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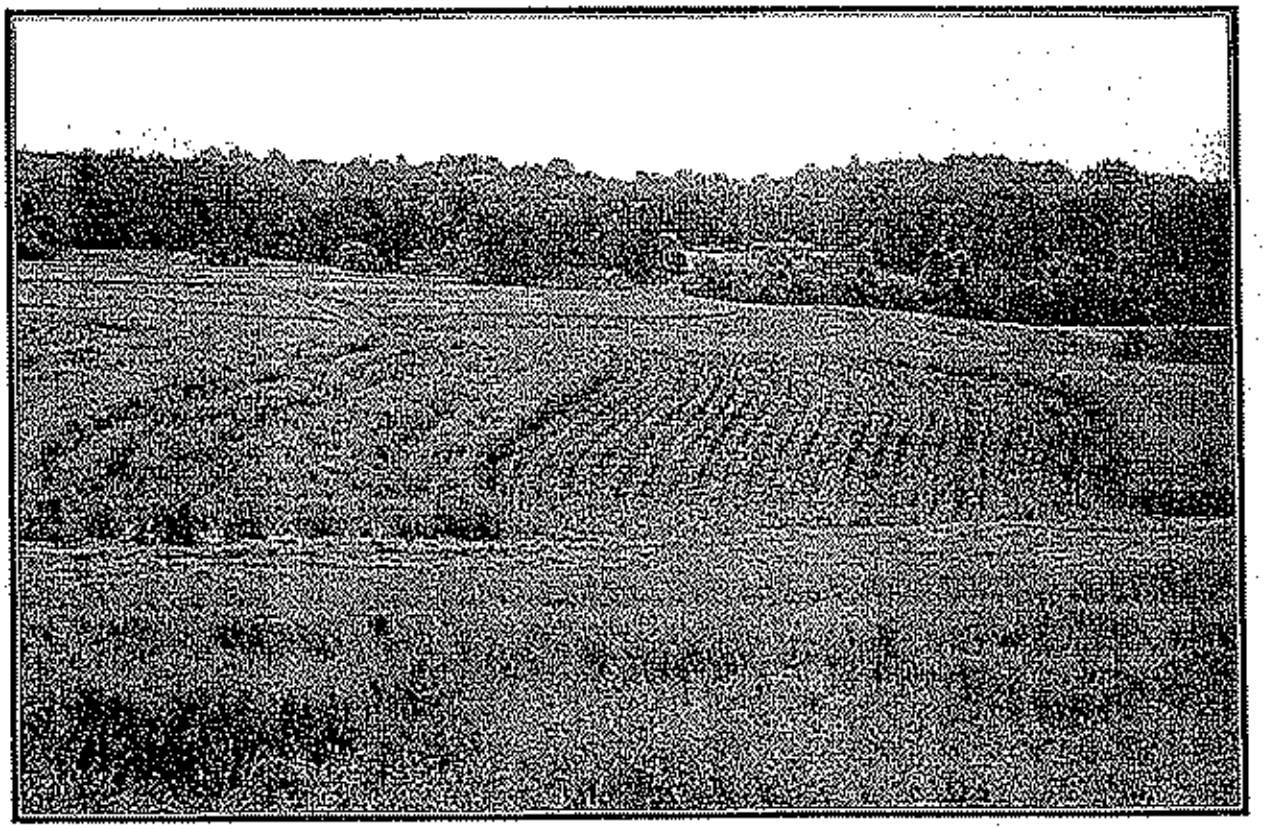
# Evaluation of Resource Management Systems for Efficient Water Management



**United States Department of Agriculture**
**Natural Resources Conservation Service**
**Raleigh, North Carolina**
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# INTRODUCTION

The original preparation of this document was done by Mr. Emmett R. Waller Jr., Assistant State Resource Conservationist with the USDA-Soil Conservation Service (later re-named the Natural Resources Conservation Service). This document was placed in area and field NRCS offices as a conservation planning technical reference.

We must always remember the importance of the maintenance and improvement of the soil resource by various erosion control techniques. However, the long-range benefits of erosion control are not as easily seen or appreciated as the more immediate water conservation benefits of the practices herein described. For example, a field of non-irrigated no-till tobacco in the piedmont was just as thrifty as a nearby field which was irrigated three times. Erosion differences were evident, but the water conservation benefits were directly tied to the current crop.

It was deemed necessary to re-print this document a second time. This presented an opportunity to slightly revise the information to reflect advances in water management technology.

