INTERCEPTION OF SOLAR RADIATION BY THREE DECIDUOUS FOREST COMMUNITIES IN NEOTOMA, A VALLEY IN SOUTHCENTRAL OHIO[1]

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Abstract. Daily direct solar plus sky radiation (global) was measured above the canopy and at the forest floor in 3 deciduous forest communities of Neotoma, a small valley in southcentral Ohio. The amount of daily global radiation at the forest floor was maximal during April and rapidly declined as the canopy closed. After canopy closure, and throughout the summer, the percent of total global radiation reaching the forest floor was constant for the mixed mesophytic and mixed oak communities; 10.1 percent for the mixed oak community, and 7.3 percent for the mixed mesophytic community. The percent of total global radiation reaching the forest floor of the ridgetop chestnut oak community was much greater, averaging 26.5%, and more variable.

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The Neotoma Ecological Laboratory (82°33′18″ W longitude 39°35′55″ N latitude) has been the site of numerous biological and microclimatic studies for more than 50 years. Early studies (1939–44) of the microenvironments of Neotoma were reported by Wolfe and co-investigators (1949). In 1953, expanded bioenvironmental studies were initiated. One of the major objectives of these studies was to further define climates near the forest floor and analyze other climatic strata in the forest at all seasons of the year (Wolfe and Gilbert 1956).

Global radiation (direct solar plus sky radiation) reaching a forest ecosystem is of major importance to the biota. As global radiation penetrates the forest canopy, the quantity of radiation is diminished and the quality (the portion of energy in a given waveband) is changed due to differential absorption and refraction by the canopy. Thus, the quantity and quality of solar radiation reaching the forest floor is a function of the thickness of the canopy, species composition, orientation of leaves and spatial pattern of stems, and other factors (Reifsnyder and Lull 1965). The amount and quality of global radiation at the forest floor controls primary production, transpiration, evaporation and other energy dependent processes important to life in this stratum.

METHODS AND MATERIALS

Global radiation studies were initiated in early spring of 1958 with the installation of Eppley 10-junction, nontemperature-compensated pyronometers 30 cm above the forest floor and approximately 3 m above the canopy in each of the 3 major study areas. The study areas were located in the central portion of the valley; one on each of the opposing slopes and one on the west ridge (fig. 1). The vegetation in the study areas was described by Wolfe and Gilbert (1956). The mixed mesophytic area (mm in fig. 1) was located on the lower northeast-facing slope in a young mixed mesophytic community. The sensors in this study area were oriented parallel to the slope 17° from the horizontal and faced northeast. The chestnut oak area (co in fig. 1) was on the relatively narrow west ridge in a chestnut oak community. The sensors at this station were horizontal. The mixed oak study area (mo in fig. 1) was approximately midslope in a mixed oak community on the southwest-facing slope. The sensors in this area were oriented 17° from the horizontal and faced southwest. Data from 2 of the 3 above-canopy sensors are not included in this report because they were not horizontal.

