Controlling LIGHT in Small Clearcuttings

by David A. Marquis

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RALPH W. MARQUIS, DIRECTOR

The Author

DAVID A. MARQUIS received his Bachelor of Science degree in forestry from the Pennsylvania State University in 1955 and his Master's degree from Yale University in 1963. Since joining the staff of the Northeastern Forest Experiment Station at Laconia, New Hampshire, in 1957, he has studied problems of regeneration and thinning in northern hardwoods.

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Importance of Light

THE various methods of regeneration cutting in use today differ from one another primarily in their effect on light exposure. For example, clearcutting permits a maximum of sunlight to reach the ground, while light selection cutting admits very little sunlight beneath the residual canopy. Small clearcuttings,[1] although seldom used, offer exceptionally good opportunities for the control of light exposure. The size, shape, and orientation of these openings can be varied to obtain light conditions ranging from full sunlight to no direct sunlight at all; from exposure during only the middle hours of the day to exposure only early in the morning or late in the afternoon. A better knowledge of the light obtained in these small clearcuttings is essential if they are to be used effectively for obtaining desired types of regeneration.

The amount of light that reaches the ground in a clearcut forest area is one of the basic environmental factors. It affects

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[1]Small clearcuttings in the present context mean areas of 1 acre or less, or strips no wider than the height of the bordering timber, on which all trees have been cut.

tree and shrub growth, transpiration, evaporation, soil moisture, snow melt and accumulation, frost occurrence, soil and air temperature, decomposition of organic matter, and other factors.

Control of light to create particular environments could be one of our most valuable management tools. The silviculturist could favor or discriminate against a particular species by using an appropriate cutting method. The wildlife manager could increase game populations by favoring certain food and cover plants. The watershed manager might alter streamflow patterns by cuttings designed to affect snow accumulation, snow melt, and other moisture relationships.

Small clearcuttings have already been used occasionally to meet these objectives. But all too often the cuttings are made without full realization of how the physical dimensions of the opening affect the primary environmental factor that is being manipulated — the sunlight reaching the forest floor.

In the Northeast, we are attempting to regenerate paper birch and yellow birch by cuttings designed to provide optimum environmental conditions for these species. Early studies have shown that small clearcuttings favor establishment of the birches, and that the size of the opening affects the amount and composition of the reproduction. But what type and size of opening will provide the best conditions? To answer this, we need to know what environmental conditions are best; and we need to know how the method of cutting affects those conditions.

Some pertinent information is available. Seeds of both species require abundant moisture for germination, and new seedlings require freely available moisture and moderate soil temperatures to survive. These conditions commonly prevail in the shaded borders of small clearcuttings. However, *some* direct sunlight is needed for growth. The two species differ somewhat in the amount of sunlight they need: paper birch apparently requires more light for growth, and withstands the dessicating effects of direct sunlight better than yellow birch. Thus each species regenerates best under a particular combination of sun and shade that is, in effect, a compromise: enough shade to permit germination and initial establishment, and enough sun to promote reasonably good growth.

More information is needed. Among other things, we need to know precisely what the light conditions are in the various types of openings. In 1960, a study was made of the patterns of sunlight and shade in small clearcuttings. This report illustrates some of the patterns and suggests how such cuttings might be done for regeneration purposes.

Procedures

The pattern of sunlight and shade created by border trees was sketched for various types of openings at different hours of the day. This required computation, for the different hours, of these three determinants:

(1) Sun's angle of elevation (altitude).

(2) Shadow length of border trees.

(3) Sun's bearing (horizontal angle between sun and due south).

The three determinants were computed by the following formulae, respectively:

[1] Sine a = (cosine L) (cosine d) (cosine H) + (sine L) (sine d).

[2] S = h/tangent a.

[3] Tangent Z = sine H/(cosine L) (cotangent p) — (sine L)(cosine H).

where:

a = sun's angle of elevation
L = latitude
d = sun's declination as obtained from a solar ephemeris.[2]
H = sun's hour angle (15 times the number of hours from solar noon).
S = shadow length cast by border trees.
h = height of border trees.
Z = sun's bearing.
p = polar angle (90° — sun's declination).

Table 1 shows computed sun positions for the hours 8 a.m. to 4 p.m. as of June 7 at latitude N. 44°, and shadow lengths for border trees 70 feet tall on level ground. The values would be different for different dates, latitudes, tree heights, or topography.

The values in table 1 are presented as examples to illustrate how shadow lengths change with sun position, and as a basis for sketches of sun-shade patterns. June 7 was chosen because it represents the median condition for the 2-month period May 21

[2]A solar ephemeris is a booklet of tables showing the calculated positions and motions of the sun from day to day. They are published by various government agencies and private companies.

