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Water budget for creosotebush-infested rangeland

J. M. Tromble

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A water budget for creosotebush-infested rangeland was calculated using values determined from a water interception study, runoff from instrumented plots, and precipitation data. Combining data generated from precipitation events received for the study period showed that 20 per cent and 9 per cent of the rainfall contributed to runoff and interception, respectively. Abstraction of approximately 30 per cent of the precipitation by these two variables impacts the onsite water availability.

Introduction

On arid and semi-arid rangelands of the south-west, providing an adequate soil water supply to establish and grow economically useful range forage plants is of continuing interest. Efforts have been expended to increase forage production on these arid rangelands, which as the name implies, are areas with an inherent lack of available water for plant growth.

In south central New Mexico, the average annual rainfall is about 230 mm. About half of that is received from July through September with the remainder falling during the other 9 months. The rainfall pattern is bimodal with a large peak in July through September (growing season) and a much smaller peak in December through February. Precipitation, however, can be received any month of the year. April, May, and June are normally the driest months of the year; therefore, soil water from winter precipitation is usually depleted by evapotranspiration before the summer growing season. Water available for growth of most plants is thus supplied by precipitation received during July through September.

Much of the Chihuahuan Desert is infested by brush species. A dominant species is creosotebush (*Larrea tridentata*) [DC.] Cov.), occupying some 18·8 million h in the south-western United States (Platt, 1959). This species can be found in almost pure stands with only small amounts of other species present.

Two important factors hindering the soil water supply, without which an adequate stand of forage plants cannot be established, are water interception by shrubby plant species and surface water runoff. Water interception has been reported for some species of shrubby plants. West & Gifford (1976) determined water interception for big sagebrush (*Artemisia tridentata* Nutt.) and shadscale (*Atriplex confertifolia* [Torr. & Frém.]s. Wats) to be 1·5 mm for both species. Water interception amounted to 5·9 mm, or about 4 per cent of the average rainfall from 1 April to 30 November in northern Utah. The interception of artifically applied rainfall by dense stands of large saltbush plants (*Atriplex argentea* Nutt.) was 50 per cent of a 150 mm rain applied in 30 minutes. Burning bush (*Kochia scoparia* [L.]

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Roth) similarly treated intercepted 44 per cent (Collins, 1970). Rainfall interception by dense stands of big sagebrush was determined to be about 30 per cent of the total rainfall between 1 April and 30 October (Hull, 1972; Hull & Klomp, 1974). Rowe (1948) and Hamilton & Rowe (1949) concluded that water interception amounted to about 8 per cent of the annual rainfall for the chaparral type in central and southern California.

Tromble (1976) reported on runoff from creosotebush and whitethorn (*Acacia constricta* Gray var. *vernicosa* [Standley] L. Benson) infested plots in Arizona. Average runoff was 16 per cent of the precipitation from storms greater than 12·7 mm. Runoff from two rangeland watersheds in Texas with an excellent ground cover of blue grama (*Bouteloua gracilis* [Kunth] Griffiths) and buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) amounted to only 2 per cent of the annual precipitation (Jones *et al.*, 1985). A few large, intense storms produced most of the runoff.

Water interception studies (Tromble, 1983) were conducted near Las Cruces in south central New Mexico. Forty-four creosotebush shrubs were subjected to simulated rainfall from a sprinkling type infiltrometer. Individual plants were selected to include the range in plant size variation within the population. Parameters determined for each shrub included: (1) crown cover, (2) shrub height, (3) leaf green weight, (4) green weight of stems, (5) oven-dry weight of leaves, (6) oven-dry weight of stems, (7) number of stems, (8) leaf area, (9) shrub volume, and (10) shrub weight. Methods of measuring these parameters are described by Tromble (1983). The average crown cover for the creosotebush community was determined from 10 line intercept transects 30·5 m long. Water interception storage data determined from the individual shrubs, and data from the line transects, were used to calculate water interception from the plant community (Tromble, 1983).

The objective of this study was to determine the amount of water available for infiltration through the soil surface from precipitation events after abstractions by interception and runoff.

Methods

Crown cover was determined from point-line transects with a total of 115 points measured for each of the four runoff plots. Interception of rainfall by creosotebush was estimated using the method described by Tromble (1983). Water interception storage data for each rainfall event was estimated, and cumulative amounts determined for each study period.

Four plots, 3·7 m by 22·1 m, were instrumented to measure runoff from an undisturbed creosotebush community. Plot locations were selected for uniformity in slope, aspect, and soils; the slope was approximately 6 per cent for the four plots. Rainfall was measured with two recording raingages at the site. Runoff generated from naturally occurring rainstorm events was measured from each plot using a 30·5 cm H-flume and a water stage recorder. Partially buried sheet metal borders define the two sides and the upper end of the rectangular plots. A metal trough across the lower end of each plot transported runoff to the flume. Data were collected after each runoff-producing precipitation event and the data analyzed to determine the amount of precipitation that contributed to runoff. Each storm event was analyzed and the total amount contributing to surface runoff was determined for each of the three study periods.

