WATER INTAKE RATES OF SHELBY-GRUNDY SOILS FROM HYDROGRAPH ANALYSES

by

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Water Intake Rates of Shelby-Grundy Soils From Hydrograph Analyses[1]

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Soil moisture intake rates for different soil conditions arising from weather and management practices on different soils should have practical value in the design of flood and erosion control structures or in the planning of irrigation systems. The rainfall runoff records collected from several single practice watersheds at the former Soil Conservation Experiment Station, Bethany, Missouri, during the period 1933-42 afford an opportunity to get considerable information on moisture intake rates for soils of the area.

The soils are described and detailed information is given for the watersheds by Zingg (12).[3] The Shelby-Grundy and related soils represented by the watersheds are dominant in North-Central Missouri, South-Central Iowa, Southeast Nebraska and Northeast Kansas. They are derived from glacial till of the Kansas era. The average slope is about 8 percent with lengths of 200 to 400 feet. The original cover was mostly grass with trees on steeper slopes and drainageways. The topography is rolling to hilly and very irregular, with an elevation approximately 1000 feet above sea level.

Records are available from eight watersheds. Seven of these were equipped for rainfall-runoff measurements by 1934. The other was in operation by 1938. They varied in area from 2 to 8 acres.

There were three pasture areas, one of which was terraced. Another had contour furrows at 1-foot vertical intervals and the other was left in its natural state. Of the three cultivated areas one was terraced, another contour farmed and the other farmed parallel to field boundaries. One watershed was hayland (alfalfa, 1933-36, small grain-lespedeza thereafter). Besides these, another watershed was strip cropped. Four strips for a rotation of corn, soybeans, wheat, meadow were used prior to 1936 when the rotation was changed to corn, oats, meadow on three strips.

Methods

Several methods of analyses or rainfall-runoff data have been proposed (1, 2, 3, 4, 5, 6, 7, 8, 9, 13). Zingg's modification (13) of the method of Sharp and Holtan (7) was used in estimating the intake rates reported here. Twelve storms with suitable characteristics for graphic analysis were selected. Where there was evidence of subsurface flow as indicated by prolonged runoff after cessation or rainfall, a small correction was made. Any runoff one hour after rainfall stopped was assumed to be about evenly distributed between channel flow from the surface and subsurface flow into the channels. Five other storms, classed as Type C according to Sharp and Holtan (7), were considered. Since they were not adapted to graphic analyses, only the average retention rates and the percentage retention were calculated. The retention percentage is the fraction of the total rainfall for the storm on the watershed that is not lost as runoff. It is expressed as $100(P - Q)/P$, or $100\ R/P$, where P is the total rainfall; Q, the runoff; and $R = P - Q$ for any given storm.

The moisture retention and intake data for the different storms were grouped according to the soil moisture condition at the beginning of each storm. The qualitative descriptions of "dry soil", "moist soil" or "wet soil" appearing in Zingg's record (12) were used to separate the results into three groupings for antecedent soil moisture conditions. For all comparisons of cropping systems or farming practices on soil moisture retention the same storms were used. In one case, for the dry soil condition data for only one storm was available. For the remaining comparisons the data from three or more storms were averaged. The inches of available moisture in the upper two feet of soil just before each of the seventeen storms was estimated using approximate evapotranspiration rates (11), available moisture capacity determinations of soils from the Station, and the rainfall-runoff records (12). The antecedent available moisture for the Dry Soil Group appeared to be less than one inch; for the Moist Soil Group, one to two inches; and for the Wet Soil Group over two inches in the upper two feet of soil.

Discussion of Results

Soil moisture intake rates are affected far more by antecedent soil moisture than by soil cover or soil management practices. None of the storms that occurred on dry soil had characteristics making them suitable for graphic analyses. Estimates of the maximum intake rates gave values of two inches or more per hour. No reliable estimates of the change of the intake rate with time can be made for these storms. Some of the storms occurring on moist and wet soil had such characteristics as to give good estimates of intake rate changes with time for moisture absorption. The change of intake rate with time during a storm occurring on wet soil is shown in Figure 1 and the change occurring for moist soil is shown in Figure 2. The intake rate for the Shelby-Grundy soils varies from more than two inches per hour, for the first few minutes of rain on very dry soil, to less than .01 inch per hour on very wet soil. The intake rate approached on very wet soil (the f_c value) is very low regardless of the cover or soil management.

