Waterponding for Increasing Soil Water on Arid Rangelands

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Abstract

Ponding dikes constructed to slow and control the overland flow of runoff water were evaluated. Infiltration and runoff measurements from a sprinkling infiltrometer indicated no differences between the control and the water ponding area. Examination of 20 years of precipitation records for June through September showed that enough ponding events occurred to supply an adequate amount of water for wetting the soil profile to below the plant rooting zone. The control areas were low in available soil water even immediately following precipitation events.

A wide-spread erosion problem exists in arid areas of Australia and the southwestern United States. In many areas in both countries the erosive forces of water and wind have removed surface soil from unprotected areas, exposing the subsoil that is, or subsequently becomes, relatively impermeable to water. The top soil, usually a sandy loam readily eroded to expose a clay subsoil.

Average annual rainfall for these areas in Australia is generally low but may range up to 500 mm (Cunningham et al. 1974). In the southwestern United States incidence of rainfall is greater in summer than winter when individual storms of high intensity and short duration occur (Herbel and Gile 1973).

Volk and Geyger (1970) have reported sites free of vegetation in many warm-arid areas of the world. These areas were distributed in a mosaic-like pattern, although precipitation was adequate for plant growth. Soil salinity or overgrazing did not cause these barren areas. There is some value as catchments for dirt tanks, though the high yields of runoff from the impermeable surface means that only a relatively small surface area is needed to fill the tank. These areas are, therefore, essentially waste land supporting little vegetation.

The features of low, unreliable rainfall, high temperatures and the nature of the eroded surfaces on these areas result in inadequate soil water (Newman 1966). Providing adequate soil water for plant growth is thus extremely difficult due to the low total quantity of rainfall, low infiltration, and high runoff rates. Jones (1969) showed that retention of water on barren sites without soil disturbance in Australia can gradually improve soil water availability and consequently plant growth, even though the infiltration rates are initially unaffected.

The objectives of this study were to observe the effects of water ponding on the amount and temporal distribution of water in the soil profile. Infiltration and runoff from both the control and water ponding treatments were examined using a sprinkling rainfall simulator.

Study Area and Methods

In March 1975, 2 areas on the Jornada Experimental Range in south central New Mexico having approximately a 1% slope were selected for a water ponding treatment with an adjacent area used as a control. Horseshoe-shaped dikes were constructed for ponding onsite and surface flows. Two depths for ponding water were selected, 7.5 and 15 cm, with 5 dikes per site. Construction of the 7.5-cm dikes was performed with a farm tractor and irrigation border disc, while the 15-cm dikes were constructed using a motor grader.

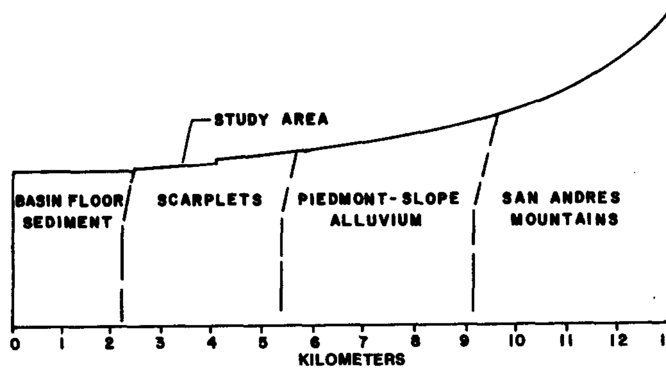

Fig. 1. *Diagrammatic cross-section of the western slope of the San Andres Mountains.*

Soils at both sites were classified (E. Bullock[1], personal communication) as being a fine loamy, mixed thermic Typic Haplargid. These soils are of the Dona Ana series and are in hydrologic soil group B having a final infiltration rate (f_c) of 0.38 to 0.76 cm/hr (Musgrave 1955).

The primary source of soil materials for the study area is the San Andres Mountain Range (dominantly marine carbonate rocks) which occur about 10 km east of the study site. The broad flat covered with tarbush *(Flourensia cernua)* and grass is underlain by silty alluvium deposited by sheet floods moving from the higher elevations. The grass cover has deteriorated over the past century (Buffington and Herbel 1965). A series of arcuated erosional scarplets exists on the cohesive silty alluvium. It is upon these scarplets that the study areas are located (Fig. 1).

