THE OHIO JOURNAL OF SCIENCE

VOL. 63 MARCH, 1963 No. 2

WATER CONSERVATION RESEARCH IN OHIO[1]

LLOYD L. HARROLD, RICHARD B. MARSTON AND GLENN O. SCHWAB[2]

Water conservation properly begins with management of the land receiving rain or snow. The term "conservation" means wise use for benefit to as many as possible. Therefore, conservation of water implies programs designed to make the best use of nature's water supply as it is delivered or stored for future use, either at its point of delivery or downstream. It could also apply to the use of underground water supplies that have accumulated over the period of many years, perhaps centuries. In the latter case, problems naturally arise where removal rates far exceed recharge rates. Heavy pumpage in areas of industrial and urban developments are notable examples.

Water conservation also applies to drainage programs for the removal and disposal of excess water on or beneath the land surface of cropland. It relates to the entire soil-water-plant relationship. Research into the field of irrigation is also within the scope of this consideration. Annual amount of precipitation averages 30 to 45 in. over Ohio of which 20 to 25 in. comes in the April-September period. Large variations from the average and erratic distributions create problems of "too much or too little." Until recent years, the effect of land treatment on erosion and water control has largely been unmeasured.

MAJOR WATER CONSERVATION PROBLEMS REQUIRING RESEARCH

The 1960 report of state and federal agencies on the subject of conservation research needs gave high priority to data on runoff peak flow, surface and underground water supplies, surface and subsurface drainage, and soil and water relationships on agricultural and forest lands of Ohio. The effects of land management and of engineering structures and programs on these factors is considered as part of the over-all subject.

Flood control programs on our headwater areas require basic information on the manner of water delivery in the form of snow or rain, its intensity, the energy of falling drops, the duration and the areal extent of storms, and how these factors cause floods of different magnitude in different seasons on both small and large watersheds. A knowledge of causative factors will help develop economic and efficient flood control systems.

The hydraulics of open channel flow have been studied but under conditions quite different from those of Ohio. Research on permissible velocities in vegetated and bare channels and drainage ditches are needed. We should know more about hydraulic principles and problems of channel transmission losses.

The effect of soils, soil moisture, geology and culture of the watersheds on

[1]Presented before section C, The Ohio Academy of Science, Cincinnati, Ohio, April 21, 1961.

[2]Hydraulic Engineer, Soil and Water Conservation Research Division, Agricultural Research Service, Coshocton, Ohio; Research Forester, Central States Forest Experiment Station, Forest Service, U.S.D.A., Columbus, Ohio; and Agricultural Engineer, Ohio Agricultural Experiment Station, Wooster, Ohio.

water conservation and flood control problems must also be studied. Research in soil surface stabilization for erosion control is also part of the same program.

Research data on water yield are required to develop water supplies to meet the need stemming from accelerated growth and development of our state. It has been said that there is plenty of water delivered by nature in a year's time but its distribution in time and space creates many problems for its best use.

Problems in connection with the purification of water for human use are many. The demands for such techniques are rapidly increasing. Research in this field of water management is recognized to be of high priority.

Drainage problems are extensive in much of the best agricultural land of Ohio Land of little slope has a small erosion problem. However, surface water in these areas collects in pockets and is difficult to remove. These lands also are noted for their poor internal drainage and low production in wet years. Much field research is needed in this phase of water management.

Research in the subject of soil, water, and plant relationships included studies of water requirements by crops and other cover types, periods of high and low water use, water efficiency by type of cover, and problems in irrigation supplies, distribution and application. Although irrigated acres are few in the State, they are quite valuable in food production. It is likely that there will be more acres under irrigation in the future. We must learn how to get the maximum food and fiber production out of each inch of rainfall. Water-rights laws need to be developed to guide the future of irrigation and of industrial water use in Ohio.

PRESENT RESEARCH PROGRAMS

The major water conservation research activities in Ohio are fostered by the State and Federal agencies. The Ohio Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture, Agricultural Research Service, has several programs of water study now under way. One pertains to a theoretical and laboratory research program on movement of water through soil which includes a sand tank and electric analog model study. A basic research study is being started on the flow of suspended material through porous media. A field study of tile drainage is being carried on near Tiffin, Ohio. This was started in 1950. A more recent field program to evaluate different methods of drainage was located at the North Central Substation near Sandusky. Within the past year, experiments were started on machine installation of plastic strips formed into drains and placed in mole channels.

The State is also actively engaged in studies of methods for treatment of water from wells and farm ponds to make it usable for human consumption. This research program is cooperative with several State and Federal agencies.