The comparison of intake rates for natural pasture and cropland is shown in Figure 3. The record of only one storm giving comparisons of maximum, average and final intake rates on dry soil was available. The data for moist and wet soil are averages of four and three storms, respectively. In general, the pasture was a little more absorptive than the cultivated watershed. This was probably the result of differences in moisture conditions as well as soil cover.

The effect of pasture terraces is shown in Figure 4. The terraced pasture is generally a little more absorptive, though the differences are not consistent. That the terraces were no

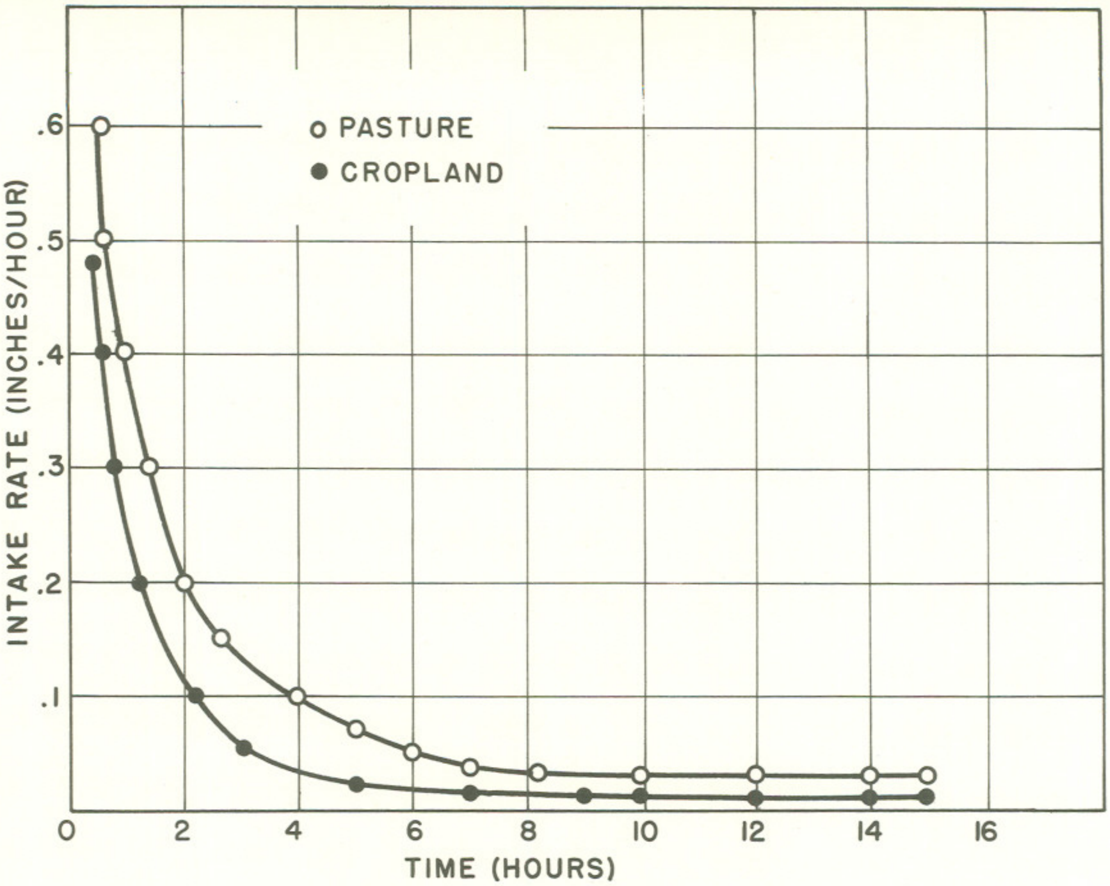

Figure 1. The change of intake rate with time for a storm occurring on wet soil.

