Streamflow Greatly Reduced by Converting Deciduous Hardwood Stands to Pine

Author(s): Wayne T. Swank and James E. Douglass

Source: *Science*, Sep. 6, 1974, New Series, Vol. 185, No. 4154 (Sep. 6, 1974), pp. 857-859

Published by: American Association for the Advancement of Science

Stable URL: https://www.jstor.org/stable/1739005

in the magnitude range 3.5 to 4 shown in Fig. 2) a large variation in resistivity was observed at receiver 1A. While the data taken before 1 June 1973 are sparse in time and have relatively large errors, it appears that the apparent resistivity began decreasing in the middle of April, dropped by 10 percent, subsequently increased at the end of May to a maximum of 10 to 15 percent above the initial level, and dropped again to the initial level by 15 June. On 22 June, at the end of this 60-day variation, a magnitude 3.9 earthquake occurred midway between the transmitter and receiver at a depth of 9.5 km. An independent set of data from receiver 1B displays the same characteristics. The data from receiver 2 also show a pronounced variation but, possibly because of poor sampling, a maximum is not observed immediately before 22 June. The near-surface resistivity monitored at receiver 3 from 1 May shows no variation, which rules out the possibility that some near-surface phenomenon on the east side of the fault near the transmitter caused the variations at receivers 1 and 2. During the period 14 April to mid-October no rain fell in the area.

During the period 15 April to 15 June there was a reduction in the number of earthquakes in the area encompassed by the array. After the magnitude 3.9 event on 22 June, a more or less regular frequency of earthquakes was observed. This may be significant, since on the basis of the dilatancy model one might expect a dilatancy hardening effect and consequently a reduction of earthquake activity during the precursor period (*6*, *7*).

A second, less significant variation occurred at receiver 2 between 15 September and 15 October. A similar response was not observed at receiver 1. It is possible that this variation is associated with a swarm of earthquakes occurring within the array between 8 and 13 October. These are identified in Fig. 1. The total strain of these events is equivalent to that of an earthquake of magnitude 3.5 (*8*). The hypocenters ranged from 2.9 to 9.8 km in depth.

Finally, a 6 percent increase in the resistivity in the middle of December at receiver 3 may be associated with a magnitude 2.6 earthquake on 14 December. The epicenter of this event lay about 1 km southwest of the southernmost current electrode of the transmitter. This association, however, is clouded by the fact that the event occurred at a depth of 13 km, while the effective sensing depth of receiver 3 is of the order of 1 to 2 km. Considerable rain fell in the area starting in the middle of October. Very little change occurred at receiver 3 during this period, except just before the 14 December event. Thus, while the earthquake occurred at considerable depth, some phenomena associated with it may have occurred much closer to the surface.

The resistivity arrays used in this study allow only a partial definition of the locations and volumes of the sources that produce the observed variations in apparent resistivity. Numerical calculations indicate that either a large volume of earth was affected before the magnitude 3.9 earthquake, or the intrinsic resistivity of a smaller volume changed dramatically. For example, the results could be accounted for by an 80 percent change in intrinsic resistivity in a region 4 km wide and 2 to 6 km deep in the fault zone. Such a change is physically possible. The resistivity changes reflect changes in the porosity and degree of water saturation of the volume of rock stressed before an earthquake and consequently support the dilatational theory of earthquake mechanisms (*6*). The 60-day precursor time before the magnitude 3.9 event fits the relation between precursor time and magnitude given by Scholz *et al.* (*6*).

The sequence of an increase followed by a decrease in resistivity with a subsequent earthquake is similar to the response reported by Barsukov (*2*) for thrust faults in the Garm region of the Soviet Union (*6*). This suggests that a similar mechanism may be involved in the two different tectonic areas. However, a detailed interpretation of the observed phenomenon in terms of a dilatational or any other model should not be made until other events have been observed with greater accuracy and more sampling.

ALDO MAZZELLA
H. FRANK MORRISON
Engineering Geoscience, University of California, Berkeley 94720

References and Notes

1. W. Brace and A. S. Orange, *J. Geophys. Res.* **73**, 1433 (1968); E. I. Parkhomenko, *Electrical Properties of Rocks* (Plenum, New York, 1967), pp. 160–184.
2. O. M. Barsukov, *Tectonophysics* **14**, 273 (1972).
3. G. V. Keller and F. C. Frischknecht, *Electrical Methods in Geophysical Prospecting* (Pergamon. New York, 1966), p. 183.
4. These data were provided by the U.S. Geological Survey, Menlo Park, California.
5. D. M. Boore and D. P. Hill, in *Proceeding of the Conference on Tectonic Problems of the San Andreas Fault System*, R. L. Kovach and A. Nur, Eds. (Stanford Univ. Press, Stanford, Calif., 1973), p. 215.
6. C. H. Scholz, L. R. Sykes, Y. P. Aggarwal, *Science* **181**, 803 (1973).
7. J. H. Whitcomb, J. D. Garmany, D. L. Anderson, *ibid.* **180**, 632 (1973).
8. C. F. Richter, *Elementary Seismology* (Freeman, San Francisco, 1958), p. 368.
9. We thank A. Dey for assistance in computer modeling and the Lawrence Berkeley Laboratory for providing computer time. Supported by U.S. Geological Survey contract 14-08-0001-G-51.

