BASIC WATER CONCEPTS FOR SOIL AND WATER CONSERVATION

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Soil erosion—a matter of current national concern—results from untamed wind and water. In this, the humid area of the country, water is the major, and wind the minor, factor in this erosion process. It is the purpose of this paper, therefore, to present for this region some of the important basic principles of water behavior on and in the land as they relate to soil and water conservation. Although certain phases of this presentation are somewhat elementary, they will provide a clearer understanding of the erosion picture and the soil- and water-conservation job ahead.

Let us start with a review of the precipitation pattern for Ohio. The average annual precipitation over the state of 37 to 40 inches of water comes mostly in the form of rain. Of the snowfall, very little is erosive unless it melts rapidly causing runoff on partly thawed bare ground. Rainfall, however, is erosive from the time the drops strike the bare ground until the runoff water reaches its resting place in ponds, lakes or oceans.

The average annual precipitation is quite evenly distributed over the months of the year. Those months averaging less than three inches of precipitation come in the 7-month period, September through February. The other five months, March to August, all have over three inches of rainfall with July having the greatest average value of nearly four inches. Let us now consider seasonal differences in rainfall characteristics, and by listing some of the most important ones (table 1) we can get a clearer picture of rainfall factors causing erosion. For comparison, we will divide the year into two seasons, namely, the growing (5 months, May-September) and the dormant (7 months, October-April).

The U. S. Weather Bureau has for many years classified storms by their intensity, listing those storms having 0.25 inch rainfall in 5 minutes, 0.35 inch rainfall in 15 minutes, 0.50 inch rainfall in 30 minutes, 0.80 inch rainfall in 60 minutes, etc., as "excessive storms." Yarnell (1935) summarized these excessive storms for the country and found that for Ohio about 90 per cent of the excessive storms occurred in the growing season. This concentration of excessive storms of high intensity and large drops with high velocity constitutes a severe erosion hazard. Borst (1945) and others found that of the annual average erosion on a plot of bare soil, about 85 per cent occurred in this 5-month period of high rainfall intensity. A few excessive storms cause the bulk of the annual erosion. It is often possible at such times to provide some protection to the land surface by adjustments in the cropping system—thus reducing erosion.

While the characteristics of normal seasonal rain-storms are fresh in mind, it is well to discuss briefly the hydrology of flood genesis. It is common knowledge that the large river-basin floods occur mostly in the late winter or early spring. They are caused by dormant-season storms of low intensity, small drop size and of low velocity, but covering large areas of wet soil and lasting for several days. Small streams are usually within their banks at this time, yet when all such tributaries contribute their flow simultaneously to the large river, a major flood results. For river basins in this section of the country having drainage areas of 10,000 square miles and larger, over 90 per cent of the greatest annual floods occur in this dormant season. For streams having areas of under 10 square miles, less than 15 per cent of the greatest annual floods are in this season. Over 85 per cent occur in the growing season. Harrold (1949) illustrated the magnitude and importance of the small-area flood for the Ohio area and related it to the definite seasonal rainfall characteristics described above.

Now let us return to the consideration of the intimate relationships between rainfall, the land, erosion, and runoff-water loss. It has been well established that the greatest erosion hazard from rainfall on bare soil is in the May-September season. From studies at Experiment Stations of the U. S. Soil Conservation Service and of the various States, it may be concluded that vegetation or any other cover on the soil surface is effective in reducing soil loss. With such complete coverage as provided in ungrazed woodland and grassland, erosion is negligible. As water absorption into the ground of such areas is usually at high rates, runoff losses are low. Although complete vegetal cover is the best for soil and water control, it does not appear economical or practical to completely eliminate from farm land crops which provide little or no soil coverage. It is reasonable, however, to make some change in this direction. Lessening of clean-cultivated acreage on erodable land and the increase of acreage in sod crops or trees is one of the main features of soil and water conservation programs. Studies in Ohio and elsewhere have

TABLE 1

Some important seasonal rain-storm characteristics

Item	Normal seasonal character	
	Growing	Dormant
Intensity	High	Low
Drop size	Large	Small
Drop velocity	High	Small
Duration	Short	Long
Storm area	Small	Large

also found it possible to reduce soil erosion by significant amounts through the proper use of mulches in orchards, row crops, and the like. Although such changes in land treatment are immediately reflected in very noticeable changes in erosion, changes in the rates and amounts of water absorption by the soil are accomplished over a period of years.