There are additional water management measures that are appropriate to include in a conservation plan, such as irrigation water management and water control structures. They are not included in this document, since the purpose is to describe those measures which have a direct positive effect on the soil resource itself.

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TECHNICAL REFERENCE

EVALUATION OF RESOURCE MANAGEMENT SYSTEMS

FOR EFFICIENT WATER MANAGEMENT

Water is fundamental for the production of all crops. North Carolina experiences periods of water excess and deficits during most crop years, and frequently more than once within a growing season. Each can adversely affect crop production. Although improved technologies have increased crop yields, potential yields are seldom obtained because of water deficiencies. Duncan, (1), estimates that 64 percent of the world's cropland suffers from drought sometime during the growing season.

## I. RAINFALL AND DISTRIBUTION

In North Carolina the greatest amounts of rainfall occur in July and August,whileOctober and November are usually the driest months. There are, however, wide variations from the average in some years. Annual precipitation distribution over the state varies from the mountains to the coast. The mountain region normally receives 44 to 58 inches of precipitation (2). Table 1 illustrates the variability by regions and months at several locations.

An indication of the difficulty in attempting to associate adequate rainfall with yearly and monthly averages can be seen by evaluating data appearing in Table 1. Rainfall from June to September averages 40 to 50 percent of the annual precipitation and it is only 35 percent of the time. Without further information, you would assume this is

adequate moisture for normal plant growth and production. This is not the case in many seasons. For example, Smithfield experiences about 60 to 65 dry periods a year, of which 5 to 10 percent equal or exceed 10 days in length (3). Yet, this number of relatively long dry periods occurs where monthly rainfall averages greater than 2.8 inches and the annual total average is 48.5 inches. A dry period is defined as 1 or more consecutive days with no measurable precipitation.

TABLE 1

Average Annual and Monthly Precipitation

| City | Jan (in) | Feb (in) | Mar (in) | Apr (in) | May (in) | Jun (in) | Jul (in) | Aug (in) | Sep (in) | Oct (in) | Nov (in) | Dec (in) | Annual (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greenville | 3.3 | 3.4 | 3.6 | 3.5 | 3.4 | 4.1 | 6.7 | 5.9 | 4.8 | 2.7 | 3.0 | 3.3 | 47.5 |
| Elizabeth City | 3.6 | 3.8 | 3.8 | 3.4 | 3.3 | 3.8 | 7.1 | 6.4 | 5.1 | 3.2 | 3.5 | 3.3 | 50.3 |
| Fayetteville | 3.0 | 3.4 | 3.9 | 3.8 | 3.6 | 4.2 | 6.1 | 6.0 | 4.4 | 2.2 | 2.8 | 3.0 | 46.4 |
| New Bern | 3.3 | 3.9 | 4.0 | 3.1 | 3.9 | 4.5 | 8.2 | 7.0 | 6.7 | 3.2 | 3.6 | 4.1 | 55.4 |
| New Holland | 3.5 | 3.8 | 3.7 | 3.1 | 3.8 | 4.7 | 7.2 | 6.7 | 5.9 | 3.4 | 3.7 | 4.0 | 53.4 |
| Smithfield | 3.4 | 3.6 | 3.9 | 6.0 | 3.6 | 4.6 | 6.0 | 6.1 | 4.2 | 2.8 | 3.0 | 3.2 | 48.5 |
| Tarboro | 3.5 | 3.5 | 3.9 | 3.4 | 3.6 | 4.5 | 6.1 | 6.2 | 4.3 | 2.9 | 3.2 | 3.2 | 48.1 |
| Burlington | 3.5 | 3.5 | 3.7 | 3.7 | 3.5 | 3.9 | 5.1 | 5.0 | 3.9 | 3.0 | 2.9 | 3.2 | 45.0 |
| Hickory | 4.1 | 4.1 | 4.7 | 3.8 | 3.6 | 3.9 | 5.0 | 5.7 | 3.8 | 3.4 | 3.1 | 4.1 | 49.2 |
| Monroe | 3.5 | 3.6 | 3.9 | 3.7 | 3.1 | 3.7 | 5.3 | 5.0 | 3.8 | 2.6 | 2.7 | 3.4 | 44.3 |
| Statesville | 4.1 | 3.9 | 4.7 | 3.7 | 3.5 | 3.6 | 5.1 | 4.6 | 3.7 | 3.3 | 3.0 | 3.8 | 47.1 |
| Boone | 4.1 | 4.0 | 5.1 | 4.7 | 4.5 | 4.4 | 6.3 | 5.4 | 4.4 | 3.8 | 4.0 | 4.1 | 54.8 |
| Grandfather Mountain | 3.9 | 3.2 | 5.3 | 5.4 | 4.5 | 6.0 | 5.8 | 6.2 | 5.9 | 5.7 | 3.8 | 3.6 | 61.1 |
| Murphy | 6.7 | 5.6 | 5.9 | 5.0 | 3.7 | 4.5 | 5.6 | 4.5 | 3.0 | 2.8 | 3.7 | 5.1 | 55.2 |
| Waynesville | 4.2 | 4.3 | 5.0 | 3.6 | 3.5 | 3.6 | 5.0 | 4.0 | 2.7 | 2.9 | 2.9 | 4.0 | 45.9 |

