Moisture Relationships Of Some Rangeland Soils Of the Southern Great Plains

HOWARD M. TAYLOR

Soil Scientist (Physics), U. S. Department of Agriculture, Soil and Water Conservation Research Division, Southwestern Great Plains Field Station, Bushland, Texas

Rainfall in the Southern Great Plains is erratic both in total quantity and in distribution. As an example, annual precipitation at Amarillo, Texas has varied from 11.1 inches in 1910 to 39.7 inches in 1923 with a 67-year average of 20.1 inches. However, approximately 60 percent of the years were below average in rainfall. Of equal or greater importance is rainfall distribution in the area. More than 40 percent of the total rainfall over a 67-year period has fallen in amounts of ¼ inch or less in any 24-hour period.

During 1958 some measurable precipitation occurred during 86 days at the Southwestern Great Plains Field Station at Bushland, Texas, but on only 12 days did the precipitation amount to more than ½ inch. The precipitation on these 12 days was 12.7 inches or 58 percent of the 21.8 inches annual total. Seventy-seven percent of this total precipitation occurred during the period April 1 to October 1. Total evaporation from a 2-foot diameter evaporation pan was 54.5 inches for the same period.

These precipitation variations will affect the quantities of moisture available for forage production. Each soil site will react differently to the type of climate found on the Southern Great Plains. A knowledge of these climate-soil moisture relationships should aid the rancher and technician to most effectively use each site for maximum long-term benefit.

Methods

All bulk density values were obtained from soil core samples of native sod in fair to good condition. The Utah soil sampler (Kelley, et al. 1947) was used to obtain triplicate cores of the Pratt, Abilene, and Miles soils and a single core of the Amarillo fine sandy loam soil. A modification of the impact core sampler described by Uhland and O'-Neal (1951) was used to obtain duplicate cores of the Portales, Tivoli, and Amarillo loamy fine sand soils. A modification of the sampler described by Lutz (1947) was used to obtain duplicate cores of the Pullman soil.

Native sod soil samples crushed to pass a 2 mm. screen were used to obtain the moisture retention data. With the exception of the Pullman soil, the ⅓ atmosphere soil moisture tension value (Richards 1948) was used to approximate field capacity and the 15 atmosphere value (Richards 1947) to approximate permanent wilting point. Available moisture data for all soils except Pullman were calculated from the difference between these two soil moisture tension values. Actual field determinations of field capacity and field minimum moisture were used to calculate moisture data for the Pullman soil.

Results and Discussion

When any given amount of precipitation arrives at the vegetative canopy over a soil, part is intercepted by the vegetation and part goes through to the soil surface. A large percentage of small showers may be intercepted by vegetation, but the percentage of interception decreases with increasing amount of rainfall or decreasing amount of vegetation.

Of the precipitation that reaches the soil surface, part may be lost through runoff and the remainder infiltrates into the soil. Figure 1 gives data for intake rates of four of the soil types. A wide range of soil characteristics—from the Tivoli fine sand, or sand dunes site, to the Pullman silty clay loam of the deep hardland site—are represented in these intake measurements. For a number of reasons, the intake curves do not give absolute or precisely comparable values. The differences between some of intake rates are so marked, however, that value can be obtained from the data. For example, a 2-inch rain would infiltrate a Tivoli sand soil in approximately 8 minutes, a Pratt fine sandy loam soil in 9 minutes, a Portales fine sandy loam soil in 16 minutes, but it would take nearly 5 hours for the same 2-inch rain to infiltrate the Pullman silty clay loam soil.

Even though much of the rainfall of the Southern Great Plains occurs as "thunderstorms" of high intensity, very little runoff would ordinarily occur on sites such as the Tivoli sand or the Pratt fine sandy loam. Considerable runoff could occur if a high

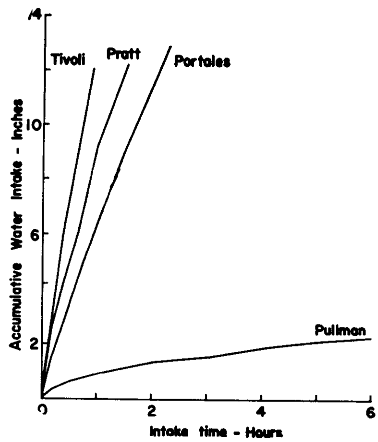

FIGURE 1. Water intake as a function of time for four soil series of the Southern Great Plains.

