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CENTRAL STATES FOREST EXPERIMENT STATION • U.S. DEPT. OF AGRICULTURE • FOREST SERVICE

TECHNICAL PAPER 184
OCTOBER 1961

Central States Forest Experiment Station, U.S. Dept. of Agriculture
Forest Service, 111 Old Federal Building, Columbus 15, Ohio

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Measuring Light

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Light, essential in the development of a forest, can be controlled within a stand by silvicultural practices. Measuring it, however, has always been a problem for silvicultural researchers (*2, 3*)[1] And accurate measurements are necessary, especially in studying the relation between light and reproduction. The desired objective is to measure the total visible light in specific units at a given place and for a given period in the forest stand. Often it is also necessary to compare the amount of light received at many different places in a forest during the same period.

The Integrating Light Meter (*1, 4*) (fig. 1) fulfills all the requirements for a good instrument but it is too expensive to be used in large numbers. The problem then is to find a way to get similar results with less expensive and more portable instruments.

Atkins (*1*) compared a Norwood Director incident light meter, which gave instantaneous readings in foot-candles, with the Integrating Light Meter measuring cumulative light in even-aged white pine stands. These two meters gave closely corresponding results when exposed at the same time and place.

The purpose here is to describe an extension and adaptation of Atkins' work for measuring cumulative light within hardwood stands, and to illustrate the method by some study results. The validity of the light data obtained by this method is shown by a comparison with data taken with the Integrating Light Meter (*4*).

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[1]Numbers in parentheses refer to Literature Cited, page 9.

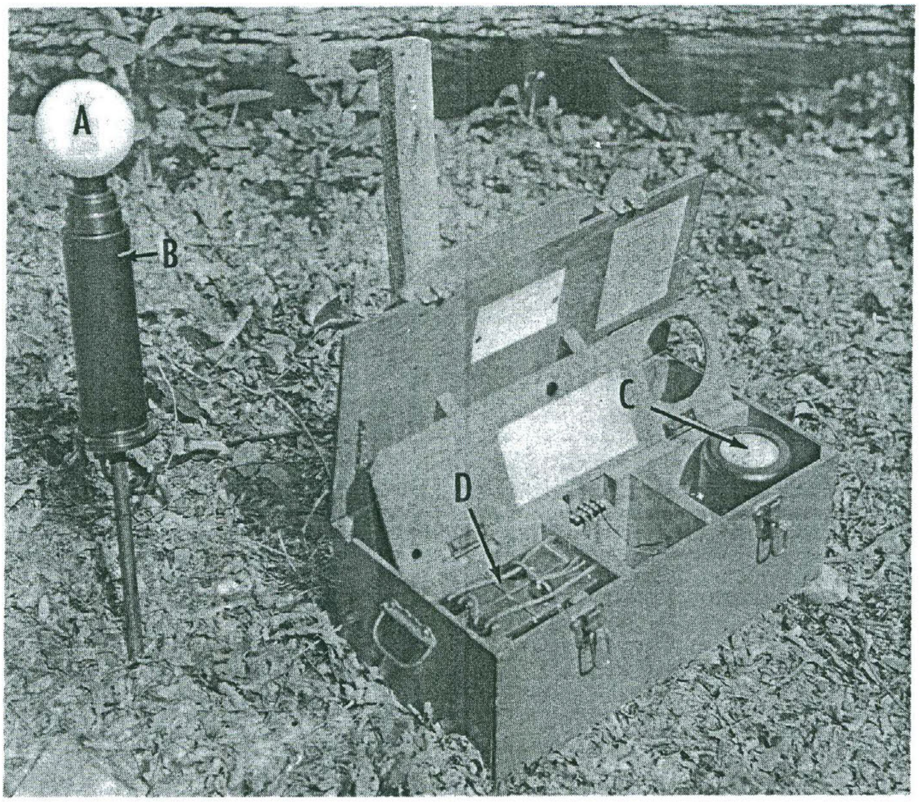

FIGURE 1. — *The Integrating Light Meter: (A) Globular opal glass light diffusion element with color filters, passing only visible light, in base; (B) steel housing containing photo-electric tubes and capacitors; (C) electronic impulse counter; (D) batteries.*

METHODS USED AND SOME RESULTS

The instantaneous light readings in the hardwood stands used in the present study were taken with a Brockway exposure meter. This meter is equipped with an incident light scale in foot-candles and a bright-light slide for increasing the effective light range, and operates by a photo-electric cell. It is essentially identical in all respects to the Norwood meter used by Atkins *(1)*.

