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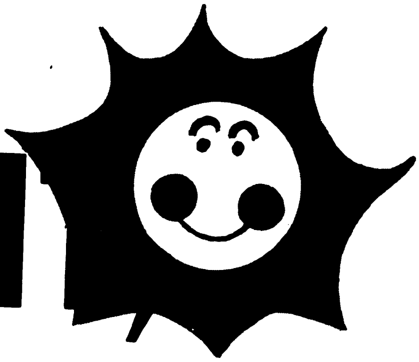
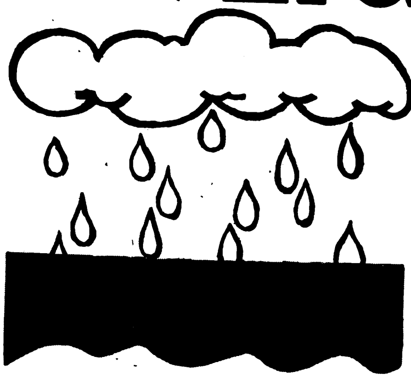
LIGH 



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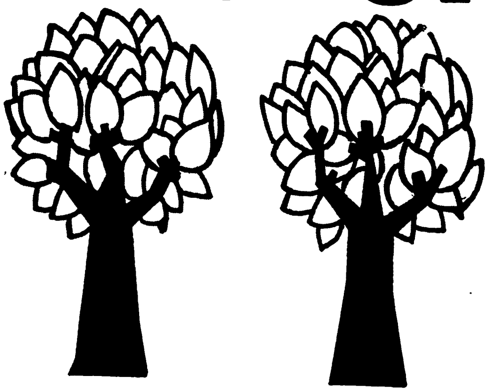

and TREE REPRODUCTION in HARDWOOD FOREST OPENINGS

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LIGHT, SOIL MOISTURE, AND TREE REPRODUCTION IN HARDWOOD FOREST OPENINGS

Leon S. Minckler, John D. Woerheide, and Richard C. Schlesinger

Much research has been done in recent years to quantify the available light in forest openings and its influence on regeneration. This research has been approached both from a theoretical and an empirical basis. Our studies, conducted in mixed-hardwood stands in southern Illinois, show that the amount of light reaching the forest floor is related to size of openings, aspect, position in the opening, time of day, and season. Although exact quantification of available light in these openings was limited by the experimental setup and sampling methods, the results clearly demonstrate that light and soil moisture are related in complex ways to the above variables. Some of these relationships are discussed in this report.

METHODS

The study was conducted in several mixed-hardwood stands on the Kaskaskia Experimental Forest in southern Illinois. White oak (*Quercus alba*) and hickory (*Carya* spp.) were the dominant species on the southerly slopes, while oaks and yellow-poplar (*Liriodendron tulipifera* L.) were the dominant species on northerly slopes and in the coves. The stands were approximately 100 to 125 years old and were well stocked (80 to 100 square feet basal area per acre).

Circular openings of six different sizes were created on each of three topographic positions in the forest stands in the spring of 1959. The diameter of these openings ranged from one-fourth to twice the height of the surrounding trees.[1] The three topographic positions included a northeast slope, a southwest slope, and a cove.[2] Thus, our study encompassed 18 openings (six sizes x three topographic positions). There was only one replication of each size x site combination and therefore statistical analysis of the data was not possible.

Five light measurements per sample day were made at each station in 1959 at 1½ hour intervals, beginning at 9:00 a.m. c.s.t. The measurement period extended from the last week in June to the first week in September, each opening being sampled on 3 to 6 separate days during this period. Additional light measurements were taken in the ½-tree height and 1-tree height openings on north and south aspects during the 1960 growing season. Light at the center stations in these four openings was measured periodically from June 1 to September 21, every 2 hours from 5:45 a.m. to 5:45 p.m. c.s.t.

All light measurements were made with a Brockway light meter, which gives instantaneous readings in foot-candles (Minckler 1961).[3] In all cases, the meter was held in a horizontal position at about waist level, thus avoiding the variation in light readings caused by understory vegetation (Gatherum 1961).

