MAXIMUM SPRINKLER IRRIGATION RUNTIME WITHOUT RUNOFF

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This article covers the practical solution to the equation developed by Hung & Krinik (1995) for determining the maximum sprinkler irrigation runtime. The authors compiled and analyzed the test data from the United States Natural Resources Conservation Service (USNRCS) and produced a series of curves representing the relationship between the maximum sprinkler irrigation runtime and the sprinkler precipitation rate for five types of soil. The curves can be used to determine the maximum sprinkler runtime for a selected or a calculated sprinkler precipitation rate for five types of soil. The application of the results from this paper will prevent sprinkler irrigation water runoff.

Introduction

The purpose of this paper was to develop a series of maximum sprinkler irrigation runtime curves for different sprinkler precipitation rates vs. soil types to maximize the sprinkler application efficiency and conserve water. Run off from the application of landscape irrigation sprinklers has been a big concern in water conservation. Hung and Krinik (1995) developed an equation for determining the maximum sprinkler runtime. However, it is necessary to develop different infiltration capacity data for various types of soil so that the equation can be applied in the field. The USNRCS (Cuenca, 1989) published a series of infiltration data for several soil families. The raw data were utilized and Kostiakov's equation (1932) was applied to determine the infiltration rates.

Method of Development

An equation for determining the maximum sprinkler irrigation runtime was developed by Hung and Krinik (1995). The equation is shown below.

$$t_{max} = (1/Pb)\{f_o - P + f_c\,[\ln (f_o - f_c)/(P - f_c)]\} \qquad (1)$$

where t_{max} = maximum irrigation runtime without runoff (hours)
P = average sprinkler precipitation rate (inches/hours)
b = Horton's constant
f_o = infiltration rate at the start or at time = 0 (inches/hour)
f_c = basic infiltration rate or saturated infiltration rate = constant (inches/hour).

In equation (1), the Horton constant, "b" can be obtained by solving Horton's equation by using the infiltration capacity curves shown in Fig. 1.

The infiltration data obtained from the USNRCS were based on 50% available soil water depletion which has been used in irrigation applications in the United States for almost a century. Kostiakov's equation was applied to obtain infiltration rate vs. test elapsed time. Kostiakov's equation is:

$$I = K\,t^a$$

where I = accumulative infiltration rate (inches)
K, a = constants which depend on the soil and initial conditions.
t = time after infiltration starts (hours).

Differentiating equation (1) with respect to time "t," we have

$$dI/dt = K\, a\, t^{a-1} \qquad (3)$$

where dI/dt = infiltration rate (inches/hour).

Based on equation (3), we were able to obtain infiltration rates at various times from the USNRCS raw infiltration data for 5 types of soils (or soil families). The infiltration rates were plotted vs. the elapsed time to obtain the best infiltration capacity curves through the Macintosh Cricket program for 5 soil types, namely: sandy, sandy loam, loamy, clay loam, and clay soils. They are shown in Fig. 1.

