Conservation Bench Terraces in Eastern Colorado

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PRIMARY crops in the west-central region of the Great Plains are winter wheat and grasslands, with some row crops for forage production. Optimum yields of these crops are limited by unfavorable distribution of annual precipitation and droughts. Fallowing is used to assure production of most crops. In recent years fallowing efficiency in the storage of soil water has averaged 28 to 34 percent (2)*.

Land-forming techniques have been developed to control erosion, improve water distribution and supplement storage in dryland areas. The level bench terraces has generated considerable interest in recent years. This system employs a leveled contour bench and ridge to control erosion and to spread and store surface runoff from a sloping area. Level bench terraces were first evaluated by Zingg and Hauser at Bushland, Texas in 1955 (8). Hauser and Cox reported that annual grain sorghum yields in level benches were increased 250 lb per acre where 1.1 in. of extra water was stored, and 1590 lb per acre where 2.3 in. of extra water was stored (4). Level bench terraces at Mandan, N.D., increased water storage and wheat yields (3). However, increases were noted only when the ratio of contributing to level bench area was greater than 1:1.

Optimum spacing of bench terraces is an important design factor. The Nebraska SCS uses a modified version of Ramser's formula to determine the spacing of their flat-channel terraces, which are similar to level bench terraces (1). The formula is dependent on the slope of the land and allows approximately 20 percent of the horizontal interval to consist of the flat channel or bench. Flat channel terraces are widely used; however, little information is available on their effect on crop yields.

Research was initiated at Akron, Colo., on conservation bench terraces in 1958. Experimental objectives were to determine: (a) optimum ratio of contributing to level bench area on silt loam soils, (b) runoff from two cropping systems on the contributing area and (c) the relationship between available water supplies and crop yields.

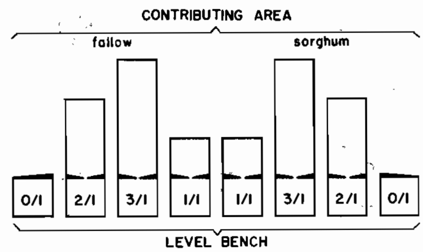

FIG. 1 Plot layout of conservation bench terrace at Akron, Colo.

Procedure

A level bench 100 ft wide and 1,000 ft long, was constructed on Rago silt loam on 1 percent slopes. The soil consists of 4 to 8 in. of silt loam at the surface and grades into a clay loam which varies from 12 to 20 in. in thickness. The layer merges downward into a pale yellow silt, the lime carbonate layer, several inches thick, and then into an unaltered parent loess that extends downward 4 to 20 ft or more. This soil constitutes one of the more productive soils in the area and can produce a wide diversification of crops when sufficient water is available (5).

The benched area had a broad terrace ridge 12 to 15 in. high as the downslope boundary and was divided into eight smaller plots, 100 ft square. Each plot was bounded at the sides with 6-in. dikes and separated by 20-ft borders. The sloping area above the bench was likewise divided into 100-ft strips with lengths to provide 0, 1, 2 and 3 times the area of the bench. The plot layout of the conservation bench terraces is shown in Fig. 1.

All benches were planted annually to grain sorghum. Sorghum and fallow were established concurrently on half of the contributing area and alternated every other year. Production in the benches was compared with that following fallow on the contributing area.

Nitrogen fertilizer was first applied in 1961 on the benches and each year thereafter at the rate of 50 lb per acre. Sorghum following fallow was not fertilized.

FW-1 waterstage recorders and 1.5-ft H-type flumes were installed on all contributing areas in 1963. The previous years runoff was measured only from slopes above the level check. Runoff for 1963 and 1964 was used to estimate runoff from all plots in 1960-62. Precipitation was measured from a weighing recording rain gage.

Available soil water was determined gravimetrically by sampling at 1-ft increments to a depth of 5 ft at seeding and harvest times. Samples were taken on 4 sites, 25 ft from plot borders, in the benches and every 100 ft up slopes through the middle of each contributing area.

Experimental Results

Precipitation and Runoff

Monthly distribution of annual precipitation for the 58-yr period and years 1960 to 1964 is shown in Fig. 2. Annual distribution of runoff is also shown for the period of actual measurement.

The average annual precipitation for the period of 1908 to 1966 at Akron, Colo., is 16.7 in. About 60 percent of the annual total occurs in May through August. From 1960 to 1964 annual precipitation averaged 13.3 in. All months except June and August had precipitation total below normal. Deficits were greatest during late fall through early spring.