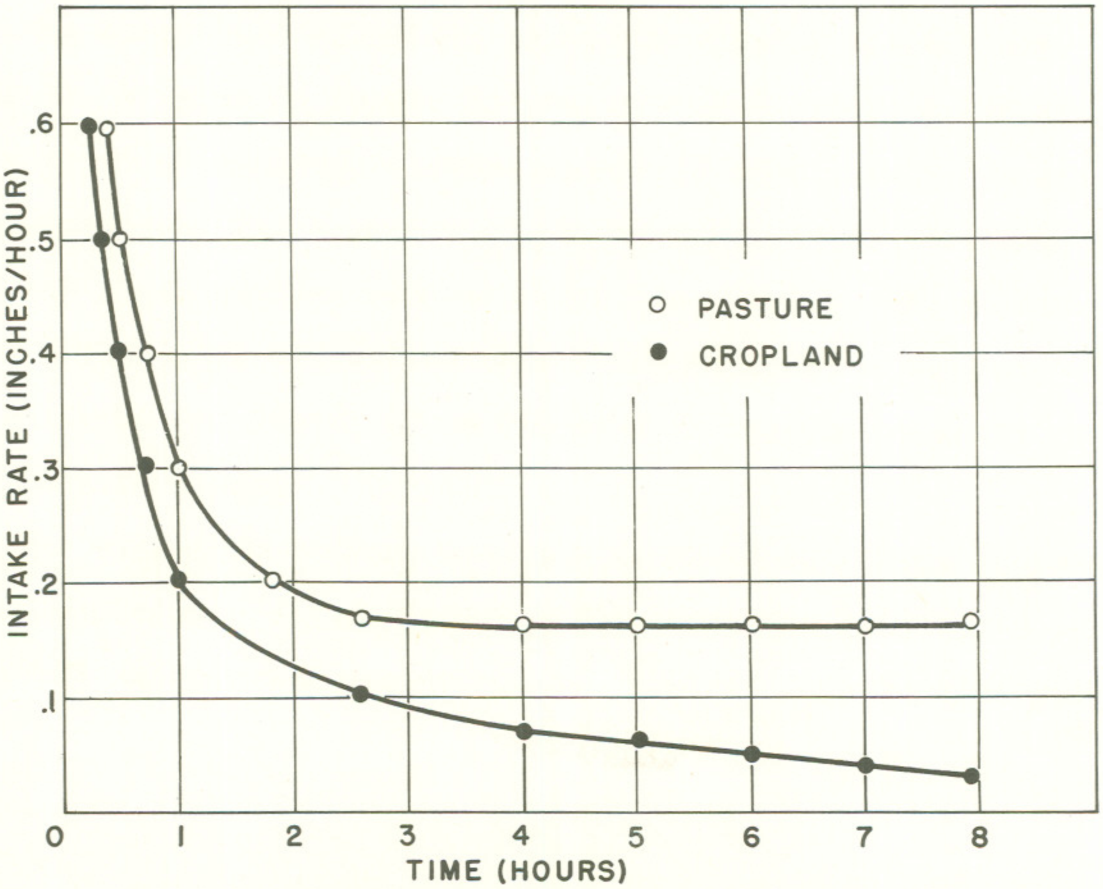

Figure 2. The change of intake rate with time for a storm occurring on moist soil.