Effect of ponding water on the hydrologic response of the soil surface of these problem areas was estimated by examining three 1-m² infiltrometer plots within the 7.5-cm dikes, the 15-cm dikes, and on each of the 2 control areas. The sprinkling rainfall simulator applied water at a rate of 16.4 cm/hr for 1 hour. This application rate was used to decrease the time before initiation of runoff and to reduce evaporation. Infiltrometer measurements were made 2 years after construction of the dikes.

Runoff from the 1-m² infiltrometer plots, with 3 replications per treatment, was recorded continuously by a water stage recorder installed on a volumetric tank. The effects of antecedent soil water on infiltration were determined for the 4 treatments by repeating the infiltration test 24 hours after the initial test. Treatments were analyzed using an analysis of variance and Duncan's multiple range test (Duncan 1955).

Infiltration data were collected in June, 1976, prior to the summer convective storms which generally began in July. The dikes would pond water from onsite precipitation or runin water with the advent of the summer storms and supply increased amounts of soil water when compared to the control areas. Annual

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[1]E. Bullock, soil scientist, Soil Conservation Service, Las Cruces, N. Mex. 1976.

precipitation is approximately 231 mm with 55% occurring in the summer and 45% occurring from fall and winter frontal storms.

Soil water content was monitored by using a neutron probe. The soil water profile measurements were taken to a depth of 180 cm in 30-cm increments. Three replications were made within the 3 ponding areas in both the 7.5- and 15-cm dikes as well as 3 replications in each of 2 control areas.

Results and Discussion

Runoff values from the 1-m^2 infiltrometer plots were similar to those that might be expected for the bare, fine textured soils. Runoff began in less than 5 minutes after beginning of rainfall application for all plots. No differences were observed to beginning of runoff between the initial and antecedent soil moisture plots.

Infiltration was very low with greater than 85% of the applied water appearing as runoff for all treatments. These results were supported by the work of Hudson (1965), who found that the infiltration rate on similar disturbed areas in Australia was as low as 1.58 cm/hr and that runoff from barren sites was almost 100%.

An analysis of variance was performed to determine if the treatments affected runoff significantly at the end of 15 and 60 minutes, respectively. Treatment differences were found to be nonsignificant for the 15-minute period with means ranging from 2.91 to 3.56 cm. The analysis of variance performed on data collected at the end of 60 minutes indicated a significant difference between treatments.

Treatment differences were more thoroughly examined using Duncan's multiple range test (Table 1). After 60 minutes the 15-cm ponding dike wet treatment had significantly less runoff than all other treatments. The greatest amounts of runoff occurred on the 15-cm, and on the 7.5-cm control dry treatments, respectively.

Table 1. Mean runoff for three replications for the 7.5-cm and 15-cm water ponding dikes after 60 minutes of artificial rainfall application.

Treatment	7	4	5	8	3	1	6	2
Means (cm)	14.1	15.1	15.2	15.2	15.7	15.7	15.8	16.3

[2]

[1](1) 7.5-cm ponding dike, dry; (2) 7.5-cm control, dry; (3) 7.5-cm ponding dike, wet; (4) 7.5-cm control, wet; (5) 15-cm ponding dike, dry; (6) 15-cm control, dry; (7) 15-cm ponding dike, wet; (8) 15-cm control, wet.
[2]Means connected by a continuous line were not significantly different from each other.

Measurements made on the 7.5- and 15-cm ponding dike treatments indicated high runoff potential under both the wet and the dry antecedent soil water conditions. The lack of distinct differences in runoff between the ponding dikes and the control areas may indicate little change to the soil structure as a result of water ponding. Also, the similarity in runoff rates between the wet antecedent soil water and the dry antecedent soil water treatments may indicate that runoff is controlled more by the soil surface morphology rather than soil water content.

In June 1981, 6 years following construction of the dikes, infiltration and runoff were again evaluated on both the controls and the water ponding areas. The objective was to determine if differences existed in infiltration and runoff after 6 years and if so, were they attributable to the water ponding. The same sprinkling infiltrometer was used in 1981 as had been used in 1976.