Soil moisture was meaured in only six of the openings (north and south ½-, 1-, and 2-tree height plots), and under the canopy. Samples were taken at depths of 6 and 18 inches near the light stations three times during the summer of 1959. The same stations

[1] *The overstory trees in the coves and on the north and south slopes averaged approximately 90, 80, and 60 feet in height, respectively.*

[2] *Slope steepness was 20 to 30 percent on north and south aspects, and cove sites were nearly level.*

[3] *This type of meter is to be contrasted with an integrating light meter which records the sum of the illumination received during its exposure period. The average of the five daily instantaneous readings was highly correlated ($r^2 = 0.93$) with readings from an integrating light meter placed at the center of the openings (Minckler 1961). The average difference between observed and predicted values was 10 percent. The meter was used with a hemispherical receiving sensor.*

were resampled once during the summer of 1962 at the 6-inch depth only. Soil moisture was determined gravimetrically and expressed as a percent of ovendry weight. Available soil moisture is the difference between this value and the percent soil moisture at the permanent wilting point (taken to be the moisture content at 15 atmospheres pressure).

The soils were derived from thin loess underlain by sandstone. The south aspect soils contained more sand and clay than the north aspect soils. Average texture for the 6-inch depth was 12 percent sand, 62 percent silt, and 26 percent clay, and for the 18-inch depth, 7, 62, and 31 percent, respectively.

Reproduction was measured in the openings during August 1959 and remeasured in October 1964. All stems were tallied in 1959 and stems considered "free to grow" were tallied in 1964. The 1/4-tree height openings were sampled with five 1.15 milacre plots centered at the light stations. The other openings were sampled with 4.5 milacre plots centered at the light stations, and for the 1-, 1½-, and 2-tree height openings an additional four plots were located halfway between the edge and center plots.

RESULTS

The 1959 data show two distinct effects of opening size on the light received at specific points within the opening. The amount of light on clear days generally increased as opening size increased for all positions except south (fig. 1). Since readings were taken facing the sun, the observer effectively shielded the light meter from the diffuse light from the opening, and the south edge readings reflect differences in the density of the surrounding stand rather than opening-size differences. Opening size also apparently affected the relative amount of light received at the five positions within an opening. For openings of 3/4-tree height and less, the north position received the most light, followed by the center, west, east, and south. For openings of 1-tree height and larger, the center position generally received the most light, followed by the north, west, east, and south.

For openings of all sizes, light intensity was greatest on south slopes, coves, and north slopes, in that order. Because the measured light was that received on a horizontal surface, the slope effect is one of shadow