The average annual runoff from the years 1960 to 1964 was 1.2 in. with more than 90 percent of this amount occurring in May through August. No snowmelt runoff occurred during the period of measurement; such runoff occurs only in years when soil is frozen before snowfall.

Annual runoff from various lengths of slopes in fallow and contoured sorghum is summarized in Table 1. Runoff from fallow averaged almost 0.6 in. greater annually than that from sorghum, and runoff decreased with increasing length of slope.

Soil Water Storage

Benches with the fallow contributing areas gained 4.1 in. of stored soil water, compared with 3.5 in. in benches with sorghum contributing areas. (Table 2). This difference was attributed to the greater amounts of runoff from the fallowed contributing areas in years when it occurred before planting. Runoff during the storage period before sorghum planting resulted solely from rainfall in May of 1962 and 1965. In years of no runoff, the increase was due to snow which drifted from the contributing area, which was fallowed the previous summer, and accumulated in stubble on the benches.

Soil water storage in the bench was

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* Numbers in parentheses refer to the appended references.

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TABLE 1. ANNUAL PRECIPITATION AND RUNOFF FROM SORGHUM AND FALLOW CONTRIBUTING AREAS OF 100, 200 AND 300 FEET IN LENGTH (1960-1964)

Year	Annual precipitation, inches*	Annual runoff, inches — Length of contributing area, feet 100	200	300	Mean runoff, inches
		Fallow contributing area			
1960	10.48	0.00	0.00	0.00	0.00
1961	13.72	2.91	2.55	2.30	2.49
1962	16.34	3.30	2.90	2.62	2.83
1963	14.94	0.78	0.84	0.61	0.72
1964	11.14	1.45	1.14	1.25	1.25
Fallow mean	13.32	1.69	1.49	1.36	1.46
		Sorghum contributing area			
1960		0.00	0.00	0.00	0.00
1961		1.07	0.99	0.74	0.88
1962		2.67	2.48	1.87	2.21
1963		0.93	0.51	0.39	0.52
1964		0.83	1.09	0.66	0.83
Sorghum mean		1.10	1.01	0.73	0.89

* Normal precipitation for the area is 16.7 in. (58-yr mean).

not affected by the length of contributing area above. The expected difference due to runoff was apparently offset by the amount of snow trapped in the benches.

Fallow on the contributing area gained 4.4 in. of available water compared with 3.8 in. in the benches; however, the storage period on fallow land was 19 months versus 7 months for the benches. Approximately 65 percent of the total water stored on fallow was received during the first winter and 28 percent during the second winter. Only 7 percent of the precipitation was stored in the soil during the growing season. Fallow efficiency averaged 22 percent compared with 61.7 percent in the benches. Eight percent of the water losses on fallow resulted in runoff and 70 percent as evapotranspiration.

Benches without the contributing area stored as much soil water as those within the contributing area. This unexpected relationship was believed due because the level checks located on both ends of the benched area trapped more of the drifting snow than benches with contributing areas from winds at all angles except those normal to the slope.

Available soil water at seeding time was almost the same in the benches and on fallow. Although fallow plots stored more water, they generally had lower water content at the previous harvest time. The amount of soil water at planting time in the benches increased with increasing length of contributing area, but not significantly.

Growing Season Water Supplies and Yields

The effect of cropping systems and ratio of contributing to level bench area on total available water supplies during the growing season and grain sorghum yields are given in Table 3. Average dates for planting and harvesting were June 9 and October 31, respectively. Rainfall during this period averaged 7.3 in., which was about 1.5 in. below normal.

Benches with fallowed contributing areas had about 1.2 in. more available water than the benches with sorghum contributing area. However, yields averaged 260 lb less per acre on benches receiving the greater amounts of water. Rainfall and runoff were highest during June.

Benches with contributing areas of 100, 200 and 300 ft long, received 0.7, 1.3 and 1.7 in. of runoff, respectively, during the growing season (Table 3). Total water supplies increased with increasing length of slope. Grain sorghum yields on the benches were highest when the contributing areas were 200 ft long. The depressed yields in benches with contributing areas 300 ft long were not due to excess total water for the growing season (6, 7). The extra water received immediately following planting was believed to have reduced yield potential on the benches having a 3:1 ratio.

Grain sorghum yields in benches with contributing areas were 295 pounds more per acre annually with 1 inch of extra water than that in benches without the contributing areas (Table 3). The yield increase over fallow was 400 lb per acre annually from 1.7 in. of extra water received in the benches. When yields in benches with runoff are compared with those on fallow over a 2-yr period, total production in benches receiving runoff was about 2790 lb per acre compared with 1000 lb per acre for sorghum on fallow and 2200 pounds per acre in benches without contributing areas.