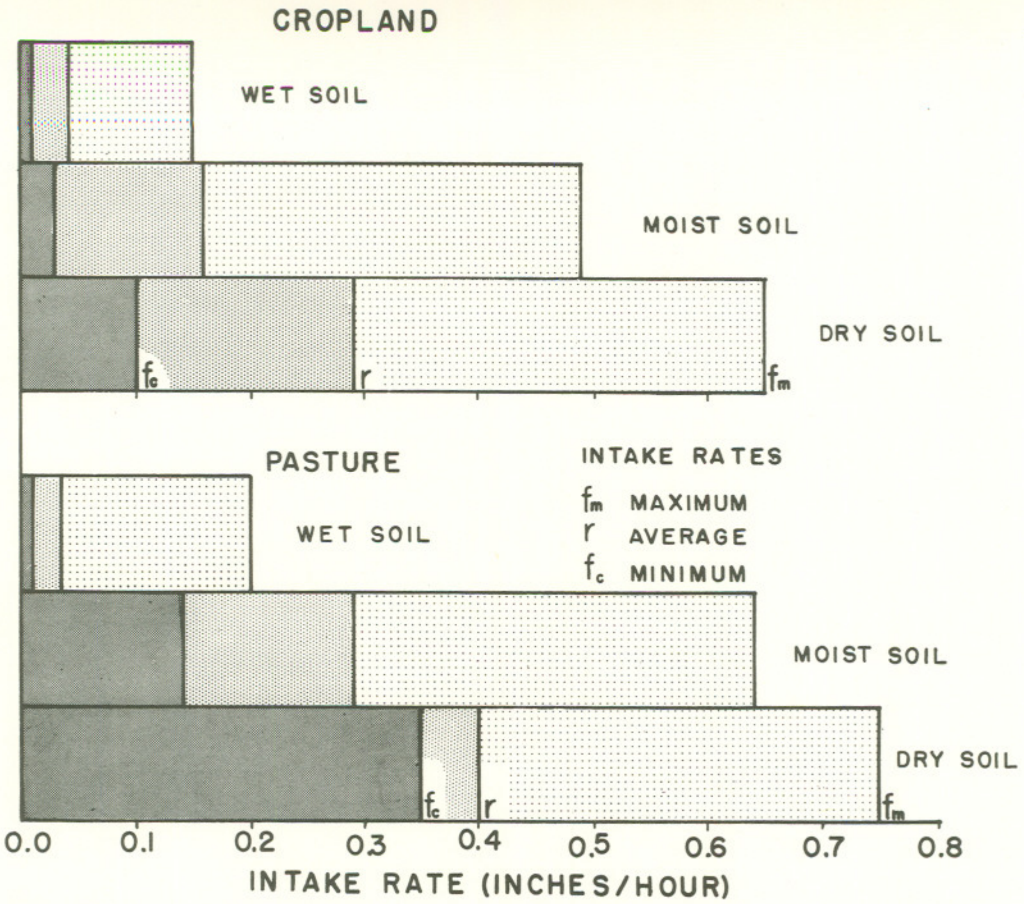

Figure 3. Soil moisture intake rates on pasture and cropland. Values of r and f_c superimposed on f_m.