Results and discussion

Interception

Canopy storage capacity is the most important parameter in the water interception process (Aston, 1979). Leonard (1965) reported that canopy storage capacity is a function of leaf area, leaf area index, storm intensity, and surface-tension forces resulting from leaf surface configuration, liquid viscosity, and mechanical activity.

Tromble (1983), reporting on data from a simulated rainfall interception study on creosotebush, stated, for a storm of sufficient volume and intensity to completely wet these shrubs, 3·6 mm of precipitation would be intercepted. Extrapolation of this to a creosotebush community with 30·5 per cent crown cover and ignoring events less than 3·6 mm, this amounted to a 12 per cent change in the water budget as a result of precipitation interception by these shrubs. Rainfall events of 3·6 mm or less were not included because this amount was needed to satisfy the interception component.

The summer precipitation (1 May–31 October) amounts to about 55 per cent, or 126 mm, of the 230 mm annual average for south central New Mexico. This amount is received from events of varying amounts and intensities when the creosotebush is in full leaf and has maximum water interception potential. According to National Oceanic and Atmospheric Administration records from 1 May 1956 to 31 October 1965, there was an average of 14 events per year that exceeded 3·6 mm. Disregarding rainfall events of less than 3·6 mm, and considering a crown cover of 30·5 per cent for the creosotebush community, an average of about 15·4 mm would be intercepted each summer. This would amount to 12 per cent of the summer rainfall.

Runoff

Surface runoff is dependent on a number of factors, some of which are vegetation cover, litter, slope, antecedent soil water, soil texture, and microrelief of the soil surface.

Almost all runoff in the summer occurs from convective storms of short duration and high intensity. Surface runoff data were collected from 1983 to 1985 from the replicated plots. An average of 16 precipitation events exceeding 3·6 mm occurred each year during the summer season (1 May to 31 October) and ranged from 12 to 21 events. There were 3, 14, and 7 runoff-producing events for 1983, 1984, and 1985, respectively. The largest precipitation event occurred on 24 July 1983 when 42·8 mm of rain was received. Runoff generated from this event was 19·6 mm, or 42 per cent of the precipitation received.

Water budget

Calculation of a water budget for this creosotebush study area from 1 May to 31 October was performed using the precipitation, water interception, and runoff data. Water in excess of that intercepted or contributing to surface runoff and disregarding evaporation, should be available for infiltration and enhancement of soil water. This may be described as

$$I_f = p - (Q + I_c) \text{ eqn.} \qquad (1)$$

where

I_f = infiltration
p = precipitation
Q = surface runoff
I_c = interception

Table 1 gives the calculated and measured values for precipitation, water interception, runoff, and infiltration for 1 May to 31 October, 1983, 1984, and 1985, respectively. Water interception was determined from storms exceeding 3·6 mm.

Total runoff from three events in 1983 was 51 mm and water interception calculated from 14 events was 15 mm. The total abstraction of water by both runoff and interception was 66 mm, 42 per cent of the summer rainfall. The amount of water available for infiltration into the soil would be the difference between precipitation and runoff plus interception, or 90 mm. Infiltration amounted to only 58 per cent of the total summer rainfall received in 1983 from events greater than 3·6 mm.

Water interception and runoff accounted for 65 mm and 34 mm of rainfall received in 1984 and 1985, respectively. Thus, 170 mm and 142 mm of rainfall were available for infiltration in these two years. Combining data for all years shows the average amount of

Table 1. *Precipitation (measured), interception (estimated), runoff (measured), and infiltration (calculated) values for runoff plots on creosotebush infested rangeland*

Year*	Precipitation (mm)	Interception (mm)	Runoff (mm)	Infiltration (mm)
1983	156	15	51	90
1984	235	23	42	170
1985	176	13	21	142
Average	189	17	38	134

* Time period for each year was 1 May to 31 October.

precipitation received to be 189 mm. From this amount, 9 per cent was abstracted by interception and 20 per cent contributed to runoff. About 30 per cent of the rainfall received on the site was removed and was not available for infiltration and replenishment of the soil water supply.

In arid environments, reducing the available soil water supply by 30 per cent, or 1 cm from every 3 cm, can inhibit or severely limit the establishment and growth of desirable plants. These data indicate that conservation practices designed to convert arid and semi-arid rangelands from brush species to grass species may not be practical under these conditions and for this site, unless water losses by runoff and interception are reduced.

Water interception and surface water runoff can cause large changes in water disposition on arid and semi-arid rangelands. With approximately 30 per cent of the rainfall being abstracted by interception and runoff, and not available for infiltration, incorporation of these two variables into rangeland models is important.

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