TABLE 1. Sun's apparent position at hourly intervals on June 7 from latitude N. 44°, and shadows cast by 70-foot trees

Hour, true solar time	Sun's hour angle	Sun's bearing	Sun's angle of elevation	Length of shadow cast by 70-foot tree on level ground, feet
8:00	60°	S 87° E	36°55′	93
9:00	45°	S 75° E	47°34′	64
10:00	30°	S 59° E	57°30′	45
11:00	15°	S 35° E	65°28′	32
12:00	0°	South	68°48′	27
1:00	15°	S 35° W	65°28′	32
2:00	30°	S 59° W	57°31′	45
3:00	45°	S 75° W	47°34′	64
4:00	60°	S 87° W	36°56′	93

to July 21[3], which is generally the most critical period for germination and initial seedling establishment. The hours shown are true solar time. The middle 8 hours of the day, from 8 a.m. to 4 p.m., are regarded as the critical part of the day for young seedlings, even though in certain orientations of stand openings, some direct sunlight may be received at earlier or later hours. In the discussion to follow, the term *day* generally refers to the period 8 a.m. to 4 p.m.

Results

The shade with which we are concerned is the open shade cast by trees along the borders of small clearcuttings (fig. 1). This area of open shade occurs because, in the temperate zone, the sun never gets directly overhead. Thus one or another of the borders will cast a shadow onto the clearcut area at any given time of day. Because the sun's apparent position changes, this area of shade also changes during the day.

From our position on earth, the sun appears to move from a low angle in the east in the morning to a high angle in the south at noon, to a low angle in the west in the afternoon. As a result,

[3]During this 2-month period there is comparatively little variation in the sun's angle—a total of 3¼° versus a variation of about 47° over the year. During this period, shadows will be slightly shorter on half the days, slightly longer the other half. The difference in noon-time shadow-lengths between June 7 and June 21 is 3 feet.

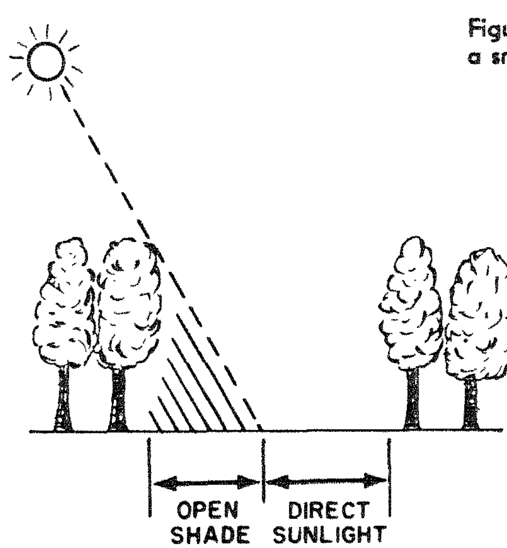

Figure 1.—Open shade in a small clearcutting.

any clearcutting will have shaded areas along its east border in the morning, its west border in the afternoon, and its south border during both morning and afternoon (fig. 2). The shaded area in any clearcutting follows the general pattern shown in figure 2; but the size, shape, and orientation of the opening affect the pattern considerably.

Small clearcuttings may be grouped into two categories: (1) patches — round, square, rectangular, or irregular openings for which the dimensions are either equal or not greatly different;

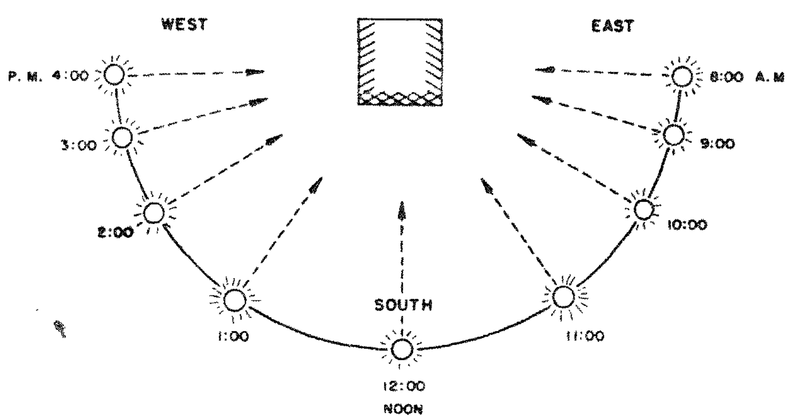

Figure 2.—Apparent movement of the sun around a small clearcutting.

and (2) strips — long, narrow openings in which the length is many times the width. In strip cuttings, the shade cast by border trees on the short sides (ends) is so small, relatively, that it may be ignored. In patch cuttings, however, the shade from east, south, and west borders must all be considered.