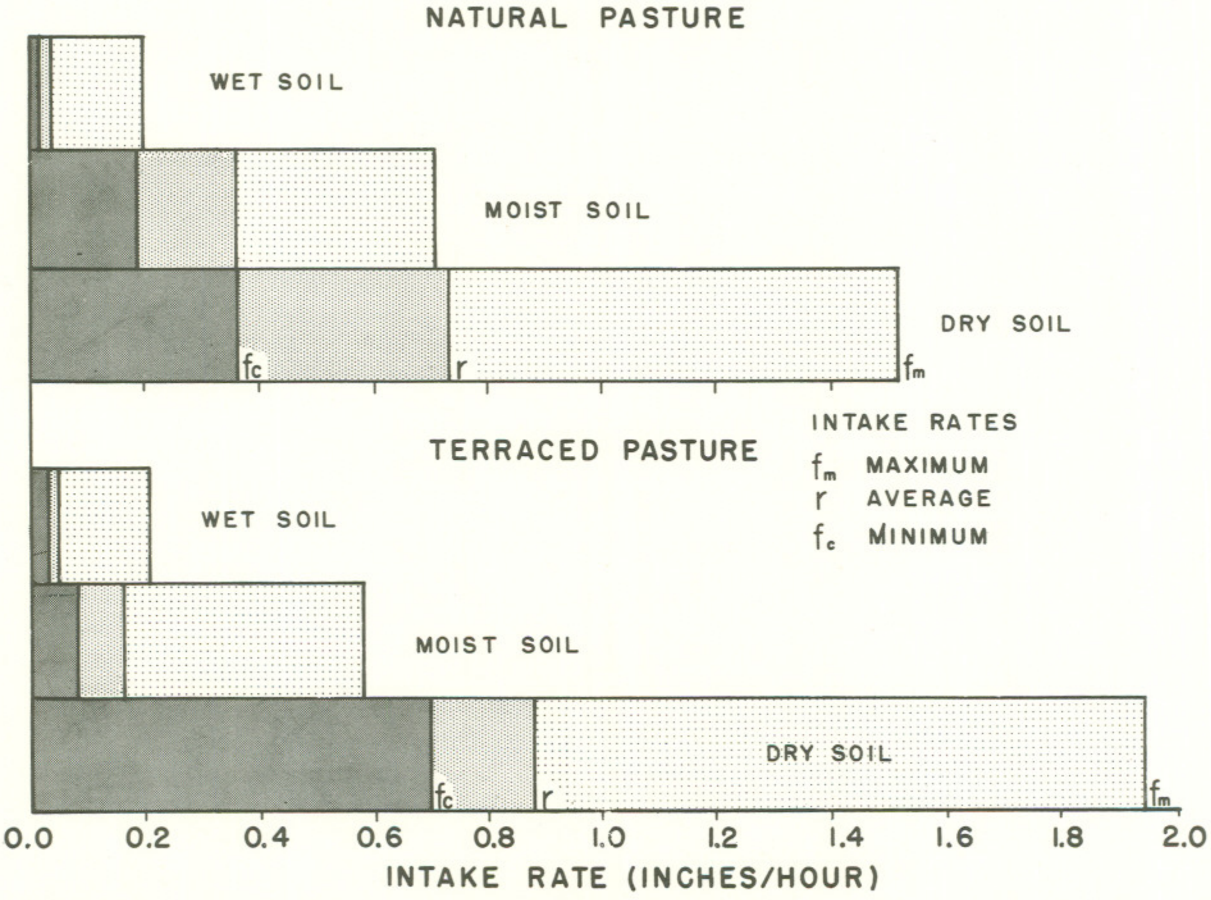

Figure 4. Soil moisture intake rates on terraced and natural pasture. Values of r and f_c superimposed on f_m.

more effective may arise from initial differences in the areas. Zingg's (12) record indicates some evidence of erosion on the one pasture before the terraces were established while none was observed on the pasture left in its natural state. The erosion observed is probably indicative of lower intake characteristics which was intensified by removal of most of the topsoil from the channel area during terrace construction.

Moisture intake rates for an area farmed parallel to field boundaries regardless of slope ("conventional farming") and for an area in rotational strip crops are shown in Figure 5. The rates for strip crop management are consistently better than those for the outdated farming practice. The values are averages of the same storms for each of the three general moisture conditions. There were comparable data available for four storms for the dry soil, six for the moist soil and four for the wet soil condition.

It would be of interest to find the ultimate f_c value for the soil when the profile is very wet. For all the storms occurring over the 1933-42 period only one or two soils appeared to reach this condition. Such a storm occurred on June 1, 1935. An estimate of antecedent available moisture in the upper two feet indicates it was more than 2.5 inches. The values of the final intake rates and the retention percentages for this storm are shown in Table 1. The final intake rates appear to be a little more for the terraced watersheds than for the other areas. The increase in retention percentage from less than ten to about twenty-five percent of the rainfall may be due to retention storage in the terrace channels. It appears that the ultimate intake rates for these watersheds with the soil very wet would be somewhat less than .01 inch per hour regardless of soil surface condition.

The retention percentage for storms occurring on four watersheds and the three soil moisture level groupings are shown in Figure 6. Comparable data are available for four storms on soil classed as dry, seven for moist soil, and five for the wet soil grouping. The retention percentage or portion of rainfall retained varies more with the soil moisture content than with soil cover or surface conditions. By extrapolation to a very wet soil condition it is apparent that the percentage retention from rainfall of average intensity and duration would be somewhat less than ten percent (See also Table 1). In general, retention by cropland is a little less than for pasture, hayland or the strip-cropped area. Of course, the differences in retention are due to differences in moisture conditions at the beginning of various storms as well as to differences in soil conditions due to management practices or cropping systems.