Table 1. Some moisture relationships for eight soil types of the Southern Great Plains.

Soil type and site location	Field capacity	Wilting point	Bulk density	Available water	Total Water held in upper 6 inches	Total depth soil wetted by 2-inch rain	Precipitation effectiveness
	Percent	Percent	g./cc.	Inches	Inches	Inches	Percent
Pullman silty clay loam Southwestern Great Plains Fld. Sta., Bushland, Tex.							
0-12″	28.35	12.50	1.30	2.47	2.21	5.4	0
12-24″	25.10	14.10	1.50	1.98			
24-36″	23.90	13.90	1.50	1.80			
36-48″	22.70	13.80	1.58	1.69			
Total				7.94			
Portales fine sandy loam 6 miles SW of Tarzan, Tex.							
0-12″	13.25	6.68	1.49	1.17	1.18	14.2	41.0
12-24″	16.62	8.90	1.35	1.25			
24-36″	22.31	14.11	1.33	1.31			
36-48″	23.37	15.43	1.72	1.64			
Total				5.37			
Amarillo fine sandy loam 5 miles E. of Spade, Tex.							
0-12″	14.86	7.66	1.41	1.22	1.09	14.7	45.0
12-24″	16.55	8.55	1.43	1.37			
24-36″	15.39	7.23	1.45	1.42			
36-48″	13.04	6.04	1.58	1.33			
Total				5.34			
Amarillo loamy fine sand 9 miles WSW, Welch, Tex.							
0-12″	5.45	1.86	1.68	.72	.55	20.4	73.0
12-24″	18.50	9.69	1.45	1.53			
24-36″	22.04	10.44	1.58	2.20			
36-48″	22.10	10.50	1.60	2.23			
Total				6.68			
Tivoli sand 12 miles N. Littlefield, Tex.							
0-12″	0.78	0.39	1.60	.07	.07	337.0	11.0
12-24″	0.78	0.39	1.58	.07			
24-36″	0.78	0.39	1.62	.07			
36-48″	0.78	0.39	1.60	.07			
Total				.28			
Pratt fine sandy loam Southern Great Plains Field Station, Woodward, Okla.							
0-12″	12.06	4.94	1.42	1.21	.87	19.1	56.0
12-24″	9.95	4.49	1.36	.89			
24-36″	12.52	5.38	1.35	1.16			
36-48″	18.57	8.14	1.43	1.79			
Total				5.05			
Abilene loam 2 miles NW Lakeview, Tex.							
0-12″	14.55	6.22	1.41	1.41	1.23	12.6	38.0
12-24″	18.26	8.54	1.48	1.73			
24-36″	20.46	9.12	1.61	2.19			
36-48″	21.80	10.14	1.68	2.35			
Total				7.68			

Miles fine sandy loam							
4 miles SE Turkey, Texas							
0-12″	15.60	6.84	1.38	1.45	1.36	11.3	32.0
12-24″	18.40	8.92	1.40	1.59			
24-36″	18.22	9.07	1.46	1.71			
36-48″	16.22	7.68	1.54	1.58			
Total				6.33			

intensity rain occurred while the surface foot of the Pullman soil was wet. The runoff from the Portales soil should be intermediate between the runoff from the others. Any surface runoff reduces the amount of moisture which can possibly be available for forage production on that particular site.

Research workers in plant-soil-water relations have developed the concepts of "water holding capacity" or preferably "field capacity" and "permanent wilting percentage". Field capacity is the amount of water a soil will hold against gravity when measured a few days after a rain or irrigation. Permanent wilting percentage is the lower limt of water that plants can readily extract from the soil. Wilting percentage and field capacity are more or less independent of the plant and are used as soil constants. The difference between field capacity and wilting percentage is variously termed "available soil moisture", "available moisture", "available water", and "plant available water".

The field capacity, permanent wilting percentage, bulk density and inches of available water for each foot of eight soil profiles are listed in table 1. The total available water held in a four foot profile varies from approximately ¼ inch for the Tivoli sand to 8 inches for the Pullman silty clay loam. Of course, rooting depths are usually greater than four feet in the Tivoli sand dunes site.