In patches, size affects the amount of sunlight reaching the ground more than either shape or orientation. The larger the patch, the greater the proportion of it that will receive direct sunlight. Shape and orientation are most important where the size of patch is about ½ acre. For very small (1/10 acre) or very large (1 acre) patches, shape and orientation do not make much difference. For a given size, patches shaped and oriented so as to have the east-west dimension smaller than the north-south dimension will receive less sunlight than others.

Figures 3 and 4 illustrate various patch cuttings. Those in figure 3 are 1/10 acre; those in figure 4 are the same shapes and orientations as those in figure 3, but are ½ acre in size. The numbers at the bottom of each figure represent the average proportion of the patch exposed to direct sunlight over the 8-hour day and may be used for comparisons between the different types. All these diagrams and others in later figures are based on a tree height of 70 feet and level topography.

The changing pattern of sunlight in a patch cutting is further illustrated in figure 5. Here a ½-acre rectangular patch, oriented east-west, has been divided into segments showing the number of hours of sunlight received at various positions. Note that, even in this small opening, part of the area gets full sunlight during the 8-hour day, and that exposures range all the way from full sunlight to full shade.

In strip cuttings, both orientation and width affect the amount and pattern of sunlight; orientation is especially important when strips are relatively narrow. An east-west orientation best utilizes the shade of the south border. When so oriented, narrow strips receive sunlight early in the morning and late in the afternoon, but are shaded in large part during the middle of the day. Width of strip is critical. To be completely shaded all day, the strip could be no more than 5 feet wide. However, a strip 23 feet wide would receive no sunlight between 10 a.m. and 2 p.m. (fig. 6). In wider east-west strips, all area beyond 27 feet from the south edge, except near the ends, would receive full sunlight.

North-south oriented strips have an opposite pattern. They are most exposed around noon, when the sun shines directly down the long axis; and are more shaded in the morning and afternoon.

