

# Streamflow Greatly Reduced by Converting Deciduous Hardwood Stands to Pine

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*Abstract. Fifteen years after two experimental watersheds in the southern Appalachians had been converted from a mature deciduous hardwood cover to white pine, annual streamflow was reduced about 20 centimeters (20 percent) below that expected for the hardwood cover. Streamflow was reduced during every month, with the largest monthly reductions (1.5 to 3.5 centimeters) occurring in the dormant and early growing seasons.*

Do different forest types vary substantially in evapotranspiration on a given site? This question has long been debated, and conclusive experimental evidence has generally been lacking (1). The results of experiments at the Coweeta Hydrologic Laboratory reported in 1968 (2) showed small reductions in streamflow and thus greater evapotranspiration only 10 years after mature hardwoods had been removed and eastern white pines (*Pinus strobus* L.) had been planted. The 5 years of additional data reported here provide conclusive evidence that evapotranspiration from the young white pine stands is substantially greater than from mature, deciduous forests. Evapotranspiration includes transpiration from plants, evaporation of water intercepted by plants and litter, and evaporation from soil.

The study site is in the southwestern corner of North Carolina in the Appalachian Mountains. Summers are cool, and winters are mild; rainfall is adequate in all seasons (3). The average annual precipitation varies from 2500 mm on the upper slopes to 1700 mm at the lower elevations. The two study watersheds of interest are characterized by deep, permeable soils and steep slopes. Watershed 1 covers 16.1 hectares, has a relief of 293 m, and slopes to the south. After a calibration period, the oak-hickory forest was clearcut in 1956 and white pine

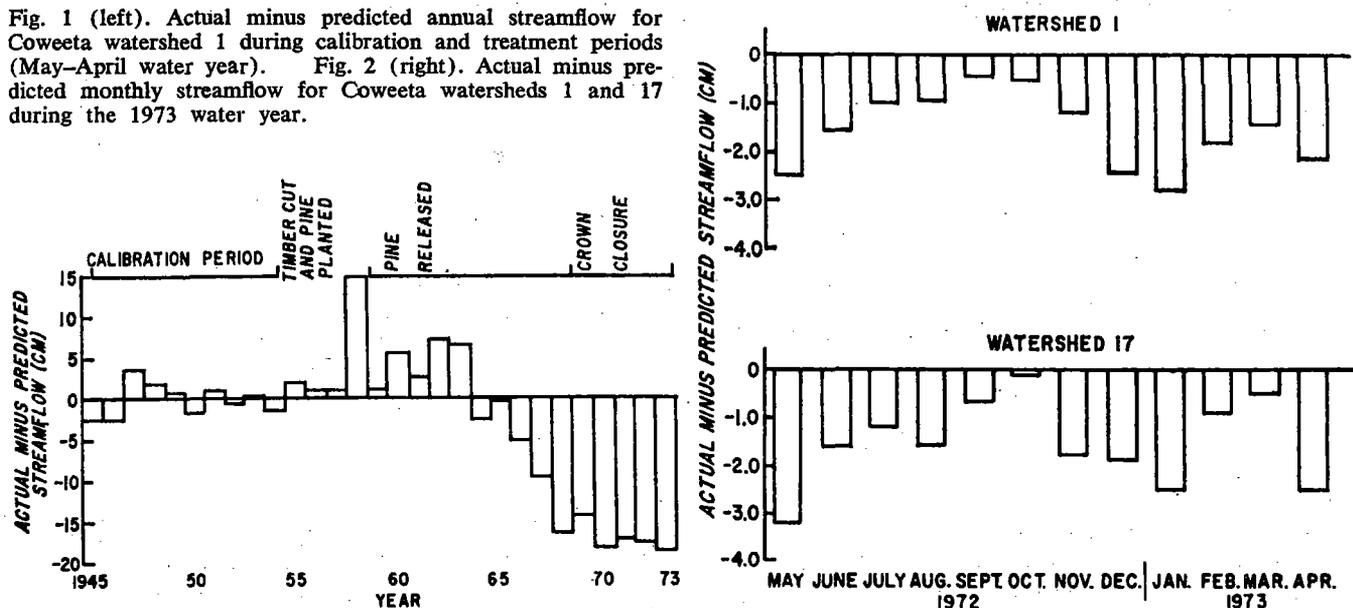
seedlings were planted in 1957. Watershed 17 covers 13.4 hectares, has a relief of 280 m, and slopes to the northwest. The native hardwood forest was cut in 1942; thereafter, sprouts were cut almost every year between 1943 and 1955. White pine was planted in 1956. Competing hardwood sprouts were cut or sprayed with chemicals as required to release the pine. The watersheds and their treatment have been described in detail elsewhere (2). The effects of vegetative changes on water yield were assessed by the paired or control watershed method (4). Monthly streamflow prediction equations were derived from a calibration period during which a control watershed and the watershed to be treated were both undisturbed. Annual treatment effects are the sums of deviations from 12 monthly calibration regressions (actual minus predicted flow). The deviations for watershed 1 are shown in Fig. 1. The calibration regression is shown as the zero line, and the small deviations during the period of calibration represent random error. In the treatment period, error terms are relatively small. For example, the annual streamflow in 1967 is significantly different at the .95 probability level if it differs from the predicted flow by more than  $\pm 3.0$  cm for watershed 1.