Research programs on plant-soil-water relations in Ohio by the federal government are conducted by the U. S. Department of Agriculture. Although they are located in Ohio, their responsibility is regional. The Agricultural Research Service of the U.S.D.A. has soil and water conservation studies involving (1) drainage theory at the Ohio Agricultural Experiment Station (described above) and (2) watershed technology at Coshocton. Both stations make hydrologic evaluations of the effect of land use. At the Coshocton Station, data are gathered on agricultural watersheds ranging in size from 1 to 4,580 acres. Studies of flood flows and water yield are also being made there. Weighing monolith lysimeters provide data on consumptive use of water by crops, and on percolation water for recharging underground water reservoirs. Studies are under way to determine how data from a small, single-crop watershed can be used to derive estimates of flow for larger complex watersheds. This involves the mapping of water bearing geologic formations and how water from them contributes to stream flow.

Forested areas greatly influence the disposition of the water falling upon them. This influence extends from the time the precipitation reaches the uppermost tips of the canopy until the excess water is delivered as streamflow at the mouth of the watershed. A research responsibility of the Forest Service, USDA, is to assess this forest cover influence on the water and land resources of the oak-hickory forest area of the nation's 30 to 50 in. rainfall belt. Because the area's geology, microclimate, soils, and forest cover vary widely, it is believed that for wide application, basic information on the effects of different kinds of forest cover upon the hydrologic processes will be most useful. At the present time, these studies are concentrated in Ohio because it is typical of the Central U. S. Investigations are being made of the interrelations and effects of the forest cover on hydrology in a combination of laboratory and plot studies, and the results are being tested on small watersheds. Some of the major effects appear in the processes of infiltration, subsoil water movement, evapotranspiration, and water yield.

APPROPRIATE RESULTS OF SOIL AND WATER RESEARCH ON FARM LANDS

The Zanesville soil and water research station in operation from 1934 to 1945 provided data on which many of the early conservation practices were founded. Determinations there of the effects of degree and length of slope influenced the spacing of terraces, width of contour strips, and land use capability in this region. Three small watersheds, woods, pasture, and crop rotation, of only a few acres in size were gauged to supply information on runoff, flood peaks, and erosion.

The watershed research station near Coshocton established in the period 1935–40 has developed a great deal of data from watersheds of 1 to 17,540 acres. Observations are being made of the entire hydrologic cycle—as influenced by land treatment. The results in brief show that surface runoff from storm rainfall was least on the small wooded areas, somewhat greater on pasture land, and most on crop rotation land. Conservation farming methods such as contour tillage, contour strip cropping, crop rotation, mulch, and minimum tillage practices, have been found to reduce soil erosion materially. Surface and subsurface drainage studies have resulted in water removal and improved land management for production.

Greatest quantities of storm runoff from watersheds of less than 10 square miles were found to occur in the growing season as a result of intense local thunderstorms. Maximum floods on these small areas also occurred then. Soil pore space within the root zone in this season was often enough to absorb most of the storm rainfall volume. Infiltration rates and water transmission rates within the soil were, however, not great enough at times to permit utilization of the soil storage capacity to prevent excessive runoff.

On the larger watersheds, 10 square miles and larger, the greatest volumes of stream flow were found in the winter-spring season. Most of this flow was from underground sources—some shallow and some deep. At this season, soil moisture was usually at its maximum, pore space for water absorption at its minimum, and drainage to surface streams and to lower depths at its maximum.

The small watersheds mentioned earlier usually are found at elevations above the major aquifers and their flow was mostly surface runoff. The stream channels of the larger watersheds received large contributions of underground flow from the aquifers through which they cut. The average annual flow volume in the large streams reached 15 watershed-inches, whereas that from the small upland watersheds was less than 2 in. The geology of the area had a great influence on this relationship.

Flood peaks from watersheds up to about 500 square miles drainage area were most frequent and of highest magnitude in the growing season as reported by Harrold (1949). Floods from watersheds greater than 500 square miles in this region, on the other hand, occurred mostly in the winter-spring season. They were caused by long-duration, large-area storms falling on very wet soils. The intense summer storms were usually of small-area occurrence, and therefore caused no frequent flood problems in the larger drainage areas.

Crops which have different rooting depths, have in this area been observed to extract different amounts of moisture from the soil. Bluegrass or poverty grass having shallow roots, wilted after depleting the available moisture in a shallow depth of soil. Deeper-rooted vegetation like alfalfa and bromegrass, or trees, took water from several feet of soil. Annual percolation (recharge to ground water) under alfalfa-brome was over 5 in. less than that under poverty grass. Brakensiek and Amerman (1960) found that annual stream flow from a 43-acre reforested watershed 19 years after planting trees was over 5 in. less than it would have been if no trees had been planted. Reduction from an average dormant-season flow of 8.6 in. was 3.8 in. Reduction from an average growing-season flow of 3.4 in. was 1.7 in. Both surface and subsurface flow were affected. *Average* flood peaks were greatly reduced by this reforestation. Those infrequent flood peaks of high rates resulting from the unusually big storms were not yet found to have been affected by reforestation. However, tree planting has stopped accelerated erosion.