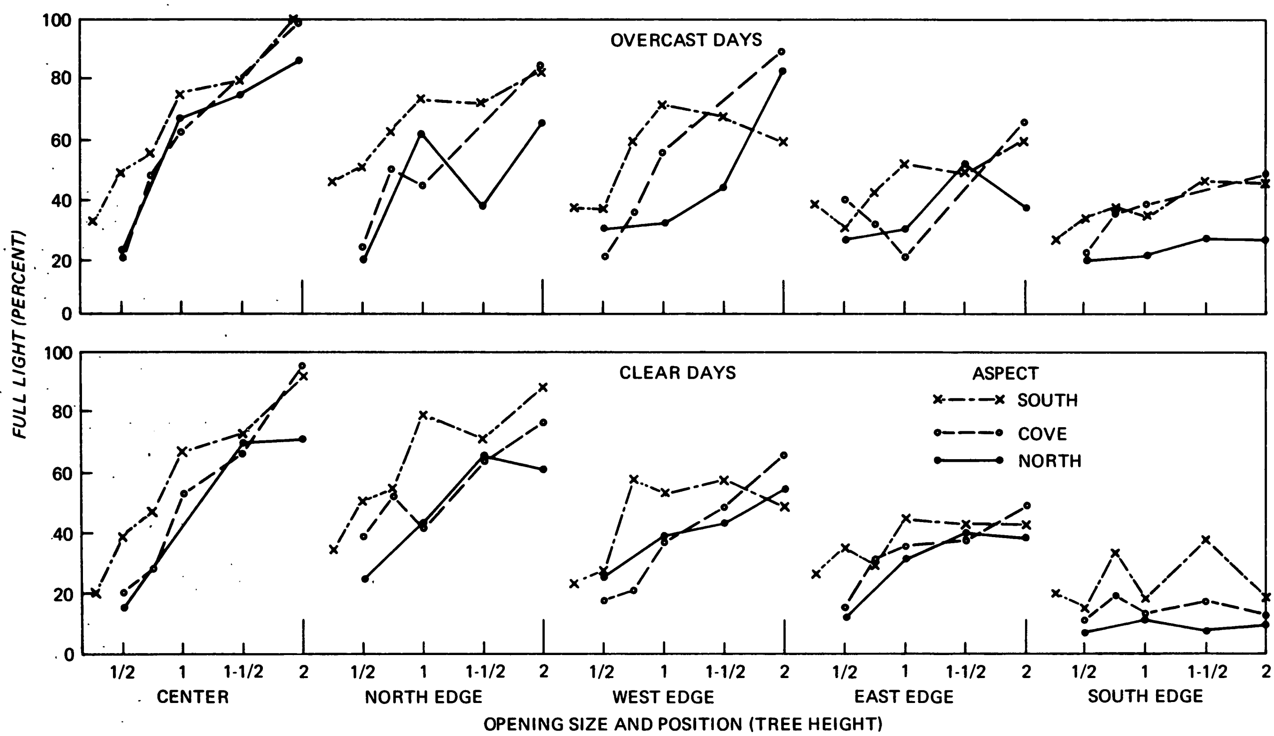

Figure 1. — *Average light as related to opening size, aspect, and position in opening.*

length. The shadow-casting trees are in effect below the opening on south slopes and above the opening on north slopes.

Light in the openings on overcast days, expressed in percent of full light, was greater than on clear days, but the total light in foot-candles was only 55 percent as much as on clear days. On overcast days there is greater light dispersal, so stations at the edges of openings received relatively more light.

The 1960 data showed that little information was lost by not measuring light as early or as late in the day during 1959. The measurements earlier and later in the season indicate that the differences between the center of the north and south 1-tree height openings increased as the season progressed (fig. 2). The centers of the ½-tree height plots received nearly equal illumination throughout the season.

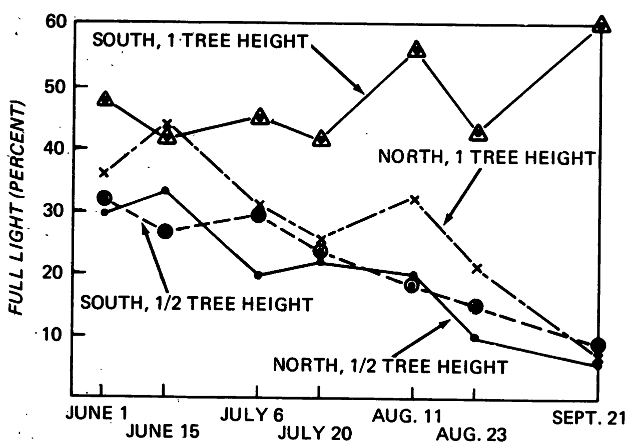

Figure 2. — *Light in center of openings during the 1960 growing season.*

Measurements on July 14, 1959, showed that the center of the openings had from two to eight times more available soil moisture than the adjacent forest soil (table 1). Fletcher and Lull (1963) found a similar moisture advantage of open areas over forested areas. There were slight differences in soil moisture between the two soil depths, but no consistent differences between opening sizes or aspects. Soil moisture content at the edges of the openings, in all cases, was intermediate between that in the center of the opening and under the stand.