Water-Use Efficiency

Benches in general were more efficient in water utilization than fallow (Fig. 3). Maximum efficiency of 125 lb per in. was obtained in benches with contributing areas 200 ft long. Reason for a reduced efficiency in benches with contributing area 300 ft in length was the same as that postulated for yields. Water use, as described, is the amount of grain produced per inch of water used during the growing season.

Effect of Cuts and Fills

Depths of cut varied from 0.4 to 0.7 ft in bench leveling. Fill in benches averaged 0.5 ft. Total volume of soil moved was almost 600 yards, which was 164 percent of the fill yardage to allow enough soil to construct the terrace ridge. Amount of soil moved per lineal foot of bench averaged 0.6 yard.

The effect of cut and fill on yields and available soil water at seeding is shown for the years 1961 through 1964 in Table 4. Sampling sites were approximately 25 ft in from the bench borders on the cut and fill sides. Crop yields on the cut side of bench in 1960, the first year following construction, was about one-half that on the fill side.

Nitrogen fertilizer was applied at 50 pounds N per acre in 1961 through 1964. With the exception of 1963, grain yields were higher in the fill area. However, the difference was reduced from 200 lb per acre in 1961 to 30 lb per acre in 1964. In 1963 rainfall and runoff did not occur until July and then at frequent intervals thereafter through September. The year was very favorable for grain sorghum production. Also in 1963, the benches were split in half by throwing up a 6-in. dike through the middle so that the ratio of contributing area to level bench area was increased from 1, 2 and 3:1 to 2, 4, and 6:1. In previous years it appeared the benches were not receiving enough runoff and that increasing the ratio

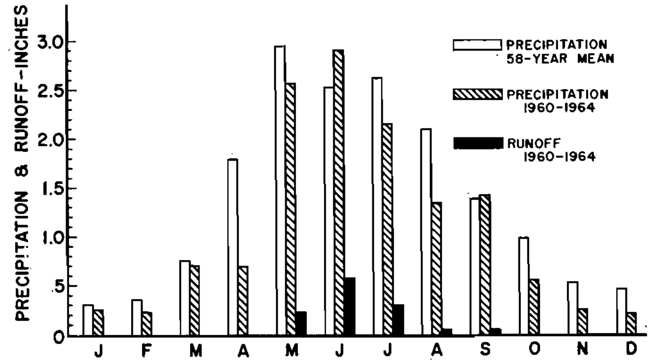

FIG. 2 Annual distribution of precipitation for a period of 58 years and for 1960-64, and runoff for 1960-64.

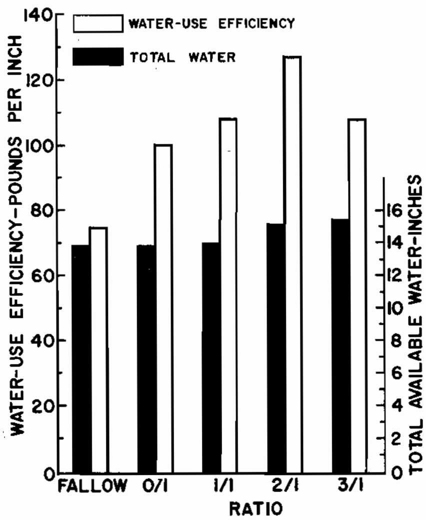

FIG. 3 Effect of contributing to level bench area ratio on water-use efficiency and total available water during the growing season, 1960-64.

TABLE 3. RUNOFF AND TOTAL AVAILABLE WATER (SOIL WATER AT SEEDING, RAINFALL AND RUNOFF) DURING THE GROWING SEASON AND GRAIN SORGHUM YIELDS IN LEVEL BENCHES AND CONTRIBUTING AREAS (1960-1964)

Treatment	Runoff, inches*	Total available water, inches†	Grain yield, pounds per acre‡
Bench—fallow contributing	1.57	15.44	1266
Bench—sorghum contributing	0.92	14.21	1526
Bench—100-ft contributing	0.74	14.01	1258
Bench—200-ft contributing	1.33	15.06	1569
Bench—300-ft contributing	1.66	15.40	1361
Bench—receiving runoff	1.24	14.82	1396
Bench—level check	0.00	13.88	1101
Fallow—contributing area	−0.46	13.13	996
1963 results when benches were reduced to half their original width:			
Bench—100-ft contributing	1.52	16.71	2218
Bench—200-ft contributing	2.72	17.99	2542
Bench—300-ft contributing	3.02	19.33	2862

* Amount of water received as surface runoff in the level benches and lost from the contributing area above during the growing season between seeding and harvest times.
† Available soil water at seeding, runoff and precipitation which averaged 7.28 in. during the growing season.
‡ Grain yield at 12.5 percent moisture content.

would provide more water. The effect of increasing this ratio on available water supplies and crop yields in 1963 is shown in Table 3. Sorghum was well established in 1963 before any runoff occurred. Maximum yields and water supplies were obtained in benches with contributing areas 300 ft in length or in the ratio of 6:1.