If the frequency or distribution of rainfall were no problem, the water intake rates and the amount of available water in the profile would be of greatest importance in soil-plant-water relations of rangeland soils. However, climatic variations on the Southern Great Plains mean that the precipitation effectiveness also must be considered. Effective precipitation is the amount of rainfall that enters the soil profile and is not again lost to the atmosphere through evaporation or to depths below rooting zones of productive range plants. Generally, some available soil moisture is stored during winter when most of the plants are dead or dormant. During the summer growth period, plants utilize this stored available water to supplement the effective precipitation. In the Southern Great Plains, it is usually evaporation and not deep percolation that decreases effectiveness of precipitation on most sites. Because of the low amounts of available water per foot of soil depth that can be held, deep percolation may become a serious problem on sites such as the Tivoli sand.

Some aspects of precipitation effectiveness are shown in portions of table 1. The following assumptions were made in constructing the table:

1. The surface 6 inches of soil was air dry at the time of the rain.
2. The moisture held in the surface 6 inches of soil was not effective due to rapid evaporation after the rain.
3. The soil at depths below 6 inches was at permanent wilting point.
4. A 2-inch rain storm occurred and all of it infiltrated the soil.
5. The moisture that penetrated to depths greater than 4 feet was not effective because of deep percolation.

Under these stated hypothetical conditions, a 2-inch rain would wet the Tivoli sand to a depth of 337 inches but would wet the Pullman silty clay loam to a depth of only 5 inches. During the summer season on the Southern Great Plains, most of the moisture contained within the top 6-inch layer of soil will be lost through evapotranspiration within 2 or 3 weeks—usually most will be lost before the next appreciable quantity of precipitation. As indicated in table 1, a greater percentage of a given rain will be stored below 6 inches depth on a moderately sandy than on a silty clay loam soil—even when no runoff occurs.

Two inches of water entering any soil will penetrate deeper on a moist than a dry soil. The deeper penetration on a moist soil will cause a greater percentage of the rain to be stored at depths where evaporation is less important. Therefore, the effectiveness of precipitation is greater on moist than on dry soils, providing equal amounts of water enter the two soils. However, the reduced rate of water entry caused by moist soil may increase runoff.

When active roots are present within the top 6 inches of soil, much of the moisture contained within that soil layer will be used before evaporation dries it out. With a soil such as the Pullman "hardlands" site, vegetation that has a fibrous well developed root system near the surface capable of quickly utilizing moisture will tend to predominate within the Southern Great Plains. On the Tivoli sand site, climax vegetation which has deep and widespread rooting characteristics will predominate. Since each foot of soil holds only .07 inch of water, plant roots must explore a large volume of soil to supply the water necessary for vegetative growth.

In the Southern Great Plains, large acreage of soil exists where a sandy loam or loamy sand surface horizon is underlain by a loam, sandy clay loam, or clay loam subsoil. The soil-plant-water relations of these soil sites are generally better than those of either a medium-or a sandy-textured profile. The Amarillo loamy fine sand soil is an example. The sandy surface horizon allows a high water intake rate while at the same time retains only small quantities of water within the top few inches where evaporative loss is rapid. The heavier textured sandy clay loam subsoil has a fairly high available water storage and generally an adequate intake rate. For rangeland plant production, this soil profile combines the best features of sandy and finer textured profiles. On poor condition rangeland, this site may be highly subject to wind erosion, however.

Certain topographic situations exist that alter the normal soil-plant-water relations of any of the soils discussed in this article. If a soil site collects water from another area, whether that water is added by surface or underground flow, the climax vegetation tends to acquire the characteristics of a more humid situation. In flat areas where runoff from slopes provides extra water, or on first or second terraces of drainage channels, mid—or tall grass vegetation may predominate on sites that would ordinarily produce only short grass.

Plant-soil-water relations that determine the type and amount of vegetation in the climax or post-climax situation within the Southern Great Plains have been emphasized. In certain situations—such as the Tivoli sand—lack of fertility may be a controlling factor. The probability that lack of fertility is a major factor in the production of climax vegetation increases as the soil-plant-water relations of a soil become better. In general, however, the quantity and seasonal distribution of soil moisture will determine the productive value of a particular soil site on the Southern Great Plains.

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