Figure 1

Infiltration Capacity vs. Time for 5 Soil Families

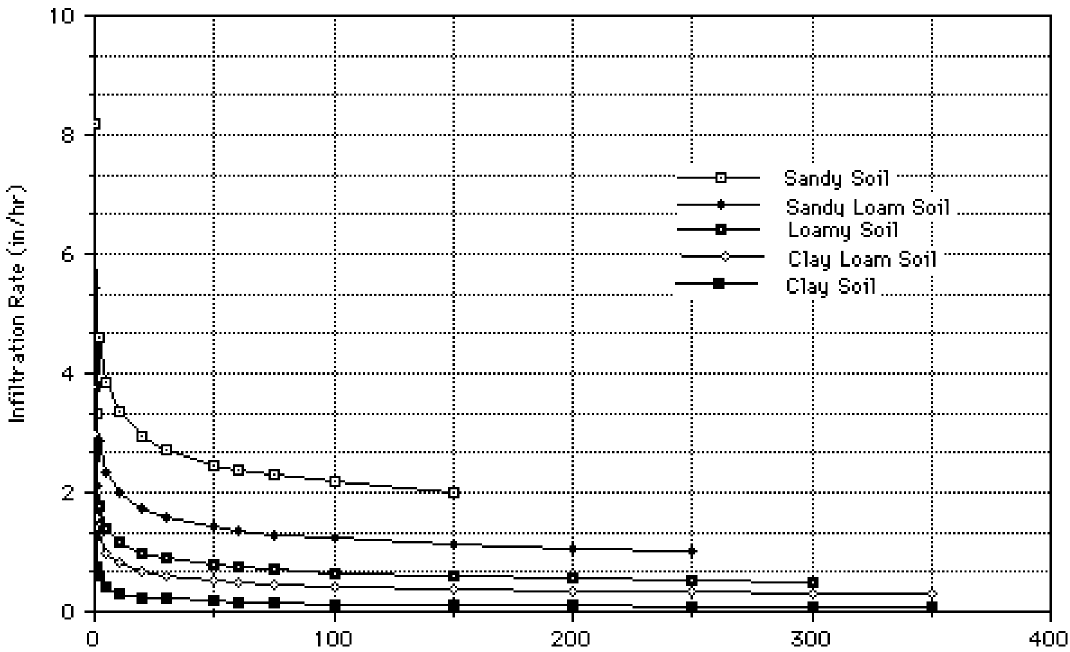


Fig. 1 Elapsed Time (minuites) (Raw Data From The USSCS)

Horton's equation (1939, 1940) is shown below:

$$f = f_c + (f_o - f_c)\, e^{-bt} \qquad (4)$$

where f = infiltration rate (inches/hour)
f_o = infiltration rate at time = 0
f_c = basic infiltration rate (inches/hour)
b = Horton's constant
t = elapsed time (hours).

Results and Example

Table 1 shows the Horton's constant b, for the 5 soil families.

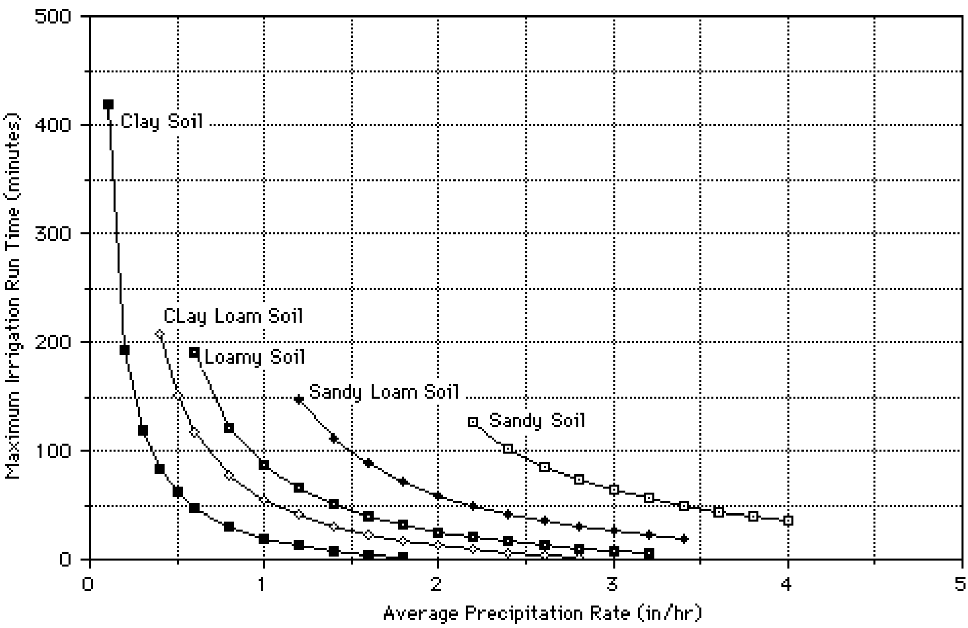
Table 1 Horton's Constants (b) For 5 Types of Soils

Soil Type	Horton's Constant (b)
Sandy	2.76
Sandy Loam	2.48
Loam	2.57
Clay Loam	2.60
Clay	2.81

The maximum runtime for five types of soils vs. assumed precipitation rates are plotted in Fig. 2.

Figure 2

Maximum Irrigation Run Time vs. Average Sprinkler Precipitation Rate



Example: If the total flow rate of 5 gallon per minute (GPM) provided by the sprinklers covered on an area of 20 feet x 20 feet, what is the maximum runtime per application? Assume that the soil is loamy.

Solution: 1. Calculate the average precipitation rate by

$$\text{Precipitation Rate (in/hr)} = (96.3 \times \text{gpm})/A \tag{5}$$

where 96.3 = conversion factor

A = area (ft^2).

Precipitation Rate (PR) = (96.3 x 5)/20 x 20)

= 1.20 in/hr

2. From Fig. 2, we have the maximum runtime of 75 minutes.

Conclusions

The construction of Fig. 2 was based on the raw data. In fact, Fig. 2 can be used as excellent reference as the maximum limit of sprinkler irrigation runtime. If the required irrigation runtime exceeds the maximum runtime, repeat cycles of application may be needed. Since the raw data were based on the level bare soil infiltration tests, some adjustment of the maximum runtime may be necessary when Fig. 2 is applied to lawn sprinkler irrigation and/ or slopes.

References

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