## II. WATER NEEDS FOR PRODUCTION

Plants require varying amounts of water for optimum production. Research at the West Tennessee Experiment Station shows that one acre-inch of water is required to produce 1.7 bushels of soybeans (4) or 16,000 gallons to produce one bushel. In other words, it takes about 640,000 gallons or 24 acre-inches of water to produce 40 bushels of soybeans. A cutting of Alfalfa requires about 325,800 gallons of water per acre, and a bale of cotton requires about 800,000 gallons (5). Thus, 50 to 70 percent of the annual rainfall is needed to produce normal yields at 100 percent efficiency of use.

The importance of resource management systems containing water conservation and management practices increases as available water becomes more limiting. The major objective of the system is to obtain a balance between plant water needs and the supply. In this technical reference, water management is defined as the application of conservation and management practices to most efficiently use both precipitation and irrigation water for crop production.

The principle sources of water for agricultural production are precipitation and irrigation. Water supplied from these sources is lost by runoff, evaporation, deep drainage; transpired from plants; or stored in the soil. Some water will also be retained in plants, but the amount is negligible when considered in relation to the total amount used to produce the plant (6).

## III. WATER DISPOSAL

### A. RUNOFF

"Runoff", or surface water flow, occurs when the rate of precipitation exceeds the demands of evaporation, infiltration, interception, surface storage, and surface detention (7). After infiltration and evaporation rates are satisfied, water begins to fill the depressions on the soil surface and overland flow begins and continues in equilibrium with the rate of precipitation less infiltration and interception.

Surface runoff can account for considerable water loss where the land is either sloping or somewhat impervious to water. As much as 50 to 60 percent of the annual precipitation may be lost in runoff (8). While this water loss itself is deplorable, the erosion that accompanies it is usually even more serious, especially from the standpoint of the physical condition of the surface layer. Surface soil is gradually taken away, resulting in a change in the nature of the soil properties.

Rainfall and runoff measurements made form 1961 to 1967 at the Southeastern Piedmont Conservation Research Center, located in Watkinsville, GA, showed 10 to 33 percent runoff. Table 2 summarizes the results from individual rain storms on plots 70 feet in length with varying slope percents. The plots were predominately Cecil sandy loam soil. Runoff was tabulated by storms, months, seasons, and years (9).

TABLE 2

Average Annual Rainfall and Runoff by Various Crops and Slopes for a 6 Year Period

| Treatment No. | Crop | Slope (%) | Rainfall (in) | Runoff (in) | % of Rainfall loss as Runoff |
|---|---|---|---|---|---|
| 1 | Fallow | 7 | 55.7 | 18.4 | 33 |
| 2 | Cotton Continuously | 7 | 55.7 | 9.8 | 18 |
| 3 | Corn Continuously | 3 | 55.7 | 6.5 | 12 |
| 3A | Corn Continuously | 7 | 55.7 | 7.0 | 13 |

A Wake County field containing 9 acres of continuously cropped soybean land having an average slope of 10 percent, yielded .72 inches of runoff from a one-inch short duration storm event May 27, 1982, (Buddy Atkins, unpublished data). The soil is a severely eroded Cecil Sandy Loam Soil.

Several factors can affect the rate and volume of runoff. Duration, intensity, and area distribution as well as the physical properties of the site must be considered in evaluating the effectiveness of conservation measures for reducing runoff. For example,

an intense storm will exceed the infiltration capacity by a greater margin than does a gentle rain; thus, the total volume of runoff is greater for the intense storm even though total precipitation for the two rains may be the same. The intense storm can decrease the infiltration rate because of its destructive action on the soil structure at the surface.