Relative soil losses in comparison with water losses for the different watersheds as reported by Smith and his co-workers (10) are of interest. Water losses for any storm and given pair of watersheds seldom exceeded a ratio of 2:1 while corresponding soil losses were sometimes more than 50:1. For a storm occurring on May 1, 1935, the runoff from terraced pasture was 0.46 inches, and

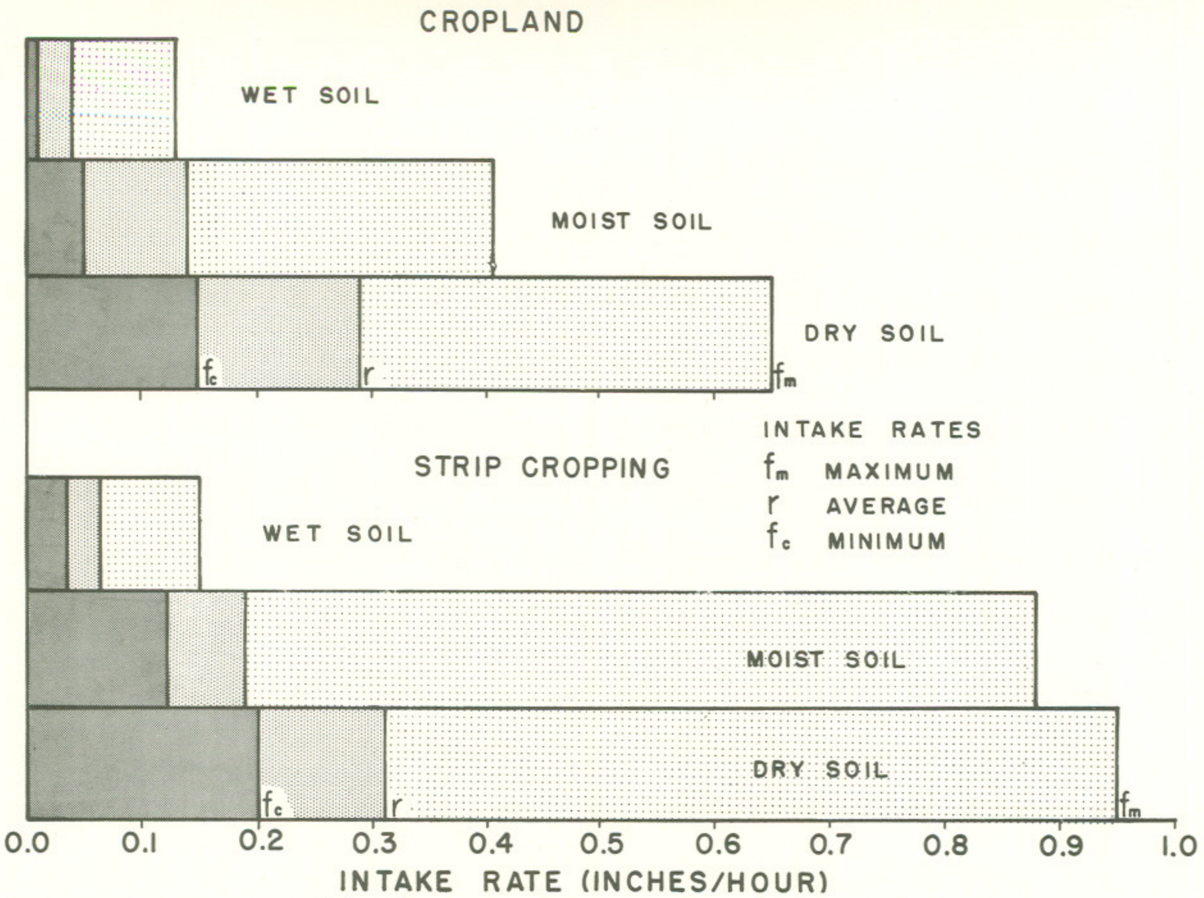

Figure 5. Soil moisture intake rates conventional farmed and strip-cropped areas. Values of r and f_c superimposed on f_m.