Realizing that certain areas in row crops will still be required to meet crop goals, experiments are being made to determine how this can be done on sloping land while keeping soil and water losses to an acceptable minimum. Contour cultivation, terraces, contour strip cropping and the like, have been found to retard the down-hill flow of water and reduce the amount of soil loss. In straight-row farming on 12 per cent land slope where the down-hill flow of water was rapid, the corn-season erosion amounted to about 20 tons of soil per acre. That from contoured cornland totaled only four or five tons. In sloping rows the excess water flowed rapidly thus carrying large quantities of soil. In contour rows, the flow of water was very slow and the amount of soil carried low. There was very little difference in the amount of runoff water from both areas.

On contoured land, provision must be made to transport excess water from the contour furrows down hill to the stream channels. When excess water in the furrows of contoured farmland on sloping ground is released haphazardly, erosion is as serious as in straight-row cornland. Soil erosion is a definite loss in either case. Sod waterways properly designed, constructed, and maintained have been found to handle this down-hill release of water without erosion.

The general concept of erosion has been a big pile of soil weighing many tons. It is more than that. Soil carried off the farm in runoff water includes high concentrations of organic matter, nitrogen, phosphate, potash, and other plant-food elements. Robert Hickok, Soil Conservation Service Research technician in Indiana, found that these losses were great even on a low slope of only three per cent. In the yearly runoff water from a straight-row cornfield there was found 22 pounds of nitrates, whereas on a contoured cornfield this loss was only five pounds per acre. So we find that erosion is more than just tons, it has a significant dollar value. It is part of an investment.

The foregoing discussion on the benefits of contour farming pertains mainly to sloping land where erosion is significant. For such sloping land, the amount of water held in the furrow depressions is a function of the degree of slope. On rolling and hill land, the effectiveness of contour cultivation on water conservation becomes less as the land slope increases. On the flatter lands, contour furrows retain a considerable amount of water—in fact, too much water at times in some areas of Ohio. The additional water retained on poorly-drained soils by contour cultivation has caused crop-yield reductions. In such areas, it is desirable to speed up the removal of excess surface water by tiling, open ditches, land smoothing (removal of pockets), bedding, and by agronomic practices which improve the internal drainage of the soil profile. Benefits will accrue by retention of more water on some land but in other areas it is desirable to remove excess surface water rather quickly. In all cases, however, where water leaves the farmland, its flow should be managed so as to keep erosion to a minimum.

TABLE 2

Infiltration rate for Muskingum silt loam topsoil

Soil moisture content (percentage by volume)	Infiltration rate of 7-inch topsoil (inches of water per hour)
5	9
20	6
40	2
45	1

Studies of rainfall, runoff, and infiltration have shown that the ability of a particular soil to absorb rainfall is greatly influenced by the dryness of the soil. If the soil is quite dry, there are many unfilled pores through which water can be transmitted by gravity to lower depths. If the soil is wet, the water-transmission rate will be slow. These factors affect the infiltration rates of most soils, somewhat as they do for the Muskingum silt loam topsoil of the Coshocton Experiment Station (table 2). The permeability of the profile below this topsoil is much less—being about one-twelfth the amount as fet forth in table 2.

A knowledge of these and other hydrologic characteristics of the soil will aid in the interpretation of the soil's part in the disposal of rainfall into runoff, infiltration, percolation and water held in storage. Some of these important qualities are:

1. Saturation. All pores filled with water.
2. Field capacity. Amount of water held in soil after gravity water has drained out. Volume of de-watered pores termed "air space porosity" is indicative of the soil permeability.
3. Wilting point. Water held in soil so securely that plants wilt from lack of water.

For a root-zone of 40 inches of the Muskingum silt loam soil, according to

Dreibelbis (1944), there is about 17 inches of water in the profile at saturation, 13 inches at field capacity and 3 inches remaining at wilting point. Whenever there is on the average more than 13 inches of water in the 40-inch profile, there is some free water that drains to greater depths. In order to help visualize these factors and the part they play in soil-water supplies and movements, they may be illustrated on a graph with the months of the year along the bottom scale and soil-moisture content as the vertical scale. Lines for saturation, field capacity and wilting-point moisture can then be drawn horizontally across the graph at the proper soil-moisture figure on the vertical scale.

On this graph, a curve can be sketched in to show the general trend of soil moisture in the 40-inch profile throughout the year. Usually this curve will approach saturation in the late winter and early spring period. The curve then normally dips down close to the moisture content of wilting point near the end of the summer. As the moisture content of the soil depletes by drainage or by evaporation and transpiration, soil pores are de-watered and a potential water-storage reservoir develops within the root zone. At times in the summer the volume of de-watered pores in the 40-inch profile is large enough to absorb up to 10 inches of rainfall.