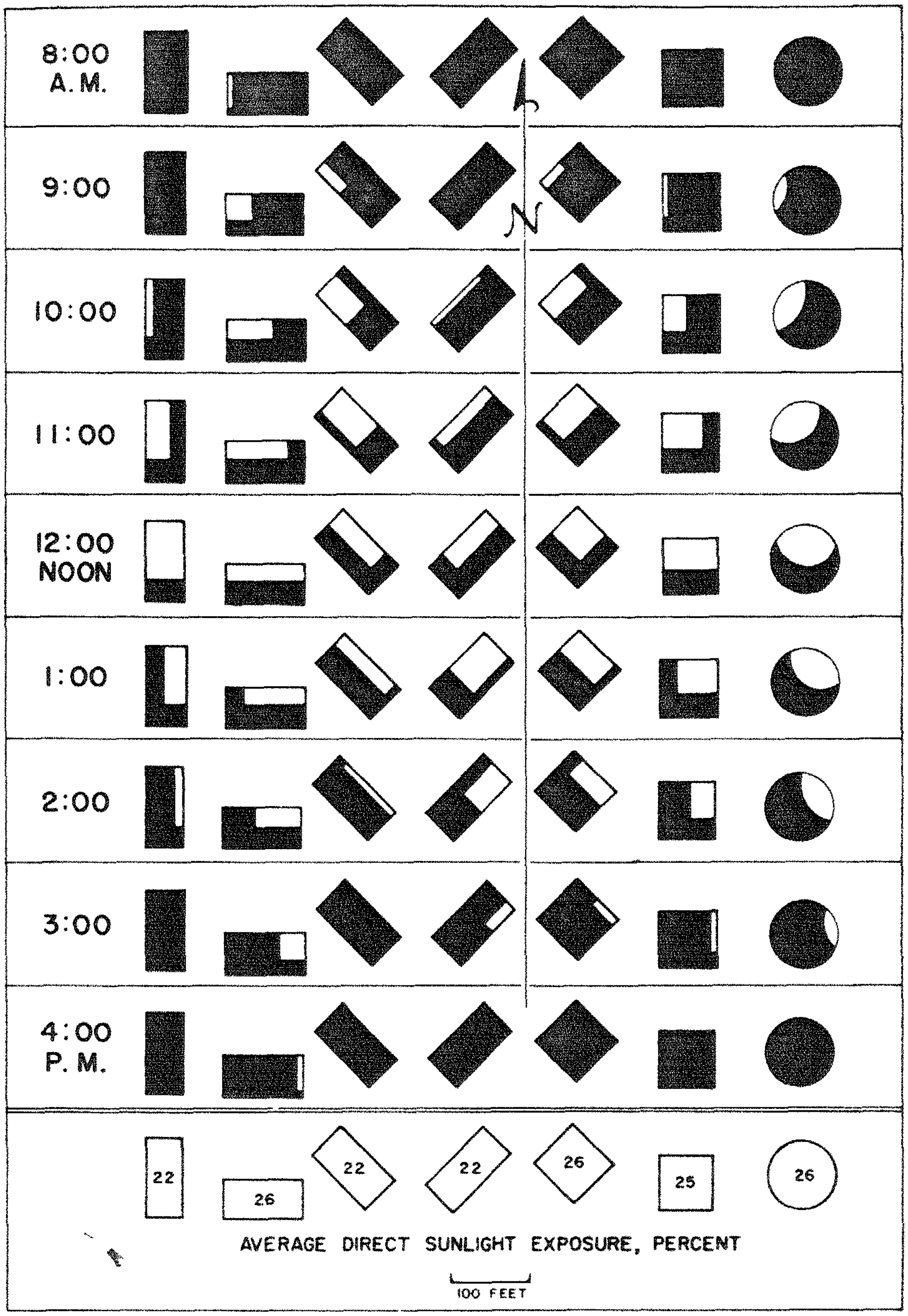

Figure 3.—Patterns of light and shade in various 1/10-acre patches—June 7, latitude N. 44°, at different times of day.

