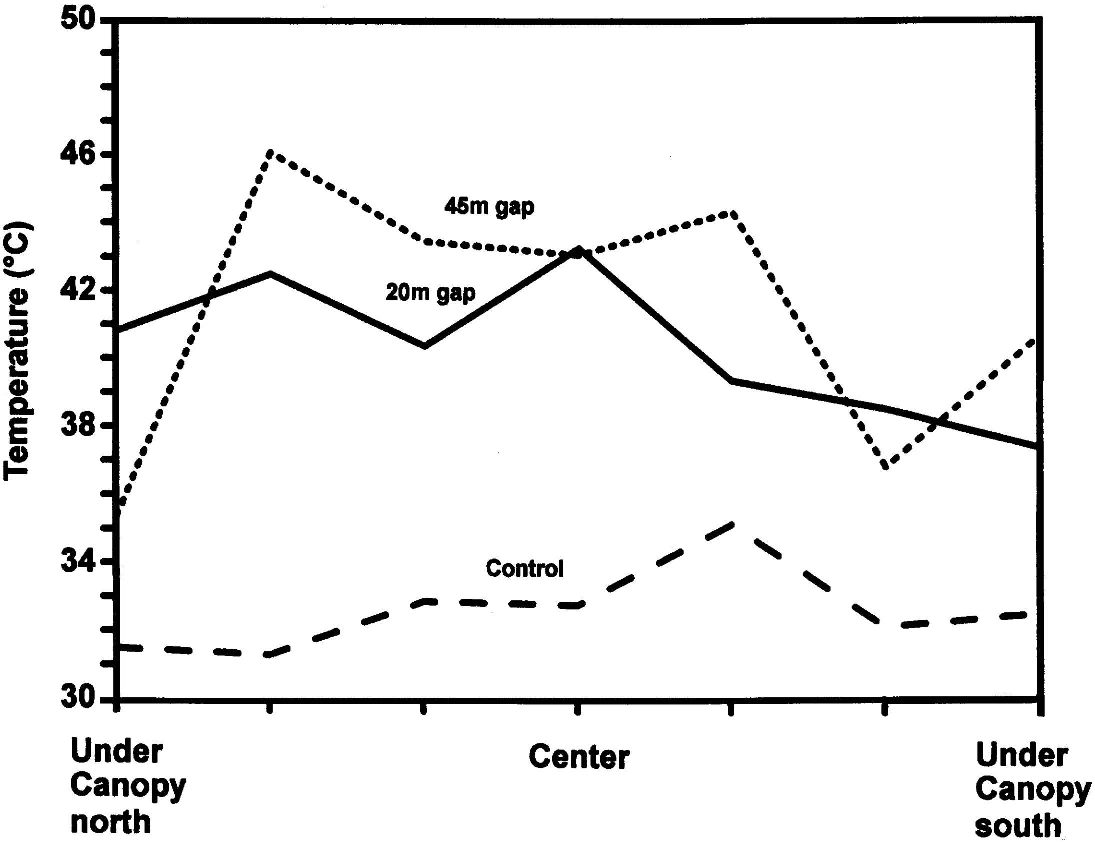

Figure 5.—Extreme high temperature events in the canopy gap study 0.1 m above the ground at the center of the control, 20-m gap, and 45-m gap treatments, June 18, 1995.

treatments (Figure 5). On June 18, 1995, temperatures rose to 46°C 0.1 m above the soil surface on the north side of the 45-m gap. Sustained temperatures at this level not only stop growth but also may kill small seedlings. Similar temperatures were recorded in the clearcut treatment of the partial cutting study on the same day at 0.1 m above the soil surface.

SUMMARY

Silvicultural treatments certainly influence the microclimate near the ground. Cutting increases the range of maximum and minimum temperatures. Temperatures near the soil surface can reach lethal levels (both cold and hot) in larger openings. We need an understanding of the relationships between the environment and plant responses resulting from different silvicultural practices. Past monitoring of silvicultural practices has usually been of vegetation and usually tree species. Today we need to adapt old silvicultural practices to fulfill timber management objectives as well as those for wildlife, biodiversity, aesthetic, and other management objectives. To predict vegetation responses and to learn how to develop desired plant composition, monitoring of more than vegetation is required. By monitoring the microenviroment along with vegetation responses to different silvicultural practices, we can learn how to grow specific plants or plant communities by adapting the current silvicultural guides.

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