For soil and water conservation and other public and private programs, it may be most desirable to have near the soil surface a large potential storage reservoir such as this. As the moisture content of the soil lessens, the volume of the potential storage increases. This situation ceases to be ideal when the soil moisture becomes so low that it is inadequate to meet crop requirements. The possibility of making good use of this storage reservoir during storm periods depends on a number of factors such as soil structure, vegetal cover, and land management. Soils having good internal drainage characteristics and tilled or managed at the surface so as to maintain high infiltration rates, will make use of their storage capacities over and over again. From time to time, rainwater from flash summer storms is absorbed into this soil reservoir. The pores become wholly or partly filled with water to varying depths. Some soil water will drain to lower levels, some will be evaporated from the land surface, and some will be transpired by vegetation. Thus, the soil reservoir is de-watered and ready to absorb water from the next storm.

Variations in the permeability of the soil profile are found in almost all soil types. Those at the Coshocton Experiment Station have a fairly permeable topsoil to a depth of 7 inches as illustrated before. If the land surface is protected and does not pack and seal, the de-watered pores in this topsoil fill rapidly during a storm period. Often the volume of these pores is great enough so that there is no runoff water. Since the subsoil is much less permeable, the de-watered pores therein fill very slowly. The storm is often over before its water penetrates much below the 7-inch depth. Observations indicate that runoff has occurred many times when there was enough volume of de-watered pores within a foot of the land surface to absorb all of the rainwater. This waste ought not to be.

The greatest factor restricting the use of the soil of crop land as a reservoir is surface sealing and packing from raindrop impact. The large raindrops falling at high velocities strike bare soil with great force. This energy is expended in packing the soil and breaking soil crumbs into fine particles. Both actions tend to change a loose, porous soil surface into a dense, tight, nearly impervious layer. It is not uncommon to have large quantities of water and soil lost from cultivated fields during a summer storm although there was within a few inches of the land surface sufficient de-watered pores to absorb all the storm rainwater. On July 28, 1951, for example, only about half of 1.1-inch rainfall was absorbed into a contoured cornfield and half was lost in runoff. Before the storm, the volume of de-watered pores in the 7-inch topsoil totaled 2.8 inches. All of the storm water could have been absorbed, yet half ran off carrying 2 tons of soil from each acre of the field. This is just one example of many. Again, this waste ought not to be.

Studies of the hydrologic characteristics of the soil profile along with a knowledge of the erosion hazard of our rainfall, fluctuations of soil moisture, and efficiency in the use and re-use of de-watered pore-reservoir capacity point to the need for the determination of ways and means of land management for greater water conservation and less soil erosion. Experiments are showing that mulches on bare soils reduce the effect of raindrop impact on surface sealing. Here, the force of many falling raindrops is expended on the mulch material rather than on the soil particles. For the same storm used in the above example, there was no runoff or erosion from the mulched corn watershed. Thus, if the surface seal in bare land can be eliminated or even partly reduced by use of mulches or other means, it may be possible for the de-watered pores at shallow depth to be used more frequently.

Besides the problem of maintaining a porous soil surface, there is a need to determine if it is possible to affect the permeability of various layers in the soil profile for improving their water-handling characteristics. Many soils, like those on the Coshocton Experiment Station, have layers of fairly low permeability at shallow depth which often limits the amount of storm water than can be absorbed. By gradually adding to the depth of plowing which would deepen the placement of organic matter or by other means, it may be possible to increase the depth to which storm water would move rapidly. If so, a volume of de-watered soil pores at greater depths would become more readily available and thus provide further improvement in the water conservation and management job.

Another of the basic water concepts which has influenced some of those previously discussed is that of the crop needs for water. Soil-moisture depletion by a deep-rooted grass, legume, or tree crop is at times more extensive than that of shallow-rooted crops. Moisture depletion rates for some crops are different from others for various months of the long growing season. For example, a corn crop in June has generally been found to de-water soil pores at a much slower rate than a good meadow or pasture.

Water needs for crops is an item of general concern, especially when drought conditions are experienced. In some areas it has been found desirable and economical to provide a means of supplementing rainfall with irrigation water. Because auxiliary water supplies for this purpose are often limited and in some places becoming exhausted, and because the delivery of this water to the plant is rather costly, it is most desirable to supply just enough irrigation water and no more. In other words, eliminate any waste of water. An understanding of the basic soil, water and plant relationships such as saturation, field capacity, infiltration and permeability rates, water demands of crops (evapo-transpiration), and wilting point is most important in this field of agriculture.

As a knowledge of various soil, water, and plant relationships is advanced, there will be available a sounder basis for water management programs of all types and a more complete set of facts for planning the proper land management under a wide variety of field conditions.

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