Differences in infiltration and runoff between the controls and the water ponding areas were very small (<0.1 cm/hr). These data indicated that ponding on site and runin water had no effect on changing the soil surface for increasing the infiltration rate.

Our study differed from Australian studies (Cunningham et al. 1974) in which a swelling and heaving of the clay subsoil followed infiltration and was accompanied by leaching of salts at selected sites. In Australia the smooth surface soil disintegrated, giving way to a deeply, well-structured surface which readily absorbed water and increased infiltration rates. Although Australian studies (Cunningham et al. 1974) indicated soil cracking, increased infiltration rates, and vegetation growth on similar soils after 2 years, our studies indicated relatively stable runoff rates, no increase in infiltration rates, and very little soil cracking occurring on the nonsaline Jornada soil. Benefits from water ponding would result: (1) by increasing the length of time for infiltration to occur rather than through increased infiltration rates and (2) by reducing the velocity of surface flows, thereby reducing erosion.

July through September corresponds to the summer rainy season and consequently the growing season in southern New Mexico. Rainfall for this period in 1976 was 80 mm, well below the 126 mm average, and yet precipitation was adequate for the enhancement of soil water due to water ponding within the dikes.

It was determined through infiltrometer studies and by visual observation that 5 mm of precipitation would cause overland flow and water ponding. On this basis, inspection of onsite rainfall records indicated that 13 ponding events occurred from May 1976 through September 1977. Seven events occurred in the first year (May 1976–May 1977) which resulted in water ponding. These events were evenly distributed throughout the year with 4 events in the summer and 3 events in the winter. The other 6 ponding events occurred during the summer convective storm period of 1977. Total precipitation for this period was 358 mm, with a maximum of

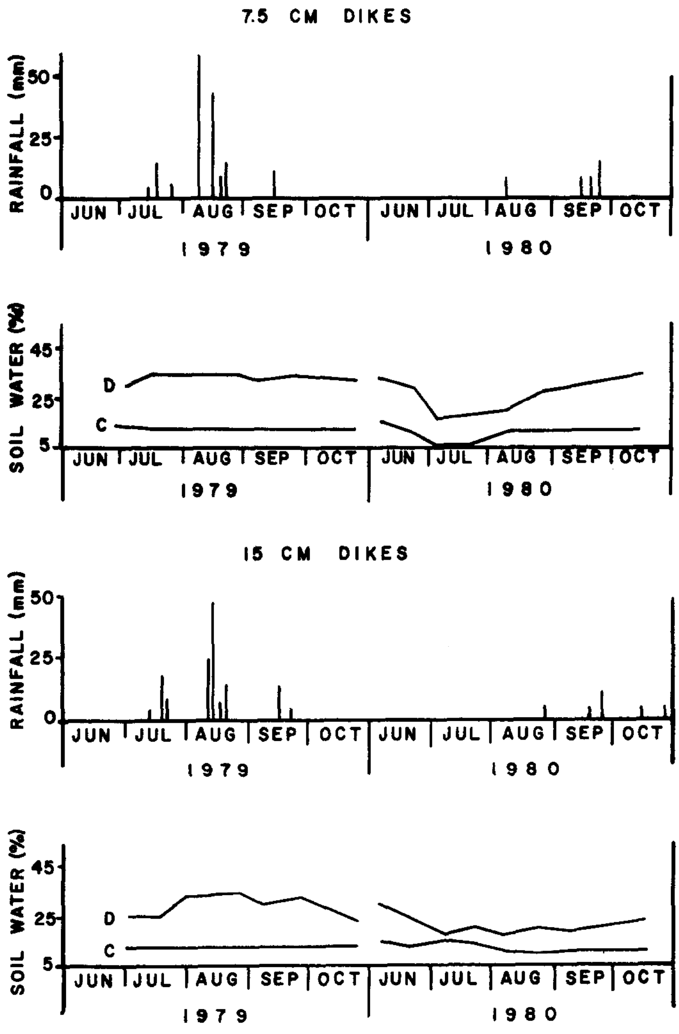

Fig. 2. *Rainfall (>5mm) and soil water for June through October 1979 and 1980. Soil water measured at 30 cm in the control (C) and in the ponding dikes (D).*