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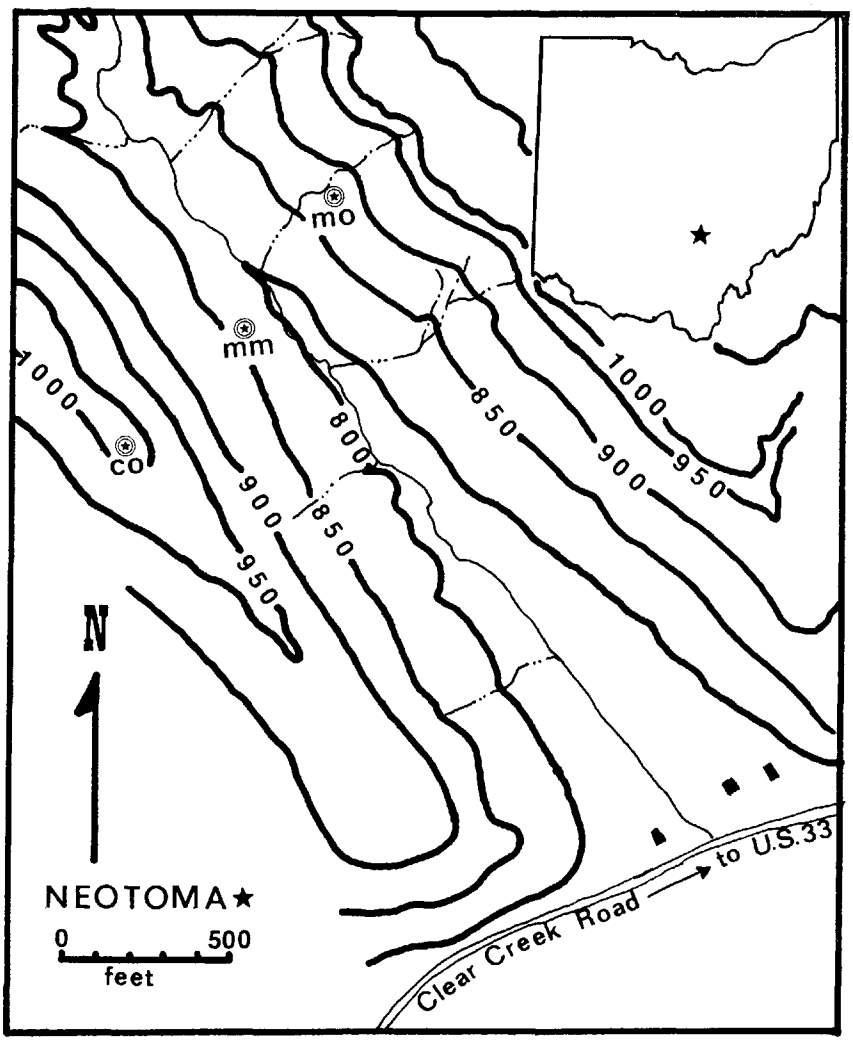

FIGURE 1. Location of Neotoma and location of study areas within valley. Neotoma is located 8.5 miles SSE of Lancaster, OH in Hocking County (NE ¼ Sec. 16 Goodhope Township), the center of the valley being located approximately 82°33′18″ W longitude and 39°35′55″ N latitude. The mixed oak study area (mo) is located at mid-elevation of southwest-facing slope, the mixed mesophytic study area (mm) is located on the lower portion of the northeast-facing slope and the chestnut oak study area (co) is located on the west ridge.

The millivolt output of the Eppley pyronometer was recorded by a Leeds and Northrup Speedomax G multipoint recorder. The points on the chart for each Eppley unit defined a curve whose area represented the total daily global radiation. A planimeter was used to measure the morning and afternoon areas separately and the data were transferred to computer cards for analyses. The study was discontinued in 1961 but data are not complete for all stations due to occasional malfunctions of equipment and electrical outages.

RESULTS AND DISCUSSION

The forest floor received its maximum radiation during the month of April (fig. 2). By the latter half of April, the buds of most canopy species had broken dormancy and leaf expansion occurred rapidly during the first part of May (Wolfe *et al* 1949). The impact of leaf expansion on global radiation at the forest floor was clearly indicated by a

drop in the radiation curve (fig. 2). The increasing above-canopy radiation (fig. 3) was not sufficient to compensate for attenuation by the closing canopy, resulting in a decreasing amount of global radiation at the forest floor. Leaf expansion was essentially complete by the 25th of May and both the quantity and percent of global radiation reaching the forest floor remained relatively uniform throughout the summer season. The amount of global radiation reaching the forest floor did not increase until initiation of leaf abscission during the latter part of October. The increase, however, was not nearly as striking as the decrease in May, due to the greatly reduced flux of global radiation on the canopy in late October.

The average daily total global radiation transmitted by the canopies of the 3 study areas was significantly different only during the early summer months of the year (fig. 2). The average transmitted radiation, however, was always least in the mixed mesophytic community. The chestnut oak community of the ridgetop received the greatest