19 June 1974

Streamflow Greatly Reduced by Converting Deciduous Hardwood Stands to Pine

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 ± 3.0 cm for watershed 1.

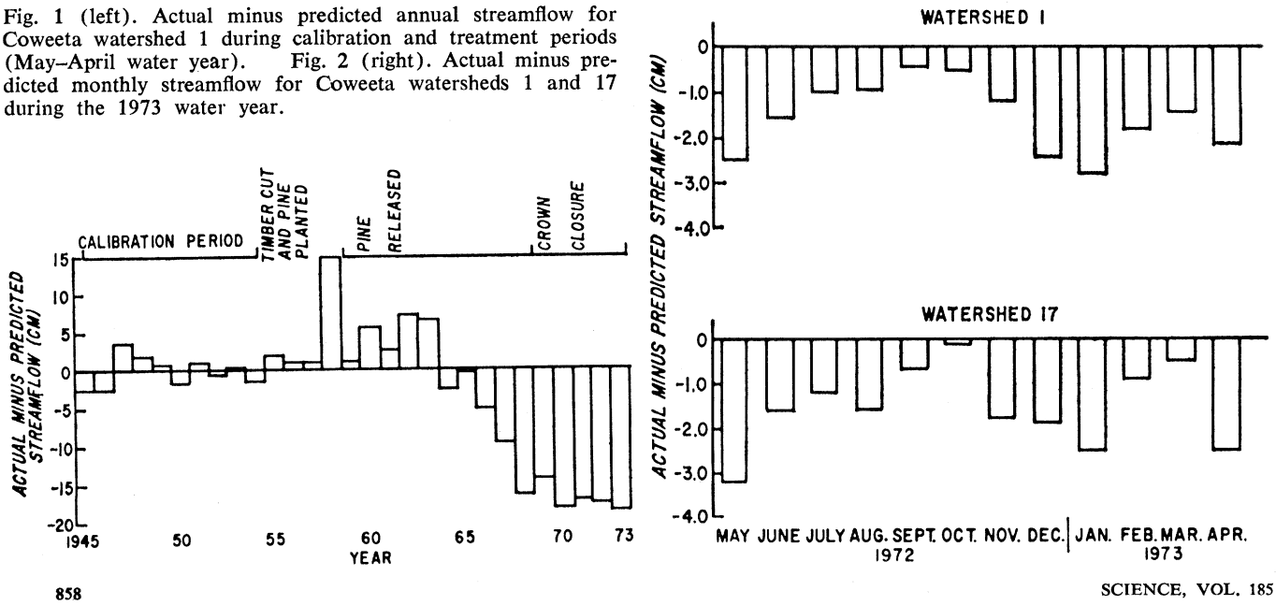
Streamflow responses to treatments prior to the planting of white pine have been reported for both watersheds (*2*, *5*). After planting, changes in annual streamflow were similar on both catchments and the results are illustrated for watershed 1 (Fig. 1). For several years, changes in streamflow from 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 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

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.



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 23.7×10^6 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.

WAYNE T. SWANK
JAMES E. DOUGLASS
Coweeta Hydrologic Laboratory, Southeastern Forest Experiment Station, Franklin, North Carolina 28734

References

1. H. L. Penman, *Vegetation and Hydrology* (Technical Communication 53, Commonwealth Bureaux of Soils, Commonwealth Agricultural Bureaux, Harpenden, England, 1963).
2. W. T. Swank and N. H. Miner, *Water Resour. Res.* 4, 947 (1968).
3. G. T. Trewartha, *An Introduction to Climate* (McGraw-Hill, New York, 1954).
4. K. G. Reinhart, in *Proceedings of the International Symposium on Forest Hydrology*, W. E. Sopper and H. W. Lull, Eds. (Pergamon, New York, 1967), pp. 715–723; J. D. Hewlett, H. W. Lull, K. G. Reinhart, *Water Resour. Res.* 5, 306 (1969).
5. A. R. Hibbert, in *Proceedings of the International Symposium on Forest Hydrology*, W. E. Sopper and H. W. Lull, Eds. (Pergamon, New York, 1967), pp. 527–543.
6. W. T. Swank and H. T. Schreuder, in *International Union of Forest Research Organizations Biomass Studies: S4.01, Mensuration, Growth and Yield, Working Party on the Mensuration of the Forest Biomass* (College of Life Sciences and Agriculture, University of Maine, Orono, 1973), pp. 171–182.
7. J. D. Helvey, *Water Resour. Res.* 3, 723 (1967).
8. L. W. Swift, Jr., W. T. Swank, J. B. Mankin, R. J. Luxmoore, R. A. Goldstein, paper presented at the Symposium on Evaporation and Transpiration from Natural Terrain, 1974 [*Eastern Deciduous Forest Biome Mem. Rep. 73–79* (1973)].
9. J. D. Helvey, in *Proceedings of the International Symposium for Hydrology Professors* (Purdue University, Lafayette, Ind., 1971).