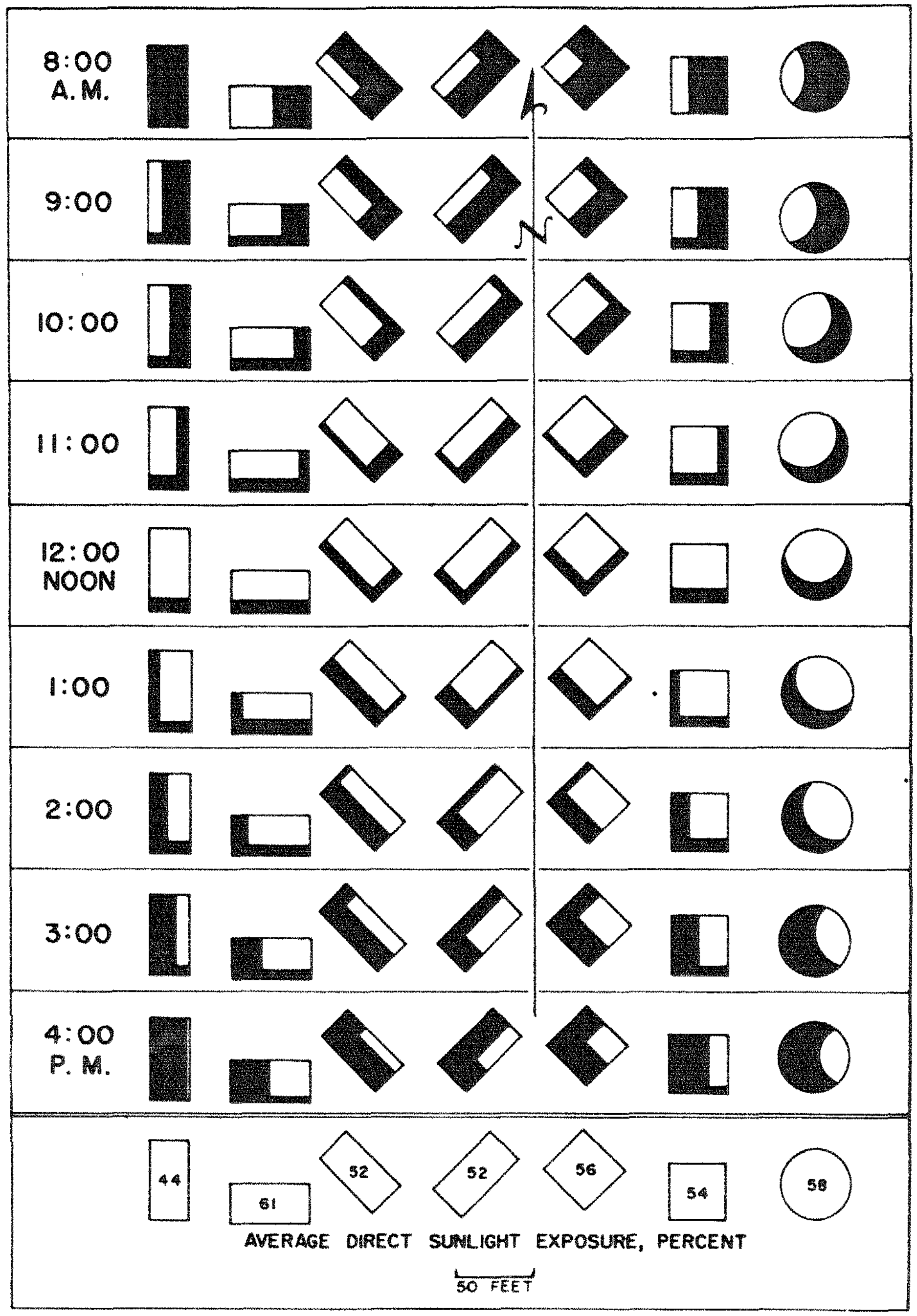

Figure 4.—Patterns of light and shade in various 1/2-acre patches—June 7, latitude N. 44°, at different times of day.

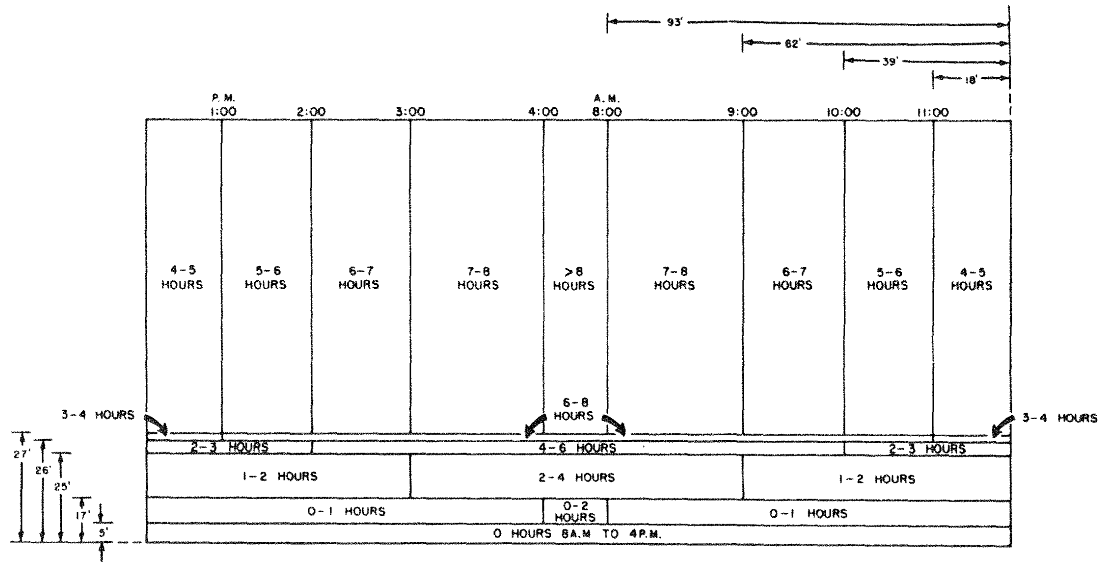

Figure 5.—Length of exposure to sunlight at various positions in a 100-foot x 200-foot (1/2-acre) opening, 8:00 a.m. to 4:00 p.m.

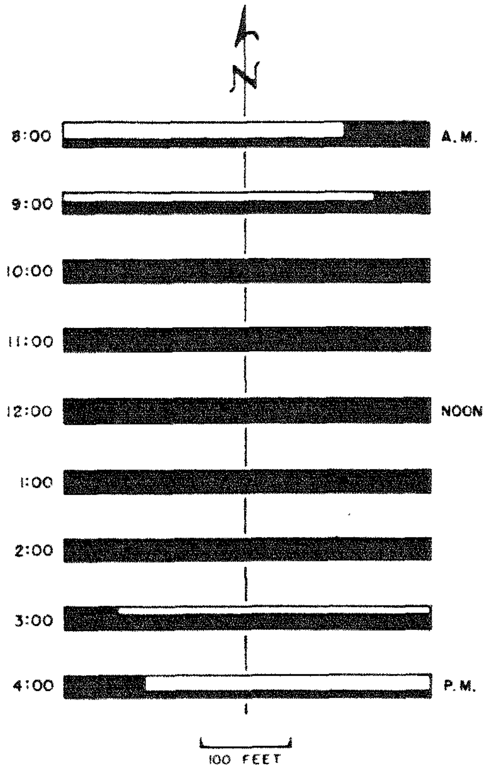

Figure 6. — Patterns of light and shade in an east-west strip 23 feet wide — June 7, latitude N. 44°.