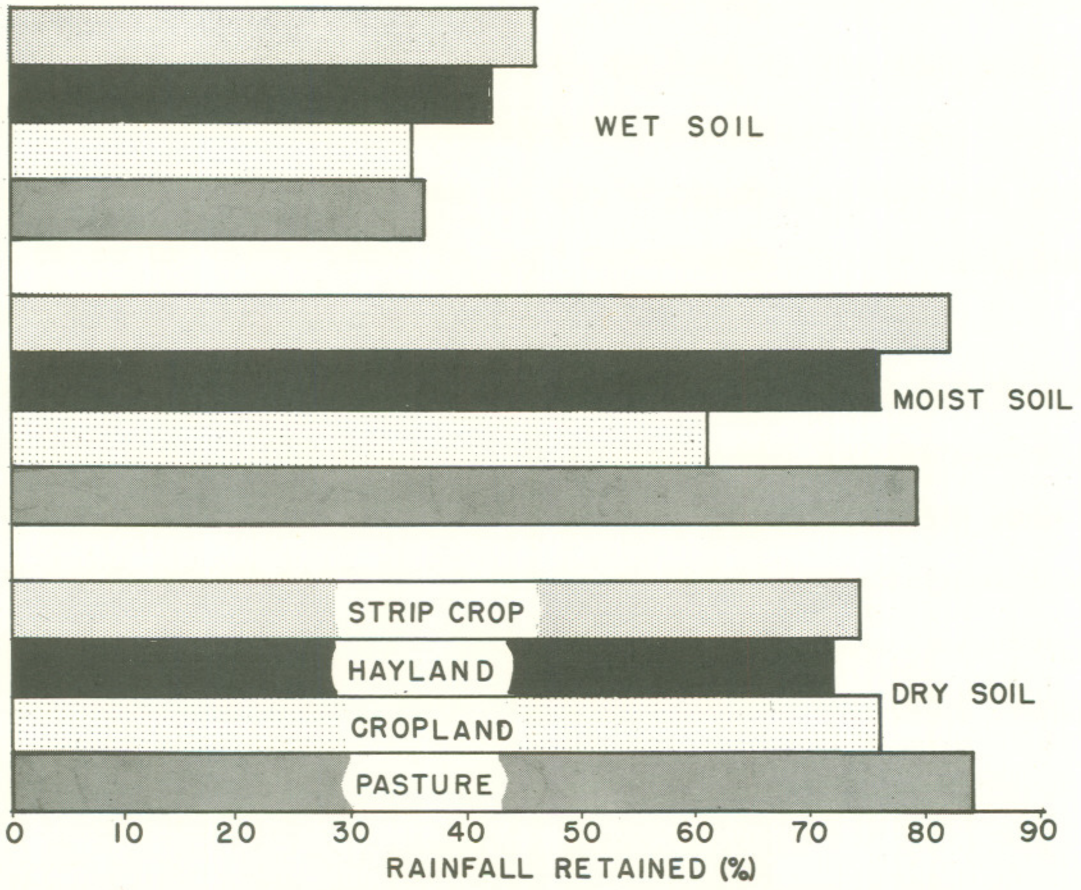

Figure 6. Retention indices for storms on pasture, cropland, hayland and strip-cropped areas.

from unterraced cropland, 0.79 inches. The soil losses for the same storm and watersheds were 0.28 and 17.12 tons per acre, respectively. It appears that for these soils good management will save some water from storms occurring during dry weather when moisture is in short supply. As the soil gets wet, intake decreases rapidly and runoff must occur. Good management has its reward in that water running from protected soil surfaces carries little sediment, while the runoff from poorly managed farms may be loaded with topsoil.

Table 1. Comparison of Percent Retention and Final Intake Rates for a Storm Occurring on Very Wet Soil.

	Final Intake Rate In/Hr.	Percent Retention %
Terraced Pasture	.010	24
Natural Pasture	.006	7
Cropland:[1/]		
Farmed paralled to boundaries	.007	9
Contour farmed	.006	7
Terraced	.010	27
Hayland (alfalfa)	.005	4
Strip Cropping[2/]	.007	8

[1/] Good cover of small grain with clover and timothy.

[2/] Good cover on hay strips, plowed ground and crop residues on alternate strips.