11 February 1974; revised 9 April 1974

Human Serum Albumin Phenotype Activation in Mouse Hepatoma–Human Leukocyte Cell Hybrids

Abstract. *Murine hepatoma cells that secreted mouse serum albumin were fused with human leukocytes that did not produce albumin. The resulting hybrids secreted both mouse and human serum albumin, as demonstrated by immunoelectrophoretic techniques. The activation of the human genome suggests that mapping genes governing specialized functions in somatic cell hybrids may be accomplished by using adifferentiated human cells as a parental line.*

Interaction between cells in different epigenetic states has been examined in a variety of somatic cell hybrid combinations (*1, 2*). Three general results have been reported: (i) The specialized phenotype continues to be expressed (*3*), (ii) it is extinguished (*4*), or (iii) the specialized phenotype is activated in the allogeneous genome (*5*). These kinds of experiments do not directly provide information about the process of cellular differentiation, but they do provide opportunities for the analysis of phenotype modulation in specialized cells. We report here the activation of the human serum albumin (HSA) phenotype in hybrid cells between a murine hepatoma line and human leukocytes. Furthermore, we propose that such allogeneous hybrid combinations between a mouse differentiated cell line and diploid human fibroblasts or leukocytes can be used to map human genes governing specialized phenotypes. Possibly such hybrids may also provide insight regarding molecular mechanisms that regulate gene expression.

Murine hepatoma cells were adapted to in vitro growth by the procedure described by Buonassisi *et al.* (*6*). The tumor from which the cells were derived is the BW 7756 hepatoma carried in C57 leaden mice (Jackson Laboratory, Bar Harbor, Maine). Hepa 1a, which is a clonal population deficient in hypoxanthine guanine phosphoribosyltransferase (HGPRT), was used as the murine parental line. This enzyme-deficient line was obtained by treating 10^6 hepatoma cells with 10 μg per milliliter of thioguanine in medium MAB 87/3 until colonies were sufficiently large to be isolated. One such colony, Hepa 1a, was expanded and then shifted to medium containing 30 μg per milliliter of thioguanine. Activity for HGPRT in these cells was measured in two ways. (i) Hepa 1a failed to grow in medium containing aminopterin, hypoxanthine, and thymidine [see (*7*)]. (ii) No enzymatic activity could be seen when cell extracts were subjected to electrophoresis and then examined by autoradiography, according to the method of Tischfield *et al.* (*8*). Hepa 1a cells have retained the ability to express some liver-specific traits in vitro (*9, 10*); of most interest is the synthesis and secretion of mouse serum albumin (MSA). The MSA secretion rate is approximately 230 ng of albumin per milligram of cellular protein per hour (*11*). Serum albumin secretion appears to be restricted solely to hepatocytes (*12, 13*). Cell line Hepa 1a has been examined for the presence of other hepatic traits, and Es-2, a liver-specific esterase (*14*), was shown to be present. Activity for alcohol dehydrogenase, xanthine oxidase, and aldolase B could not be demonstrated by starch-gel electrophoresis. The karyotype of Hepa 1a differed from the normal diploid cell; four to six bi-armed chromosomes were present and the modal chromosome number was 58. In addition, a long acrocentric chromosome containing interdigitated heterochromatic regions served as a useful marker.

The human parental cells were peripheral leukocytes from a normal male. Before hybridization, leukocytes were separated from the whole blood according to the method of Bodmer *et al.* (*15*), but with the substitution of Plasmagel (Roger Bellon Laboratories, Neuilly, France) for the dextran. After fusion (*16*), colonies grew within 8 weeks, and five of these were isolated and designated Hal 3, Hal 5, Hal 6, Hal 7a, and Hal 7b. The latter two, 7a and 7b, appeared in the same culture flask and most probably arose from a single fusion event, since they have similar chromosome and phenotype constitutions.

To verify the hybrid nature of the Hal populations, cell extracts were analyzed by enzyme electrophoresis. All hybrids expressed HGPRT activity characteristic of the human parent (see Fig. 1A for the electrophoretic mobility of this enzyme) (*17*). Cell extracts were tested for 25 additional enzymes whose electrophoretic mobilities differ between mouse and man (see legend, Table 1). The mouse forms of all enzymes were invariably present, but only a few human phenotypes were retained in any one hybrid (Table 1). No more than two human autosomally inherited markers plus the X-linked genes were seen in any Hal line, suggesting that most of the human chro-