The width of a north-south strip determines how long before and after noon it will receive sunlight. A strip 70 feet wide receives about 3½ hours' exposure; a strip 50 feet wide receives about 2½ hours' exposure; and a strip 35 feet wide receives about 2 hours' exposure. All locations within a north-south strip, except the 27-foot strip along the south edge, receive about the same amount of sunlight. Figure 7 illustrates the patterns in a north-south strip 50 feet wide.

Strip cuttings oriented at other than the cardinal directions have still different patterns. A northeast-southwest strip would be most exposed around 1:30 in the afternoon when the sun shines directly down its long axis. In the morning, the sun would be perpendicular to the long axis and much of the strip would be shaded. Conversely, a northwest-southeast strip would be most exposed in the morning and most shaded in the afternoon. Width again determines how long a strip will be exposed. A strip 30 feet wide receives about 1¾ hours and one 40 feet wide receives about 2½ hours of direct sunlight.

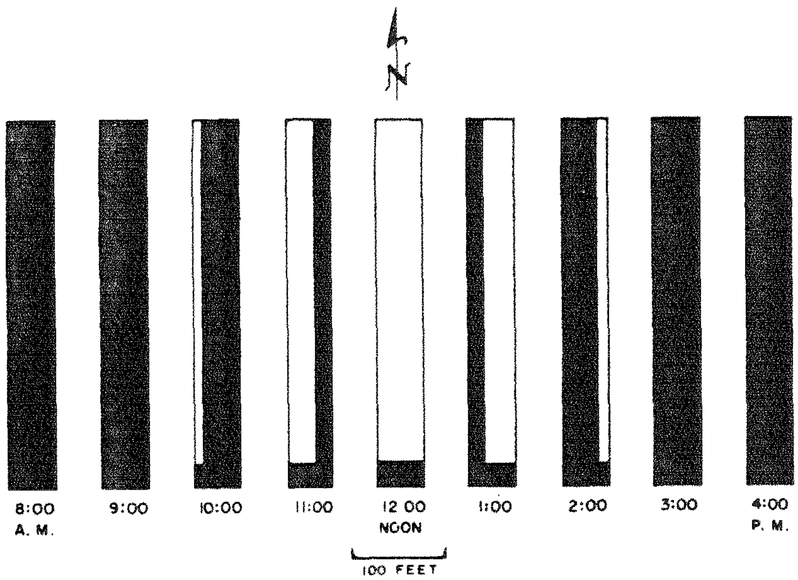

Figure 7.—Patterns of light and shade in a north-south strip 50 feet wide—June 7, latitude N. 44°.

Figure 8 illustrates the patterns in a northwest-southeast strip 30 feet wide. Such a strip offers interesting conditions: It receives sunlight needed for seedling growth during the cool morning hours and is shaded during the hot afternoon hours when direct sunlight is most likely to cause unfavorable conditions of heating and drying.

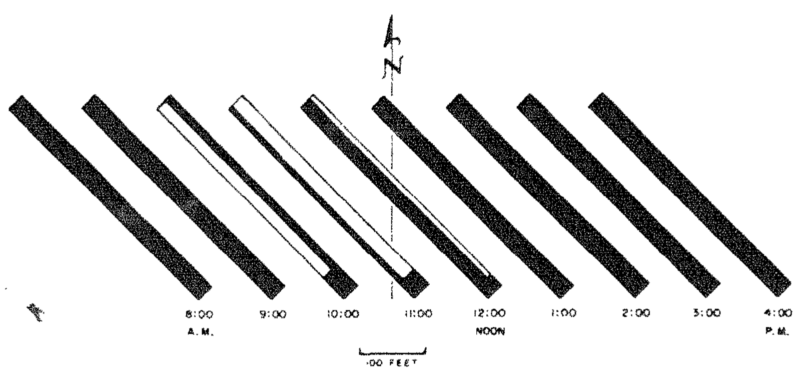

Figure 8.—Patterns of light and shade in a northwest-southeast strip 30 feet wide—June 7, latitude N. 44°.

Discussion

The selection of a type of cutting for regenerating any species must be based on a thorough knowledge of the environmental requirements of the species and on the environment created by different amounts of light and shade. As previously mentioned, the environmental requirements of the birches differ at various stages of development. During germination and early establishment, shade is desirable to conserve soil moisture and maintain moderate soil temperatures. Once established, however, the seedlings require considerable sunlight for best growth.