Measuring Light on the Forest Floor in Stands of Different Density and Structure

Instantaneous light measurements were made on 20 half-acre plots in uneven-aged hardwood stands. Light was measured throughout the summer of 1958, on clear days or on days with only scattered clouds. Half the plots were on ridges and southerly slopes and half were on northerly slopes and coves. Oaks *(Quercus* spp.) and hickories *(Carya* spp.) dominate the ridges and southerly slopes while oaks and yellow-poplar (*Liriodendron tulipfera* L.) are the most common species on the northerly slopes and coves.

Before the growing season in 1955, 18 of the half-acre plots (plus isolation strips) were cut resulting in 9 different density-structure conditions: To three densities — approximately 40, 60, and 80 square feet basal area per acre; and three structure classes — large, medium, and small sawtimber. One untreated check plot of 90 to 100 square feet basal area was left on each site (table 1). Twenty permanent light stations were located equidistant apart on each of the 20 half-acre plots so as to form a grid covering the whole plot.

Table 1. — *Stand structure treatments: approximate diameter distribution in residual stands*
(Percent of total basal area)

Aspect and structure class	Diameter class (inches)				
	5-10	11-16	17-19	20-22	23-25
Coves and lower northerly slopes					
Large sawtimber	10	30	25	20	15
Medium sawtimber	15	50	20	15	0
Small sawtimber	25	60	15	0	0
Ridges and southerly slopes					
Large sawtimber	15	45	35	5	0
Medium sawtimber	25	60	15	0	0
Small sawtimber	35	65	0	0	0

Light readings were taken at zenith (11:50 a.m. Central Standard Time), 3 hours before zenith, and 3 hours after zenith (plus or minus 15 minutes). Two plots (40 stations) were measured each clear day during the summer. Readings of full sunlight in the open were also taken each sampling period. Each of the 20 plots in the study was measured 3 or 4 times during the summer.

Readings with the Brockway meter were taken at a height of 4 feet, facing the sun, and directly over the stake marking the light station. The meter has a hemispherical light-diffusion unit that receives incident light from a 180-degree arc. To avoid bias by reflection from clothing, the observer wore a dark blue denim apron. Low vegetation that shaded the light station was eliminated. Thus, the readings were affected only by light interception by the overhead crown canopy, usually trees of pole size or larger.

Because full light varied from day to day and during the day, even on clear days, light values were expressed as percentages of full sunlight for each day. During clear days, from 9 a.m. to 3 p.m. in 1958, full light ranged from about 6,000 to 10,000 foot-candles, as measured by the Brockway meter.

The average[2] amount of light on the forest floor in the stands studied varied by aspect and stand density (basal area) (fig. 2). On the other hand, differences among the stand structures (timber size) studied had no apparent effect on the average light under the canopy. The stands on ridges and southerly slopes received from 20 to 30 percent more light on the forest floor than stands on northerly slopes and coves with the same basal area. Based on the correlation coefficients, basal area accounted for about 90 percent of the differences in average light among stands on both sites. The regression equations, developed to estimate light received in upland hardwood stands of similar composition and known basal area, show that a doubling of basal area reduces average light under the canopy by nearly half.

Measuring Light in Openings in the Forest Canopy

During the summer of 1959 light was measured in 18 openings cut in well-stocked stands on northerly slopes, southerly slopes, and in coves. The diameters of the roughly circular openings were approximately ¼, ½, ¾, 1, 1 ½, and 2 times the height of the dominant trees.

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[2] The mean of all the instantaneous light values at the 20 light stations, taken 3 times per day, and for 3 or 4 days during the summer.