Table 3 summarizes rainstorm data recorded at Statesville,North Carolina for an 8 year period and shows the relationships of runoff to rainfall intensity and to total rainfall per storm event (10). From this table, you see that 62 percent of the total precipitation occurred in medium and small storms of 0 to 2 inches, whereas, only 58 percent of the total runoff resulted from such storms. The amount of precipitation loss from these storms as runoff was 18.7 percent. At the other extreme, 10 percent of the precipitation occurred in storms of over 3 inches, but 13 percent of the runoff resulted from such storms and 26 percent of the rainfall was lost through runoff. Also, 24 percent of the rain fell at intensities greater than 3 inches per hour and resulted in 37 percent of the runoff.

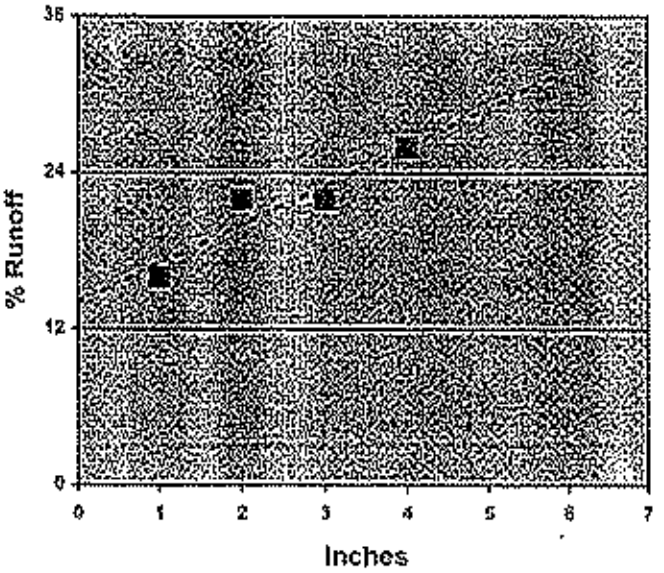
TABLE 3

Total Annual Runoff Related to Average Annual Rainfall Amounts and Intensities

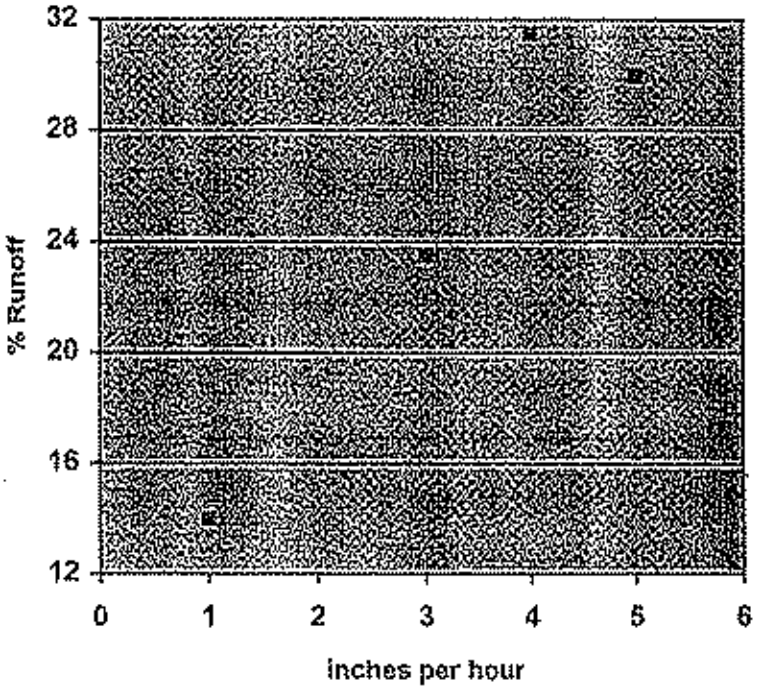
| Amount Per Event Inches | Total Annual Rainfall Inches % | Total Annual Runoff Inches % | Intensity Per Event (IPH) | Total Annual Rainfall Inches % | Total Annual Runoff Inches % |
|---|---|---|---|---|---|
| 0.1-1.0 | 14.5<br>29% | 2.2<br>22% | 0.-1.5 | 22.0<br>44% | 2.6<br>26% |
| 1.0-2.0 | 16.5<br>33% | 3.6<br>36% | 1.5-3.0 | 16.0<br>32% | 3.7<br>37% |
| 2.0-3.0 | 14.0<br>28% | 2.9<br>29% | 3.0-4.5 | 8.5<br>17% | 2.7<br>27% |
| OVER 3.0 | 5.0<br>10% | 1.3<br>13% | OVER 4.5 | 3.5<br>7% | 1.0<br>10% |
| TOTALS: | 50.0<br>100% | 10.0<br>100% | | 50<br>100% | 10.0<br>100% |