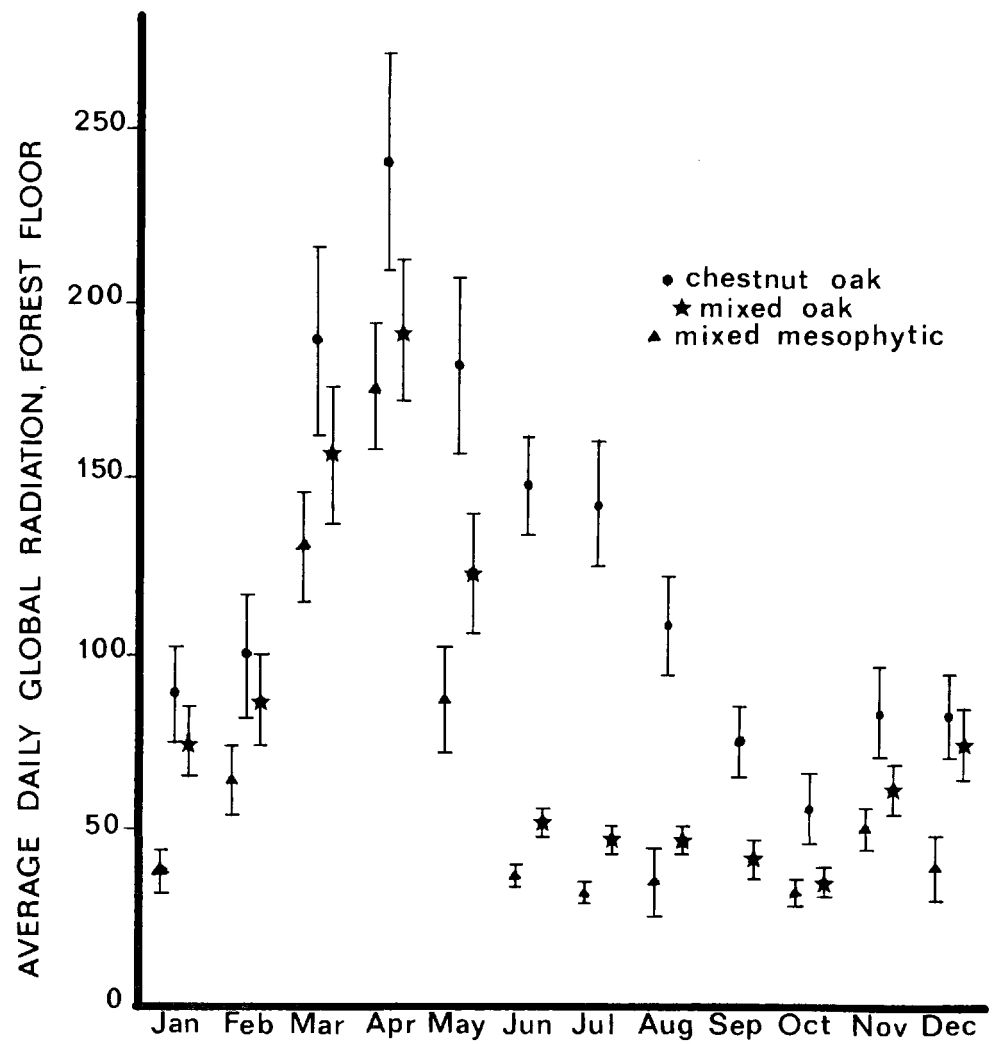

FIGURE 2. Average daily global radiation measured 30 cm above the forest floor in the three forest communities. Bars represent 95% confidence intervals. Global radiation units are cal cm^{-2} day^{-1}.