Repeat measurements 3 years later (July 27, 1962) showed that the centers of the openings still had more moisture than soils under the adjacent canopy (table 2). However, the differences had decreased, especially for the smaller openings. Soil moisture at the opening edges was about the same as under the canopy at this time.

When the openings were created in March 1959, all stems greater than 18 inches tall were removed. In August 1959 the reproduction on north aspects was generally less than a foot tall, consisting of new seedlings, advanced seedlings, seedling sprouts, and stump sprouts, depending on species (table 3). On south aspects, the mean heights were less than on north aspects. There were no consistent differences in the abundance of reproduction by opening size in either August 1959 or October 1964. The number of stems "free to grow" (not overtopped) in 1964 was about half of the total number of stems present in 1959 (table 4). On north aspects, the proportion of desirable species had increased, while on cove and south aspects, this proportion had decreased. In 1964 the mean height of the tallest stems free to grow increased as opening size increased, and within an opening the tallest trees were generally found in the center plots (table 5, fig. 3).

DISCUSSION

These results demonstrate the variability in the amount of light received at several points in forest openings. Although the measurements are not precise enough to establish absolute differences in the light received as it is influenced by location within an opening, by opening size, or by aspect, they do indicate the general relationships involved. The least light was recorded at the south edge of a ¼-tree height opening on a north slope, while the most was recorded at the center of a 2-tree height opening on a south slope. Other positions, sizes, and aspects provided the full range of intermediate conditions. Soil moisture was greatest in the center of the openings, but the difference between the openings and the uncut stand decreased as the demands of the new vegetation for moisture increased. In general, the edges of the smallest openings were least favorable for new growth, while the center of the largest openings were most favorable.

Table 1.—*Average available soil moisture in openings and adjacent forest stand; first summer after cutting openings*
(In percent)

NORTH ASPECT

Opening size (tree height)	Days since 1-inch rain	6-inch soil depth: Center of opening	6-inch soil depth: Edge of opening	6-inch soil depth: Adjacent stand	18-inch soil depth: Center of opening	18-inch soil depth: Edge of opening	18-inch soil depth: Adjacent stand
1/2	4	24.6	17.6	12.3	19.1	14.9	11.0
	19	18.5	8.6	3.1	14.9	8.6	3.5
1	4	23.6	20.6	15.1	20.4	20.3	11.1
	19	19.2	13.2	6.1	16.4	13.0	4.8
2	4	25.6	18.5	15.4	19.9	16.2	14.5
	19	20.1	9.7	5.1	18.1	10.5	7.7
SOUTH ASPECT							
1/2	1	22.0	21.6	16.4	19.4	18.4	16.1
	19	20.1	14.7	8.6	17.3	13.4	9.4
1	1	23.6	21.0	18.2	20.1	18.7	15.2
	19	15.2	12.4	7.6	15.5	9.8	5.1
2	1	23.5	20.4	19.3	19.8	18.3	15.1
	19	19.3	11.9	4.7	18.8	11.1	2.2

Table 2.—*Average available soil moisture*[1] *at 6-inch depth in openings and adjacent forest stand; fourth summer after cutting openings*
(In percent)

NORTH ASPECT

Opening size (tree height)	Center of opening	Edge of opening	Adjacent stand
1/2	2.2	1.6	1.3
1	6.0	2.2	2.3
2	10.8	3.3	3.4
SOUTH ASPECT			
1/2	5.0	2.7	3.1
1	5.5	3.4	3.8
2	7.4	2.9	3.2

1/ Taken on July 26, 16 days after a 1.1-inch rain.

Table 3. — *Mean height and description of reproduction on north slopes at start of study in 1959*

Species	Mean height of all reproduction in openings in August 1959 after complete cutting in March	Description of reproduction
	Feet	
Yellow-poplar	0.18	New seedlings
Hickory	.78	Mostly advanced regeneration
White oak	.97	Mostly seedling sprouts
Black and red oaks	.67	Mostly seedling sprouts
Miscellaneous undesirable1/	1.38	Most advanced reproduction and sprouts
Non-timber2/	.92	New seedlings, advanced reproduction, and sprouts

1/ Chiefly sugar maple, black gum, elm, and beech.
2/ More than 90 percent sassafras, but some sumac and dogwood.

