

Photosynthetically Active Radiation Measurements in Pure Pine and Mixed Pine Forests in Poland¹

Jaroslav Smialkowski²

Abstract

Photosynthetically active radiation (PAR) has been measured in pure pine and mixed pine forests on 15 sites in two transects in Poland: the "climatic" (from the western to the eastern border), and the "Silesian" (from the most to the less polluted part of the country). PAR was measured by using the standard procedure developed by the USDA Forest Service's Forest Health Monitoring Program. At each forest site PAR was measured at the "central point" and at six points 7.3 m from the central point. PAR was also measured at three additional points (at the location of litterfall collection). Eight out of 15 forests were classified as pure pine, and 7 as mixed pine. Two series of measurements were completed in September/October 1994 and in July/August 1995. The first measurements showed that the mixed pine forests were more shaded than the pure pine forests. Average leaf area index (LAI) for mixed pine forests was 2.03 and 1.78 for pure pine. Mixed forests were characterized by greater seasonal changeability of LAI because of a higher amount of broadleaved trees and shrubs. LAI and transmitted PAR (TPAR) standard deviation on a particular forest site may be treated as an index of internal forest differentiation. The indexes differ between particular forests, but average values for pure pine and mixed pine forest are almost identical. The first attempt to correlate PAR indexes and other ecological indexes suggest that there is no correlation between PAR and litterfall and the rate of litter decomposition.

Introduction

Photosynthetically active radiation (PAR) was measured in pine forests of Poland under the Polish-American cooperative program entitled "The Effect of Pollution and Climate Change on Forest Ecosystems." This program includes climatic, ecological, geobotanical, and soil research along two transects. The first transect (eight sites) runs east-west along the 52nd parallel and is associated with the increasing continentality of climate. The second transect (also of eight sites) runs from the most polluted areas of Upper Silesia to the relatively unpolluted part of Poland around the Bialowieza Forest. The most north-easterly point (K011) is common to both transects; and out of a total of 15 sites, 8 were categorized as pure pine forest, and the other 7 as mixed pine forest (*fig. 1*). All the stands contain trees between 70 to 100 years old (Breymer and others 1995).

This study measured PAR along the climatic and Silesian transects in Poland by using an analysis of the different amounts of light reaching the forest floor and procedures of the USDA Forest Service's Forest Health Monitoring Program (FHM 1994), in order to explain the rate of some ecological processes.

Methods

PAR research on the transect sites began in 1994. The first series of measurements at the study sites were recorded in September and October 1994, and the subsequent series in July and August 1995. Unfavorable weather conditions forced the abandonment of measurements at three sites in October 1995. Thus, the series of measurements at three forest sites were incomplete in October 1995.

Organic matter decomposition was sampled at each site at a central point (Breymer and others 1995), and the PAR measurements were made at the central point and at six other points that were 7.3 m from the central point (*fig. 2*). In addition,

¹ An abbreviated version of this paper was presented at the International Symposium on Air Pollution and Climate Change Effects on Forest Ecosystems, February 5-9, 1996, Riverside, California.

² Geographer, Institute of Geography and Spatial Organization, Polish Academy of Sciences, 00-927 Warsaw, Krakowskie Przedmiescie 30, Poland.

PAR was measured at three locations where litterfall was collected. Thus, PAR was measured at a total of 10 points. Analysis of results from the first series of measurements (autumn 1994) showed that data collected in conditions of variable cloud cover (especially with convection cloudiness) were difficult to interpret. Transmitted PAR (TPAR) and leaf area index (LAI) for the forest site were calculated by using incoming light below the canopy and at an ambient station in an open area. The under canopy measurement was a single ceptometer measurement lasting 10 to 15 seconds. The simultaneously collected data from the ambient station (located in an open area) were stored as 1-minute averages (FHM 1994; Decagon Devices, Inc. 1989; LI-COR, Inc. 1990)³. A false result is obtained (LAI may be below 0 and TPAR above 1) if the sun shines during the 15-second under canopy measurement, and is then covered by cloud for the rest of minute (Campbell 1991). Similar distortions of the results may be linked to the distance between a measurement point under the canopy and the ambient station (which is sometimes 300 - 500 m). Uneven convection cloudiness may easily allow the sun to shine over a forest stand, while the ambient station remains in shade. Because of the problems associated with variable cloudiness, the measurements in 1995 were only made in sunny, cloud-free weather, or at times with minimal cloud cover.

³ Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

Figure 1 — Forest sites studied on the climatic and Silesian transects in Poland.