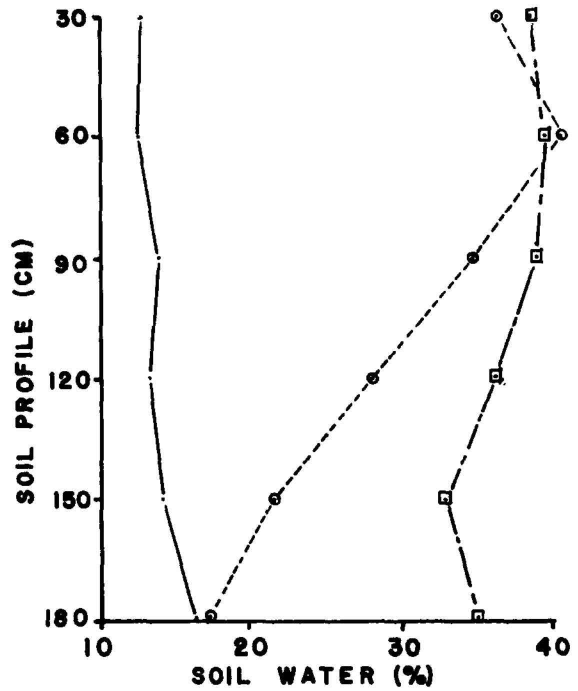

Fig. 3. *Soil water profiles for the control, 7.5-cm, and 15-cm water ponding dikes for July 31, 1979.*

38.3 mm occurring from a single event on August 12, 1977.

Twenty years of rainfall records for June through September were examined to determine the number of years that ponding water by a dike system would be successful. These data showed that the least number of ponding events that occurred in any one year was 6. From the data collected on soil water it was determined that 6 ponding events would supply an adequate amount of water for wetting the soil profile to below the plant rooting zone.

The soil water data collected within the ponding area indicated that soil water was not limiting to plant growth at or below the 20 cm depth in the ponding areas (Tromble and Gibbens 1977). The length of dryness of the soil surface within the ponding areas is regulated by the frequency and intensity of rainfall events.

Rainfall distribution and amounts from events greater than 5 mm are shown in Figure 2 for June through October of 1979 and 1980 for the 7.5- and 15-cm water ponding study sites. Soil water for the 30-cm depth is also shown for the same period. There were approximately twice the number of events occurring in 1979 as in 1980 and 2 of the events were of much greater magnitude than any of those occurring in 1980. These events appear to be reflected in the increase in soil water in 1979 when comparing the 1979 and 1980 data for the water ponding dikes. In 1979 soil water content was much greater in the dikes than in the control. There was a decrease in soil water content for October 1979 at both study sites, possibly a function of no ponding events occurring after the middle of September. The summer rainfall for 1980 was later than normal with the first runon events occurring in August. Figure 2 shows a decrease in soil water during June and into July for both study sites. There is a slight increase occurring the latter part of July caused by low rainfall (<5 mm) with greater increase in soil water following the ponding event of August 10 for the 7.5-cm dikes. Essentially no response in soil water was noted for the 15-cm dikes until September when rainfall occurred.

Measurements taken on the control areas show these areas to be low in available soil water even immediately following precipitation events. Soil water content on the control sites remained relatively constant through the summer thunderstorm period averaging about 13.5%.

Soil water measurements were taken orthogonal to the dikes. This provided an opportunity to examine the effects of water ponding at different depths on the soil water profile. The soil water profile is shown in Figure 3 for the different water ponding depths. The soil profile for the control was uniformly dry throughout when compared to the 7.5- and 15-cm treatments. The 7.5-cm treatment showed increased amounts of soil water in the profile, but with a gradual decrease occurring below 60-cm and approaching the water content of the control at 180 cm. The soil profile was moist throughout the measured depth for the 15-cm treatment. This would indicate that ponding water between the depths of 7.5- to 15-cm should provide adequate soil water for the growth of forage grasses.

An important factor limiting forage production on semiarid rangeland is lack of available soil water. Increasing the soil water content through the use of water ponding dikes on shallow slopes may be a feasible means for supplying additional soil water to low producing marginal rangelands.

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