Streamflow responses to treatments prior to the planting of white pine have

been reported for both watersheds (2, 5). After planting, changes in annual streamflow were similar on both catchments and the results are illustrated for watershed 1 (Fig. 1). For several years, changes in streamflow from the planted catchments remained relatively constant. Thereafter, streamflow declined at a rate of 2 to 5 cm per year until 1969. After crown closure, which corresponds to the culminated development of foliar surface (6), the rate of streamflow reductions tended to level off. By 1973, streamflow from both pine-covered watersheds was almost 20 cm (20 percent) less than expected under undisturbed hardwood cover. This means that annual evapotranspiration from the young pine stands is 20 cm greater than from hardwoods.

The monthly reductions in water yield from both watersheds have been similar for the past 4 years, and the patterns for watersheds 1 and 17 during 1973 are illustrated in Fig. 2. Streamflow reductions of 1.5 to 3.5 cm occurred during most months of the dormant and early growing seasons (November 1971 through June 1972). Streamflow decreased about 1 cm in July and August and about 0.5 cm during September and October. Although the reductions appear to be small in the period from August through October, streamflow is normally lowest in these months and the reductions represent a 4 to 50 percent

Fig. 1 (left). Actual minus predicted annual streamflow for Coweeta watershed 1 during calibration and treatment periods (May–April water year). Fig. 2 (right). Actual minus predicted monthly streamflow for Coweeta watersheds 1 and 17 during the 1973 water year.



decrease in flow from that predicted for the previous hardwood cover.

Reasons for greater evaporative losses from young white pine than from mature hardwoods have been given by Swank and Miner (2). Interception and subsequent evaporation of rainfall is greater for pine than hardwoods during the dormant season (7). Interception loss is a function of the leaf surface area [leaf area index (LAI)], and LAI in a hardwood stand is greatly reduced by leaf fall. The LAI values are calculated for one side on hardwood foliage but for all sides on pine foliage because these are the primary intercepting surfaces. In the dormant season (for example, the winter of 1972), LAI for hardwoods is less than 1 compared to 9.9 for white pine (6). Thus, less precipitation reaches the soil under pine and the result is lower streamflow in the dormant season. Based on the results of the simulation of evaporation for pine and hardwoods (8), we postulate that transpiration losses are also greater for pine during the dormant season. In April and May when the pine is in full leaf and hardwoods are leafing out, combined interception and transpiration losses appear to remain much greater

for pine as shown by streamflow reductions. The net effect of greater evapotranspiration is that streamflow from the white pine forests is lower during every month of the year than that from a hardwood forest.

The results on these watersheds have important implications for the management of water resources. It is clear that the quantity of streamflow can be substantially altered by changing the type of forest vegetation. On municipal watersheds in the east, white pine has long been a favorite species for planting but this practice will reduce water supplies. On watershed 1, water available for downstream use in 1972 was reduced by  $23.7 \times 10^6$  liters by converting just 16 hectares from deciduous hardwood to white pine. Identical water yield reductions would not be expected everywhere because of differences in climate and vegetation. But a summary of interception by conifers in North America (9) indicates greater interception loss for pine species and other conifers than for deciduous forests. Thus, since the evaporative processes involved are universal, a trend toward streamflow reductions when deciduous hardwood stands are converted to pine might be expected in other regions.

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11 February 1974; revised 9 April 1974

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