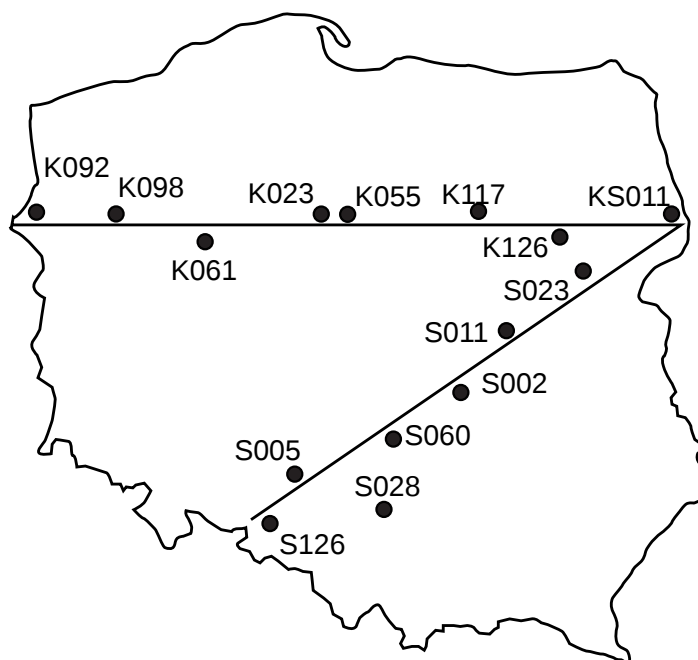
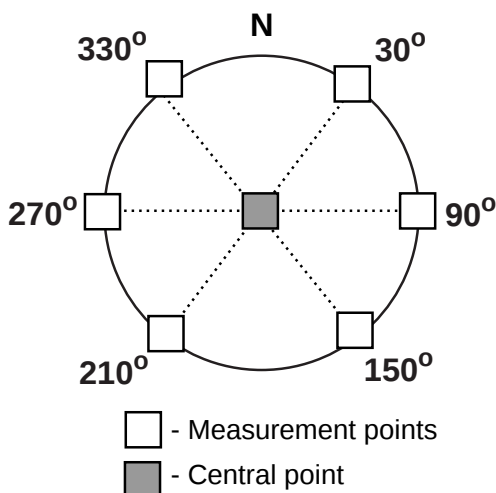


Figure 2 — Schematic diagram of PAR measurements on the forest sites.



Results

The results of the three series of measurements show that mixed pine forests are characterized by lower levels of PAR reaching the forest floor than pure pine forests. The mean for PAR in mixed pine forests was 0.25, while that for the pure pine forests was 0.21 (*fig. 3*). Still greater differences were noted in the case of LAI, which varied between 1.3 and 3 at the study sites. The mean LAI for pure pine forests was 1.78, and that for mixed pine 2.03 (*fig. 4*). These differences are associated with the greater proportion of broadleaved trees and shrubs in the mixed pine forests.

Comparison of summer and autumn measurements yielded these results: all sites for which both summer and autumn data are available showed LAI values to be higher in summer because of the presence of leaves. An exception was site S023, in which the autumn results may be erroneous because of cloudiness. When data for this point are deleted, the mean difference in summer and autumn LAI in mixed pine forest is 1.61 (i.e., a figure greater than the 1.36 recorded from pure pine forests) (*fig. 5*).

Standard deviations of the measured values of TPAR and LAI may be interpreted as a measure of heterogeneity of the forest sites under study. Standard deviation values for LAI were not related to the type of forest, but rather to its internal structure. In the case of LAI these ranged from 0.4 to 1.3. The greatest value was noted for site S005, which had a considerable number of young spruce trees growing in the forest. The mean LAI standard deviation in pure pine forests was 0.75, while that for mixed pine forests was 0.77 (*fig. 6*).

Preliminary attempts were made to correlate the PAR measurements and the other ecological indices (e.g., litterfall and litter decomposition rates). However, despite the fact that LAI is sometimes calculated based on litterfall, statistically significant linkage has not yet been found, except for the inverse correlation between LAI and TPAR.

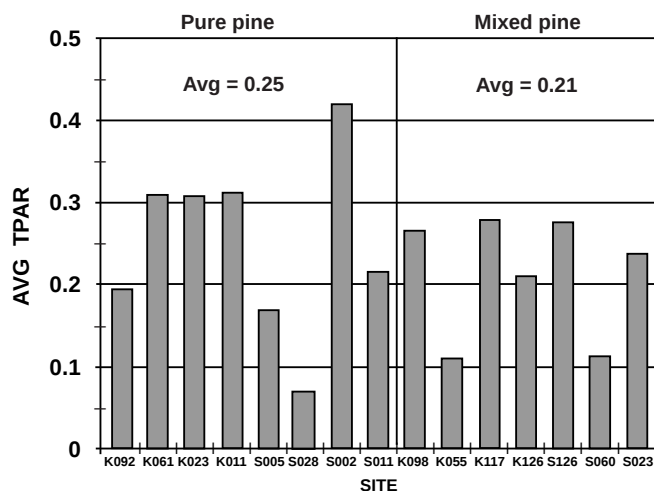


Figure 3 — Average TPAR on the forest sites.