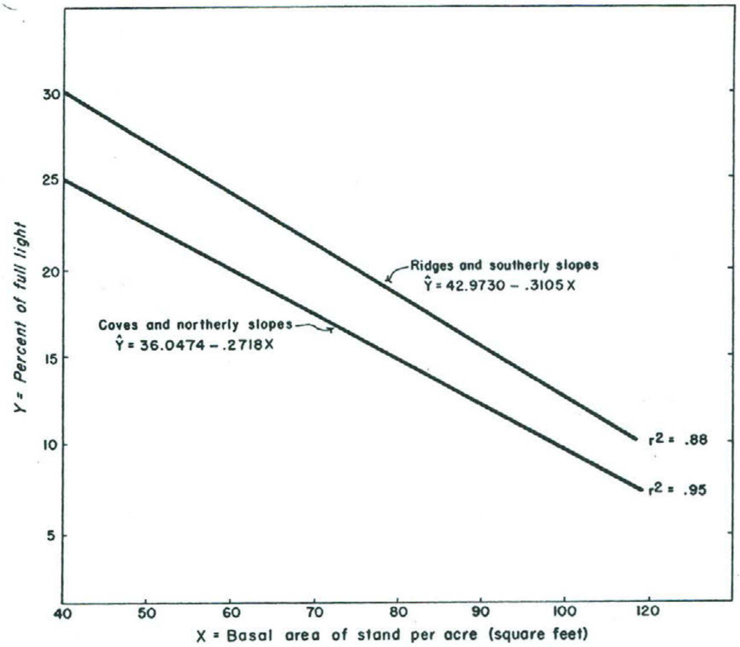


FIGURE 2. — Relation between average light on forest floor and basal area of stand.

Instantaneous light measurements with the Brockway meter were taken in each opening 5 times per day at each of 5 permanent light stations, as follows:

Location of light stations in openings	*Times of measurement at each station C.S.T.* (± 15 minutes)
Center	8:45 a.m.
South edge	10:15 a.m.
West edge	11:45 a.m. (zenith)
East edge	1:15 p.m.
North edge	2:45 p.m.

During any one day, light could be measured at only 2 or 3 openings by one man within 15 minutes of the stated times. At each reading time a full light reading was also taken in the open. The light in each opening was measured from 3 to 6 times during the summer from about July 1 to September 10 .

Average summer light in openings was calculated from instantaneous light readings taken at 5 positions in each opening, 5 times per day at each position, and on 3 to 6 clear days (or 2 to 4 overcast days) during the summer. The average light within openings was closely related to size of the opening, and was also modified by aspect (table 2). Even the smallest openings received 2 to 3 times as much light as was measured under canopies of well-stocked hardwood stands. The center and north positions in the larger openings received (depending on size) about 50 percent more light than the east and west positions and about three times as much as the south position (fig. 3).

FIGURE 3.—Average light received on clear days at five positions in different-sized openings in stands on south aspects.

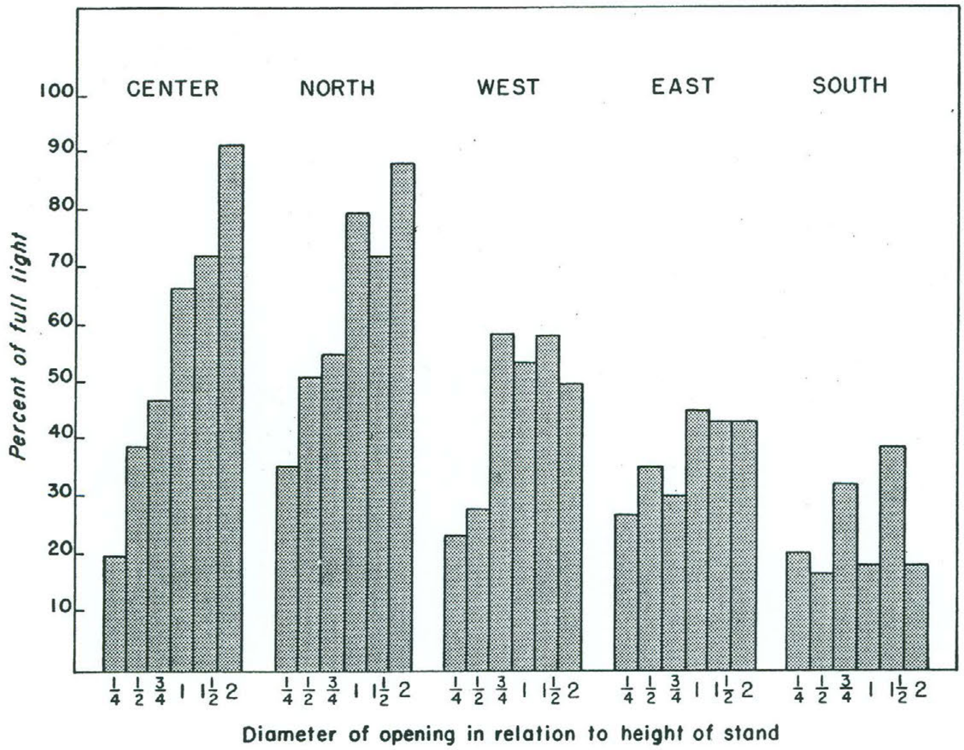


Table 2. — *Average summer light*[1] *in circular openings in hardwood stands, by opening size and aspect*