Lysimeter studies of evapotranspiration showed that increased crop yield of 50 bushels of corn increased the consumptive use of water by 1 in.; and 3 tons of hay by deeper-rooted vegetation, 5 in. per season. On row crops such as corn, water loss by evaporation from the soil surface was almost 50 per cent of the total moisture consumption. Water *use* and water evaporation loss were about equal. This suggests the possibility of studies for reducing waste of water by controlling evaporation.

RESULTS OF RESEARCH ON FOREST LANDS

The U. S. Forest Service research program has already developed some knowledge about several of the hydrologic processes on forested areas. In the summer the forest's canopy, litter, and humus absorb the falling raindrop's energy and keep the water clean. Consequently, the pores, cracks, and holes in the soil remain open and the water from the most intense summer rainstorm is either evaporated or infiltrated. Forests prevent soil from forming concrete type frost (Wray, 1959). In the winter, therefore, overland flow from forest land has been rare or nonexistent. The protective value of Ohio's forests was well illustrated during the devasting floods in early 1959. During the rainstorms that caused those floods, most of the water that fell on forested areas was absorbed and at least temporarily delayed in its progress toward stream channels.

Water moves rapidly through at least the upper soil layers of most of Ohio's forests. Several things combine to cause this rapid movement. One is the accumulation of heavy organic forest floor on top of an undisturbed soil. In one uncut oak forest area in southeast Ohio, the oven dry weight of the litter, fermentation, and humus layers totaled 8 tons per acre as reported by Carmean (1959). Another factor is that non-disturbance over a period of years allows a permeable soil structure to develop. As a result, small-animal, insect, and decayed-root channels abound. For example, on another southeast Ohio area, Gaiser (1952) reported that the number of vertical channels formed in the soil by hardwood root decay was found to exceed 4,000 per acre. It is probable that the animal and insect channels as well as the old root channels contained highly permeable materials that allowed rapid, free-water percolation.

One price exacted by a heavy forest cover in return, however, for its many benefits is a loss of water through evapotranspiration. A recent study in southeast Ohio, for example, revealed that 6½ in. more winter precipitation was required to rewet the soil under a pine forest than under shallow-rooted grass. Even on the thin soils of this study area, the difference in water use between a good forest cover and this grass shows that an opportunity exists to affect streamflow and flood control through manipulation of the forest cover. Moreover, the results from this study exemplify the two opposing objectives that may be proposed for a watershed management program. One is the possibility of increasing streamflow by decreasing transpiration through the manipulation of the vegetative cover. The other is the possibility of decreasing floods by providing in the soil the maximum amount of storage space for precipitation. Thus, increased streamflow would be expected through conversion from pine, to oak, to brush, to grass, and increased flood control benefits would be expected by proceeding in the opposite direction (fig. 1).

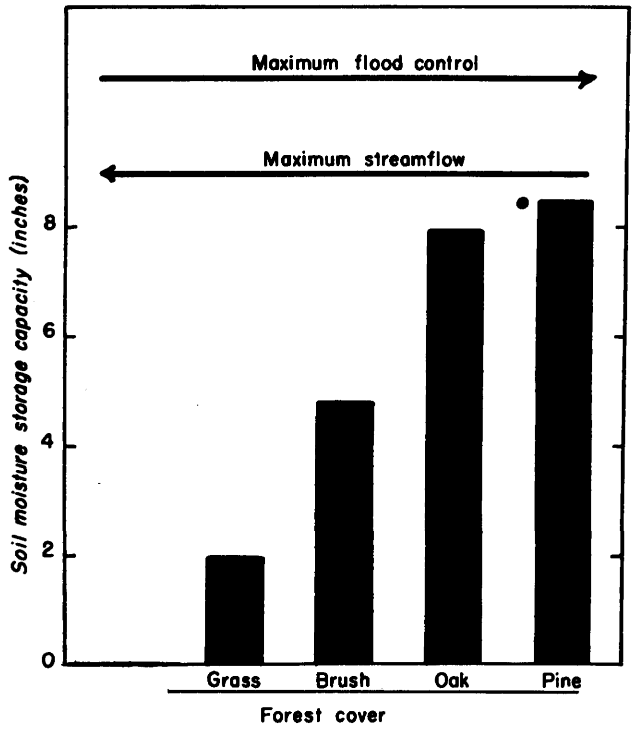

Figure 1

A recent study was made by the Forest Service on a 30,000-acre, hilly, agricultural and forested watershed that drains into the Muskingum Watershed Conservancy District reservoir created some 20 years ago near Leesville, Ohio. The conservancy program for the watershed included improving the farming methods on the more gentle slopes and planting pine tree seedlings on the steeper, badly eroded slopes. Although half the present open land on the watershed is still being farmed as it was 20 years ago, the general trend on the watershed is toward better land use. It is reasonable to assume that this trend will continue until most of the watershed is under a soil conserving program with steep lands reforested. An analysis of this reservoir's water level records for the period 1939–1958 shows that improvement in the management of the watershed's farms and woodlands has helped reduce many of the stream stormflow volumes, especially near the end of the 20-year period.