If cutting is done in a manner to provide shade for seedling establishment, provision must be made to release the seedlings from this shade after a few years. This can be done by locating the next cuttings in the series adjacent to the previous ones. Then, however, light patterns must be considered not only for single cuttings, but also for the combined openings of adjacent cuttings. Hence the entire series of cuttings must be planned in advance.

The strip system lends itself well to cuttings in a planned series. Many arrangements of strips and sequences of cutting are possible.

One example of such a series is illustrated in figure 9, A. Here the strips run east and west. Strip 1, at the northern edge of the area, is cut first. After cutting, it receives shade from the trees on its south border. This provides good conditions for germination and early survival. After an establishment period of several years, strip 2 is cut. Strip 2 then receives shade for initial establishment while strip 1 receives direct sunlight most of the day. After another period of several years, strip 3 is cut, then strip 4, and so on until the entire tract has been covered. Thus each strip first receives shade for seedling establishment and then direct sunlight for best growth.

The interval between cuttings would probably be 2 or 3 years, but it could be flexible in accordance with seed crops. In most cases, we would divide the area into sections of 2 to 4 strips each and cut simultaneously in each section. This would permit the entire cutting operation to take place within a short period of time — 6 to 9 years or less — thus establishing a relatively even-aged new stand that could be managed as a unit.

A similar series of strips could be laid out with a northwest-southeast orientation (fig. 9, B). Cutting would progress from northeast to southwest. This orientation would provide some additional sunlight in the morning, as compared to east-west strips. On strips 30 feet wide, all of the area would get some morning sunlight, but would be completely shaded all afternoon (fig. 8).

North-south oriented strips depend equally on east and west borders for shade, and therefore do not lend themselves well to serial cuttings. Only the first strip cut through a stand or section of a stand is adequately shaded; cutting a second strip on either side then reduces the shade so much that most of the advantage of the strip system is lost. About the best arrangement possible with north-south strips is the simple 1-2 alternate layout shown in figure 9, C. All the number 1 strips, comprising half the stand area, would be adequately shaded for seedling establishment. But the number 2 strips, when cut, would be left completely exposed.

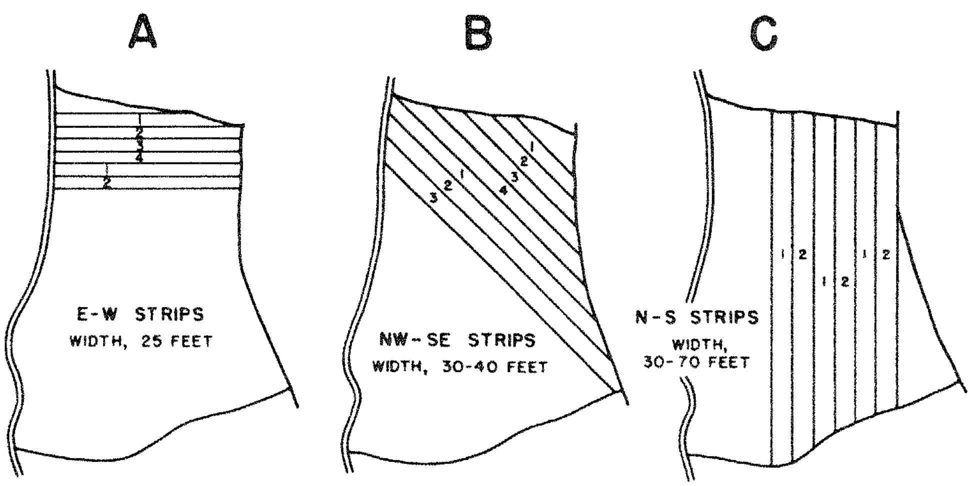

Figure 9.—Three possible layouts of strip cuttings in a management area. (Not to scale.)

Actually, the last strip in any series, regardless of orientation, is left exposed. But with orientations other than north-south, series consisting of more than two strips are feasible and a larger proportion of the total area gets shaded through one cutting cycle. Nevertheless, despite their shortcomings, north-south series of strips may be useful in some situations.

Another possibility with north-south strips would be to schedule the cuts on the number 1 and number 2 strips a half rotation apart. Thus the young trees on each strip 1 would reach almost full height before the number 2 strips were cut, and all strips would be shaded from both sides during the crucial period of seedling establishment. If the strips were wide (50 feet to 70 feet), the long-continued partial shade might not reduce height growth too seriously. The biggest disadvantage would be the long exposure of uncut strips to windthrow and other damage.