The revegetation of the openings is dependent upon many micrometeorological and biological factors not examined in this study. Nevertheless, the general trends of height growth and species composition differences within the openings demonstrate the importance of understanding the complex environment of openings as a basis for controlling the regeneration of forest stands.

Table 4. — *Number of seedlings per acre in openings in 1959 and 1964; all opening sizes combined*

Aspect	Total number seedlings, August 1959: Desirable1/ species	Total number seedlings, August 1959: Undesirable2/ species	Number of seedlings free to grow, October 1964: Desirable1/ species	Number of seedlings free to grow, October 1964: Undesirable2/ species
North	4,400	6,600	2,200	2,500
Cove	6,900	9,200	1,600	2,200
South	2,800	2,600	1,200	1,300

1/ Chiefly yellow-poplar; white, black, and red oaks; and hickory. Yellow-poplar occurred only rarely on the south aspects.
2/ Chiefly sugar maple, black gum, elm, beech, and nontimber species such as sassafras, sumac, and dogwood.

Table 5. — *Height of tallest trees*[1] *6 years after creating openings*
(In feet)

COVES AND NORTH SLOPES

Species and opening size[2]	Center	North edge	East and west edges	South edge
Yellow-poplar:				
1/4 to 1/2	--	--	--	--
3/4 to 1	7.5	--	--	2.0
1-1/2 to 2	14.3	--	--	1.8
White oak:				
1/4 to 1/2	5.3	2.4	3.7	4.2
3/4 to 1	6.7	5.3	6.0	6.9
1-1/2 to 2	10.4	--	6.2	3.3
Black and red oaks:				
1/4 to 1/2	1.8	1.9	1.9	2.1
3/4 to 1	3.9	--	3.7	3.3
1-1/2 to 2	6.3	5.8	4.5	2.4
Hickory:				
1/4 to 1/2	4.1	4.2	5.1	2.7
3/4 to 1	6.3	6.2	5.7	6.2
1-1/2 to 2	7.4	5.6	5.0	4.5
Nontimber species:				
1/4 to 1/2	5.6	4.2	5.4	3.5
3/4 to 1	10.5	8.1	5.3	6.3
1-1/2 to 2	12.8	10.7	6.2	2.9
SOUTH SLOPES				
White oak:				
1/4 to 1/2	--	3.1	2.4	3.2
3/4 to 1	8.2	7.0	--	--
1-1/2 to 2	7.9	6.5	--	--
Black and red oaks:				
1/4 to 1/2	--	--	1.3	--
3/4 to 1	4.4	5.3	4.0	2.5
1-1/2 to 2	6.5	--	4.4	2.8

1/ Based on two tallest trees in each sample plot.
2/ In tree-height.

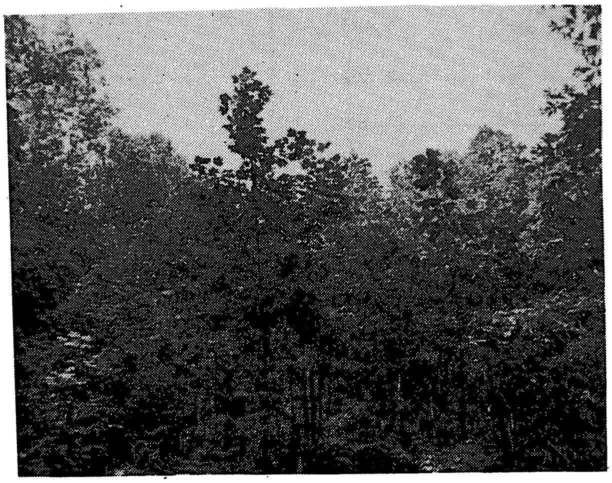

Figure 3. — *Regeneration in a 2-tree height opening on a north aspect, 9 years after cutting.*

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