Figure Titles

Figure 1. The change of intake rate with time for a storm occurring on soil containing over 2 inches available moisture in upper 2 feet.

Figure 2. The change of intake rate with time for a storm occurring on soil containing 1 to 2 inches available moisture in upper 2 feet.

Figure 3. Soil moisture intake rates on pasture and cropland. Values of r and f_c superimposed on f_m.

Figure 4. Soil moisture intake rates on terraced and natural pasture. Values of r and f_c superimposed on f_m.

Figure 5. Soil moisture intake rates conventional farmed and strip-cropped areas. Values of r and f_c superimposed on f_m.

Figure 6. Retention percentages for storms on pasture, cropland, hayland and strip-cropped areas.

LITERATURE CITED

1. Bauwer, H. 1957 Infiltration patterns for surface irrigation. Ag. Engr. 38:662-664.

2. Holtan, H. N. 1945 Time condensation in hydrograph analysis. Trans. Amer. Geophys. Union 26:405-413.

3. Horner, W. W. and Lloyd, L. C. 1940 Infiltration-capacity values as determined from the study of an eighteen-month record at Edwardville, Illinois. Trans. Amer. Geophys. Union 21:522-541.

4. ______________ 1940 The analysis of hydrologic data for small watersheds. U.S.D.A. SCS-TP-30.

5. Horton, R. E. 1939 Analysis of runoff-plot experiments with varying infiltration-capacity. Trans. Amer. Geophys. Union 20:693 - 711.

6. Sharp, A. L., and Holtan, H. N. 1940 A graphic method of analysis of sprinkled-plot hydrographs. Trans. Amer. Geophys. Union 21:558-570.

7. ______________ 1942 Extension of graphic methods of analysis of sprinkled-plot hydrographs. Trans. Amer. Geophys. Union 23:578-593.

8. ______________ 1950 Rainfall, infiltration, and hydraulics of flow in runoff computation. Trans. Amer. Geophys. Union 31 (5):771-779.

9. Sherman, A. K. 1938 Determinations of infiltration rates from surface-runoff. Trans. Amer. Geophys. Union 19:430-434.

10. Smith, D. D., Whitt, D. M. Zingg, A. W. McCall, A. G., and Bell, F. G. 1945 Investigations in erosion control and reclamation of eroded Shelby and related soils at the Conservation Experiment Station, Bethany, Mo., 1930-42. U.S.D.A. Tech. Bul. 883. April, 1945.

LITERATURE CITED (Continued)

11. van Bavel, C.H.M. 1956 Estimating soil moisture conditions and time for irrigation with the evapotranspiration method. ARS 41-11. U.S.D.A., Aug. 1956.

12. Zingg, A. W. 1941 Hydrologic studies. Compilation of rainfall and runoff from the watersheds of the Shelby loam and related soils, Cons. Exp. Sta., Bethany, Mo. SCS-TP-39 (with Supplements 1 and 2, 1942 and 1943, resp.).

13. __________ 1943 The determination of infiltration rates on small watersheds. Trans. Amer. Geophys. Union 24:475-479.

Footnotes

1. Contribution from Eastern Soil and Water Conservation Research Branch, Agricultural Research Service, U.S.D.A. and the Missouri Agricultural Experiment Station. Mo. Agric. Expt. Sta. Jour. Series No. 1933 .

2. Soil Scientist and Agricultural Engineer, respectively.

3. Numbers in parentheses refer to Literature Cited, page 10.

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Summary

Twelve storms from the Bethany SCS Experiment Station records were selected as suitable for hydrograph analyses for soil intake rates by the method of Sharp and Holtan. Intake rates from the analyses show that moisture absorption by Shelby and Grundy soils depends more on antecedent moisture content than soil cover or management practice. Intake rates varied from over 2 inches/hour on dry soil to less than .01 inch/hour on very wet soil. As the soil gets wet, intake decreases rapidly and runoff must occur. Good management will save water from storms occurring on moist to dry soils. Water flowing from protected soil will carry little sediment while runoff from poorly managed Shelby-Grundy soils may be loaded with topsoil.