Using only those rainfalls of 1 in. or more in 24 hr, average stormflow per unit of rainfall was computed by relating reservoir rise to rainfall depth. Over the period, the trend of average annual flow volumes was slightly downward; fall and summer flows decreased; winter flows declined most; but spring flows increased (fig. 2). During those periods of flow reduction, the greatest effect resulted with storms of 1 to 2 in. of rainfall. Reduction was less for storms of 2 to 3 in. No meaningful change was found in any season for storms above 3 in. From the results of this analysis it is also reasonable to assume that as more of the forest and open land is placed under good management, stormflows will decrease, at least for the smaller storms.

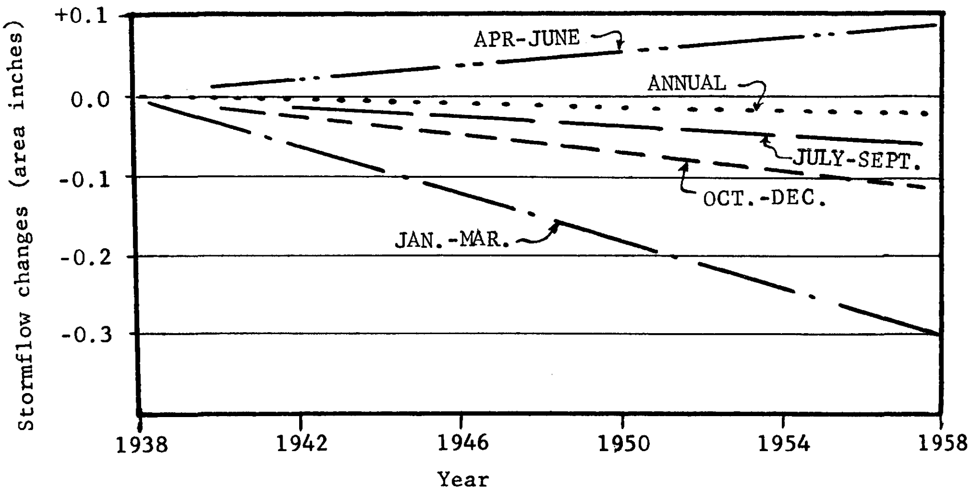

Figure 2

ADDITIONAL NEEDED RESEARCH

Research into how to make effective use of available soil pore space in agricultural and forest lands to absorb more of the summer storm rainfall than is now possible, is needed. These storms are of short duration and of high intensities. Infiltration and percolation or transmission rates for storm rainfall need to be increased. Water use by vegetation should be studied further to develop more efficiency both in food and fiber production on the watersheds, and in the water yields of the watersheds. Information is needed to evaluate the impact of recreational, industrial, highway, airport, and urban expansion on hydrologic processes. Water management studies will be required in these various fields to provide the data necessary for the development of watershed programs. The effect of land management, including the use of heavy tillage equipment and livestock packing of wooded and open pasture land, on the entire water cycle, including underground water movement, must be determined.

Improved land use methods should then be tested and evaluated on whole watersheds. Research is needed to develop techniques for applying small watershed results to hydrologic evaluations of larger complex watersheds.

Drainage problems in some of the best agricultural sections of Ohio should be the subject of increased concerted field and laboratory study. Federal and State agencies have recognized the need of a fully equipped facility for this purpose.

In all of the above needs, it is recognized that the data should be developed in such a way that would permit the use of high-speed electronic computers. This would expedite the process of reporting of findings and accelerate the application of results.

REFERENCES

Brakensiek, D. L., and **C. R. Amerman.** 1960. Evaluating effect of land use on streamflow. Agr. Eng. 41: 158–161.

Carmean, W. H. 1959. Litter weight not reduced following clear cutting of poor-site oak stands. J. For. 57(3): 208–209.

Gaiser, R. N. 1952. Root channels and roots in forest soils. Soil Sci. Proc. 16: 62–65.

Harrold, L. L. 1949. Has the small-area flood been neglected? Civil Eng. 19: 690.

Wray, R. D. 1959. Floods, frost, and forests. J. Soil Water Cons. 14(6): 266.