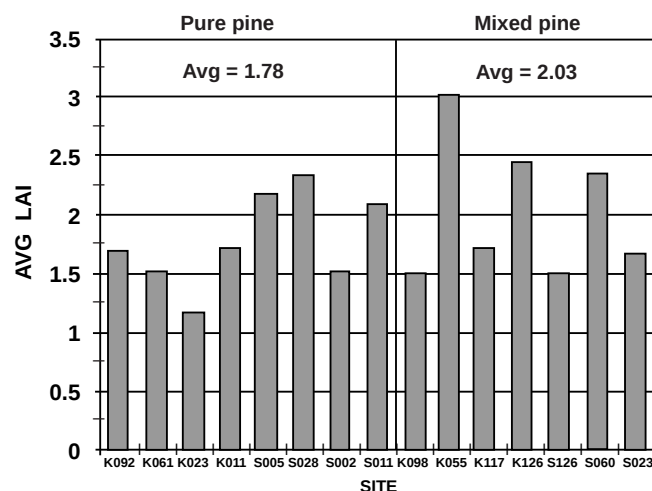


Figure 4 — Average LAI on the forest sites.

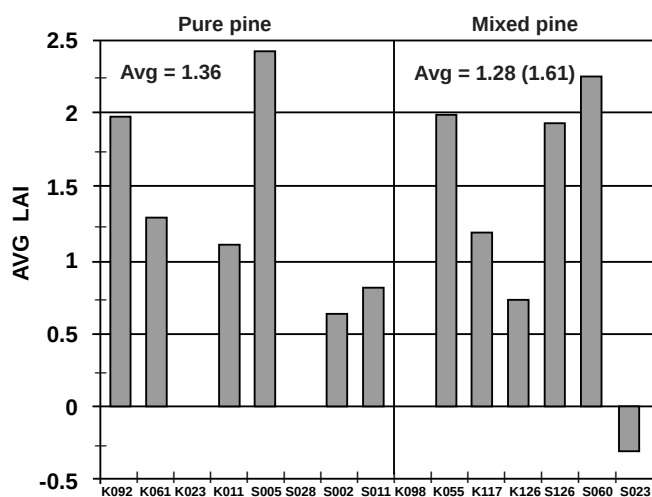


Figure 5 — Differences in LAI between autumn and summer on the forest sites. Average value for mixed pine in parenthesis is the value when data for site SO23 is deleted due to cloudiness at the site (see text).

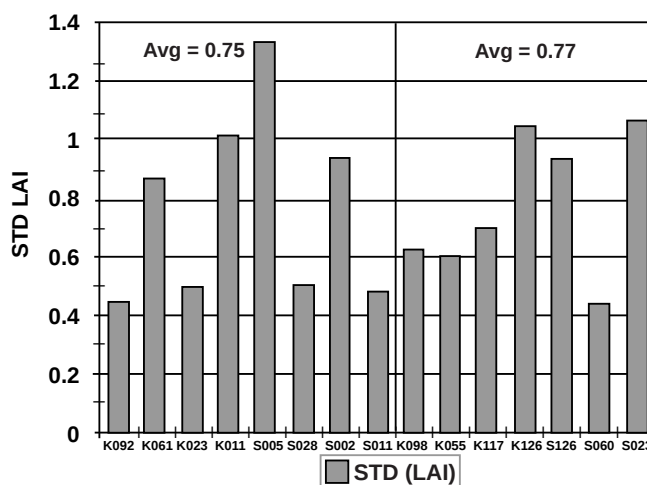


Figure 6 — Internal differentiation of the forest sites measured as standard deviation of LAI.

Acknowledgments

This work was part of a project entitled "U.S.-Poland Cooperative Project on the Status and Long-Term Trends in Forest Ecosystems: Climate, Pollution and Forest Health." The program was financed by the U.S. Environmental Protection Agency, USDA Forest Service, USDA Foreign Agriculture Service, Polish Academy of Sciences, Polish Bureau of Global Environmental Facilities (GEF), Forest Research Institute, Michigan Technological University, Bowling Green State University, and the Institute of Geography and Spatial Organization of the Polish Academy of Sciences.

References

- Breymeyer, A.; Degorski, M.; Roo-Zielinska, E.; Solon, J.; Smialkowski, J. 1995. **Effects of atmospheric deposition and climate change in forest ecosystems in central and eastern Europe and the United States, 1994-1995 report**. Warsaw: Institute of Geography and Spatial Organization, Polish Academy of Sciences.
- Campbell, G.S. 1991. **Application note: canopy leaf area index from sunfleck ceptometer PAR measurements**. Pullman, WA: Decagon Devices, Inc.
- Decagon Devices, Inc. 1989. **Sunfleck ceptometer user's manual**. Pullman, WA: Decagon Devices, Inc.
- FHM 1994. **PAR**. In: Tallent-Halsell, N.G., ed. **Forest health monitoring field methods guide**. Vol 1. Las Vegas, NV: U.S. EPA, Environmental Monitoring Systems Laboratory.
- LI-COR, Inc. 1990. **LI-1000 datalogger instruction manual**, Lincoln, NE: LI-COR, Inc.