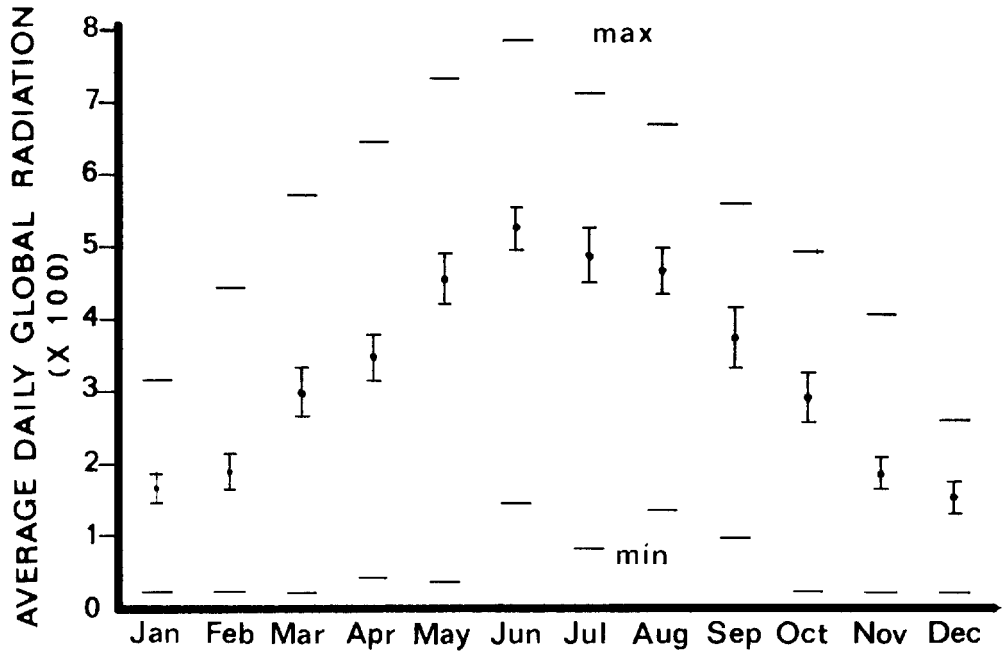

FIGURE 3. Maximum, minimum and average daily global radiation per month measured 3 m above the canopy of chestnut oak community. Bars represent 95% confidence intervals. Global radiation units are cal cm^{-2} day^{-1}.

amount of insolation and was the only station whose sky hemisphere was not blocked by some physiographic feature. Amount of daily global radiation at the forest floor in the chestnut oak community followed the above-canopy global radiation more closely than the other 2 communities (figs. 2 and 3). After the initial decrease in May due to canopy closure, daily global radiation at the forest floor in the chestnut oak community remained relatively high and averaged more than 90 cal $cm^{-2}day^{-1}$ greater than the slope communities during the summer months. The difference between the slope communities was less than 15 cal $cm^{-2}day^{-1}$.

Percent of total global radiation transmitted to the forest floor (table 1) was slightly higher than values reported for other deciduous forest communities during the summer season (Reifsnyder and Lull 1965). The difference in transmittance by the canopies of the 2 slope communities was much greater in the winter condition than during the summer. Percent of global radiation transmitted during the summer for these 2 communities was constant, as shown by scatter plots and the small standard deviations in table 1. There was a rapid decrease in the variability of the percent transmitted during the months of April and May as the canopy closed. Only in the chestnut oak community did the percent transmitted appear to increase with increasing global radiation during the summer or closed canopy period. In the mixed mesophytic and mixed oak communities, the percent radiation tranmsitted during the summer did not appear to be a function of the amount of above-canopy global radiation.

The following conclusions were based on global radiation data obtained from Eppley pyronometers 30 cm above the forest floor in each of 3 deciduous forest communities, and one pyronometer 3 m above the canopy:

1. Daily global radiation at the forest floor reached a maximum in mid-April followed by a relatively rapid decline beginning with leaf expansion in late April and continuing until canopy closure in

TABLE 1

Percent of total global radiation reaching the forest floor during the summer and winter seasons in three forest communities.

Forest community	Percent of total global radiation					
	Summer			Winter		
	Av.	SD*	N*	Av.	SD*	N*
Chestnut oak	26.5	6.24	155	57.1	14.04	125
Mixed oak	10.1	2.74	240	46.8	12.30	214
Mixed mesophytic	7.3	2.30	129	30.8	11.86	137

*SD—Standard deviation, N—Number of days of data.

late May. This effect was more pronounced in the slope communities than in the ridgetop chestnut oak community.

2. After canopy closure, the percent of total global radiation transmitted by the canopy remained relatively constant throughout the summer in both slope communities and did not appear to be a function of the amount of global radiation above the canopy. The average percent transmittance was 7.3 for the mixed mesophytic community and 10.1 for the mixed oak community.

3. Average daily global radiation at the forest floor during the summer was about 95 cal $cm^{-2}day^{-1}$ more in the chestnut oak community than in the mixed oak community, which averaged about 15 cal $cm^{-2}day^{-1}$ more than the mixed mesophytic community.

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