The strip widths shown in figure 9 are those that most fully utilize the available shade from each orientation. Some of the specified widths are relatively narrow, and it is questionable whether such narrow strips are practical to cut. Substitution of wider strips should be done cautiously, though, because small changes in width can result in surprisingly large changes in light exposure. For example, increasing the width of a north-south strip from 50 feet to 100 feet would increase the length of time that the strip is exposed to direct sunlight from 2½ to 5 hours. All areas in the strip would be equally affected. Such an increase in light exposure would be acceptable only if the desired species would regenerate satisfactorily under these conditions.

Increasing the width of an east-west strip has a different effect. As previously explained, a 23-foot wide east-west strip would be shaded throughout the middle of the day. Increasing the width would not affect the shade within 23 feet of the south edge, but all areas beyond 27 feet would receive full sunlight. Such a cutting might be acceptable, or even desirable, if it would result in a mixture of several valuable species. Such a mixture might be expected in northern hardwoods where yellow birch commonly regenerates in the more shaded portions, and paper birch in the sunnier portions, of small clearcuttings.

Sketches of any contemplated cutting will quickly reveal whether or not the desired light exposure will be obtained. Such sketches can readily be made by use of data from table 1 and figure 5. Strictly speaking, these data apply only for June 7, at latitude N. 44°, in stands 70 feet tall, and on level ground. For practical purposes, however, small departures from these conditions can be ignored. For situations that are substantially different, shadow lengths may be computed by the procedures outlined earlier in this paper. These computations are relatively simple and can be made quickly.[4] Where a lower degree of accuracy is acceptable, approximate shadow lengths for different situations can be determined by adjusting any available computed values according to the following guides.

Latitude.—Noon-time shadow length decreases about 3 feet for every 2 degrees southward in latitude. Morning (8 a.m.) and afternoon (4 p.m.) shadow lengths are not much affected by latitude within the United States and adjacent Canada. Thus, shade from an east-west border would not be of much silvicultural significance in the southern United States, but shade from north-south borders would still be useful.

Tree height.—Noon-time shadow length increases about 2 feet for every 5-foot increase in tree height. Morning and afternoon shadow lengths increase about 7 feet for each 5-foot increase in tree height.

Slope.—Noon-time shadow lengths increase about 1½ feet for each 10 percent increase in slope on north aspects and decrease similarly on south aspects. Thus, an east-west strip should be wider on a north slope and narrower on a south slope than on level ground. Even on a 40-percent slope, the strip width would be altered by only 5 to 6 feet. Adjustments would not be worthwhile on east or west slopes.

The change in morning and afternoon shadow lengths on east and west aspects varies from 15 feet on a 10-percent slope to 46 feet on a 40-percent slope. On a north-south strip, shadow lengths would not be much affected by north or south slopes, but would be altered on east or west slopes. However, adjustments in strip width are not called for, even in the latter situations, because changes in shadow length from one border on an east or west slope would be compensated by an equal and opposite change in shadow length from the other border. The net result would be a slight shift in the time of day when the strip is exposed to direct sunlight, but little change in the length of this exposure.

Although similar patterns of sunlight and shade can be obtained on both level and sloping ground, the insolation received per unit of ground area in direct sunlight differs with slope and aspect. An exposed area on a south slope receives more energy per unit area in a given interval of time than one in a similar position on a north slope because the light strikes the south slope at an angle closer to the perpendicular. This suggests that, to obtain similar environ-

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[4]Helpful data for computing shadow lengths under different conditions may be obtained from the following sources:

Fons, W. L., H. D. Bruce, and Alan McMasters. Tables for estimating direct beam solar irradiation on slopes at 30° to 46° latitude. U.S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta., 298 pp., 1960.

Aeronautical Services, Inc. Sun angle calculator. Available from Libbey-Owens-Ford Glass Co., Toledo, Ohio. 1951.

Coordinate transformers. Available from G. Felsenthal and Sons, Chicago, Ill.

ments on different slopes and aspects, different lengths of exposure to direct sunlight would be required.

Patch cuttings are not so well adapted for use over large areas as strip cuttings. The problem of fitting new patches in among several series of older ones is difficult to solve. Patch cuttings could probably be best used to advantage if no attempt were made to cover the entire area with patches. Instead, groups of mature, overmature, or defective trees would be used as nuclei for patches to be cut in conjunction with regular selection cuttings. This would help to maintain the less tolerant species such as paper birch and yellow birch in the mixture of tolerants normally maintained under the selection system.

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