Opening size (fraction of tree height)	Average diameter of circular openings (in feet)			Average light on clear days (percent of full light)		
	South aspect	Cove	North aspect	South aspect	Cove	North aspect
¼	22	30	18	25	[2]	[2]
½	32	43	42	33	21	17
¾	56	62	52	45	31	[2]
1	63	90	91	53	37	34
1½	104	123	105	57	47	46
2	132	168	133	58	64	47

[1]Includes 5 positions in openings, 5 readings per day at each position, and 3 to 6 days during the summer.

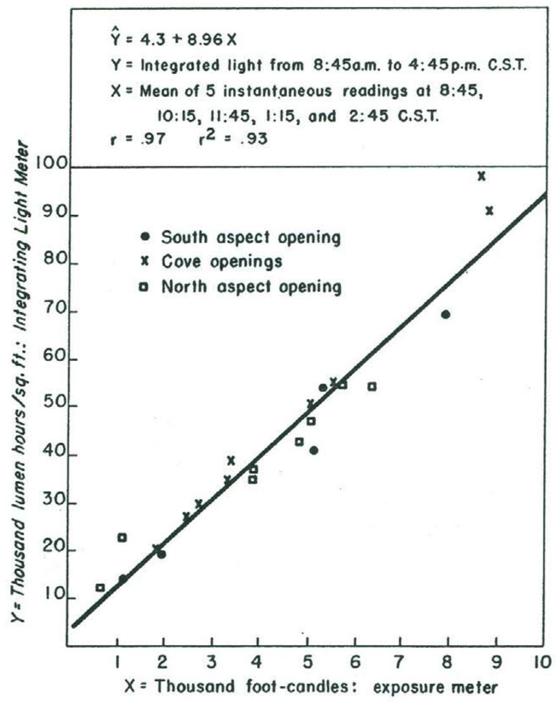
[2]Light influenced by nearby openings; data invalidated.

VALIDITY OF SAMPLING METHODS

Atkins (*1*) has shown that sampling a forest stand with instantaneous readings to obtain average light values can be accurate within acceptable limits of error. He further suggested that readings taken only at noon would be satisfactory for even-aged stands. Data taken in this study showed that noon readings alone give biased results for stands of different density and on different aspects. For example, in dense stands (80 to 85 square feet basal area) the average light at noon under the canopy was much greater than at 9 a.m. or 3 p.m. on both sites. Stands with low density (40 to 45 square feet basal area) in coves and on northerly slopes on the other hand had the same average light at 9 a.m., noon, and 3 p.m. But on southerly slopes these low-density stands had by far the highest average light on the forest floor at 3 p.m.

In this study the consistent and logical results for average light on the forest floor indicate that the sampling done by instantaneous light readings was adequate. Furthermore, on 22 clear days during July and August in 1959, the Integrating Light Meter was placed at the center of the opening where instantaneous readings were being taken. Cumulative light (Integrating Meter) was measured from 8:45 a.m. to 4:45 p.m. and instantaneous readings (Brockway meter) taken at the 5 regular times already given. The average of the 5 instantaneous readings in foot-candles was plotted over the cumulative light value in lumen-hours per square foot. The coefficient of correlation "r" was 0.97 (highly significant) and the regression equation was: $\hat{Y} = 4.3 + 8.96X$ (fig. 4). In these openings the cumulative light in lumen-hours per square foot during the 8-hour period was approximately 10 times the average of 5 instantaneous readings in foot-candles taken at 1½-hour intervals. Aspect had no effect on the relation. The 5 instantaneous readings in foot-candles at zenith and at 1½-hour intervals before and after zenith gave a reliable estimate of cumulative light in openings in the forest canopy when the Integrating Light Meter values for the day were taken as a standard.

FIGURE 4. — Correlation between light as measured by Integrating Light Meter and exposure meter at same stations on same days (clear days: 1959).



CONCLUSION

The incident light meter readings were found to be closely correlated with results obtained with the Integrating Light Meter. Repeated instantaneous measurements which properly sample the day and season provide a satisfactory substitute for measuring cumulative light in one place. Also, average light values on a forest area can be obtained by instantaneous light readings which sample the area as well as the time of day and season. Hence, the method described here can be recommended for use wherever similar light information is needed.

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