Figures 1 and 2 further illustrate the application of this data in that the total percent of runoff increases as the amount per storm and the intensity of rainfall increase.

## Figure 1. Rainfall Amounts




## Figure 2. Rainfall Intensity

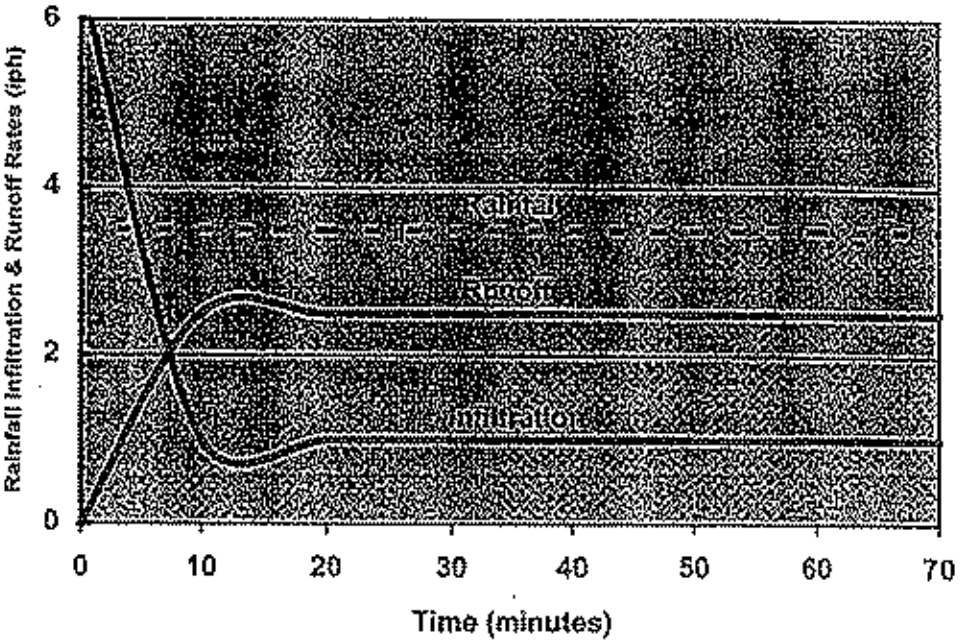


## B. INFILTRATION

Infiltration is the entry of water in the soil surface. It is of particular interest, for if water is to be conserve d in the soil and made available to plants, it must first be absorbed by the soil surface. If the infiltration rate is high, less water will pass over the soil surface and runoff quantities are lowered. Infiltration is a primary source of soil moisture for sustaining the growth of vegetation and for maintaining ground water to supply wells, springs, and streams.

During a rainstorm, the maximum infiltration rate occurs at the beginning of the rain and usually decreases very rapidly as structural changes occur in the soil surface. If the rain continues for a prolonged period, the infiltration rate will gradually approach a minimum value. This minimum value is determined by the rate at which water can enter the surface layer and by the rate at which it can be transmitted through the soil profile. In figure 3, the infiltration capacity did not drop to equal the rainfall rate until several minutes after the onset of infiltration. During this initial time period, the infiltration rate was equal to the rainfall and less than the infiltration capacity. When the infiltration capacity fell below the rainfall rate, runoff occurred.

## Figure 3. Typical Infiltration & Runoff Curves




Soil functions essentially as a pervious medium that provides a large number of passageways in which water moves. In general, the size of the passageways and the infiltration rate are dependent upon:

1. The size of the particles that make up the soil (texture)
2. The degree of aggregation between the individual particles (consistence), and
3. The arrangement of the particles and aggregates (structure). The larger the pore size that can be maintained, the greater is the resulting infiltration rate.

The importance of maintaining permanent channels, particularly at the soil surface, is critical. The usual rapid reduction in the rate of intake of water through the surface is accompanied by the formation of thin compact layer on the surface. This layer