Soil water at seeding was 0.5 to 0.8 in. greater on the cut side of bench each year except in 1962 (Table 4). The difference was attributed to the small amount of runoff not sufficient to flood the entire bench and to the snow trapped on the upper side of bench over winter.

Although some yield reduction occurred when removing 5 to 8 in. of top soil, the fertility was not seriously affected until depth of cut reached 8 in., when not only fertility became deficient, but structural characteristics of the clay-loam horizon also inhibited plant growth unless water was adequate. Fertilizer was applied annually to obtain optimum yields when water was available and had partially restored that lost in earth moving.

Discussion

Level-bench terraces in eastern Colorado have increased soil water storage enough to produce higher yields than that grown on fallowed land. They are an improvement over the conventional ridge terrace because water is distributed over a larger area and they can be designed to provide storage for higher intensity storms. Level-bench terraces are as effective as conventional ridge terraces in controlling erosion.

Three factors should be considered before construction of level-bench terraces. First, the soil should be deep enough to provide adequate storage. Yields are also not as adversely affected by cutting if soils are relatively deep. Second, bench-terracing slopes much greater than 50 percent will make costs prohibitive and reduce bench widths to a point that they will be impractical to farm. Third, the spacing or length of contributing area between terraces depends on soil type and runoff expected in a particular area and, to a lesser extent, the type of crops grown. Most hardland soils in the Akron area lend themselves very well to level-bench terraces.

Results from this experiment were based on one slope (1 percent), one soil type (Rago silt loam) and one crop (grain sorghum). The data showed over a 5-yr period that a contributing area twice the width of the bench resulted in maximum grain yields and water-use efficiency as compared to spacings of 100 or 300 ft between benches. It appeared that total dry matter production would have been a better criterion than grain yield for evaluating the bench terracing system because yield potential of most grains in this area is frequently affected by drought, short growing season, and hail. Some dry matter was produced every year in spite of the severity of various climatic hazards.

Leveling precision is essential to obtain uniform water distribution and facilitate complete drainage if the need arises. Land smoothing may be required once or twice following construction to compensate for soil settling on fill areas. Observations from other leveled sites at this station have indicated some crop drowning in minor depressions caused by soil settlement in fill areas in spite of efforts to provide complete drainage. In these instances, leveling with uniform grades of 0.5 percent or less has reduced chances for crop drowning by providing faster drainage.

Farming the level benches is not a problem when they are constructed with uniform width throughout their length. Some adjustments can be made in bench widths to accommodate farm implements. Farming problems are encountered on sloping areas between benches when topography does not lend itself to parallel construction. However, part of the difficulty can be eliminated by growing crops that require minimum cultivation during the growing season.

Leveling costs per actual leveled acre have averaged about $100. Therefore, if an entire area were bench-leveled without contributing areas, construction costs for each bench 100 ft wide would be about 23 cents per lineal foot. If benches were constructed every 100 ft

TABLE 2. RUNOFF AND WATER STORED IN 5 FEET OF SOIL FROM HARVEST TO SEEDING TIME FOR GRAIN SORGHUM IN LEVEL BENCHES AND FALLOWED CONTRIBUTING AREAS (1960-1964)

Treatments	Runoff inches*	Water stored, inches	Stored efficiency, percent†	Available soil water, inches‡
Bench—fallow contributing	1.33	4.08	66.7	6.59
Bench—sorghum contributing	0.86	3.53	57.7	6.01
Bench—100-ft contributing	0.65	3.82	62.4	5.99
Bench—200-ft contributing	1.17	3.85	62.9	6.45
Bench—300-ft contributing	1.47	3.74	61.1	6.46
Bench—receiving runoff	1.10	3.80	62.1	6.30
Bench—level check	0.00	3.76	61.4	6.60
Fallow—contributing area	−1.64	4.36	22.1	6.31

* Amount of water received as surface runoff in the level benches and lost from the contributing area above during the period of storage between harvest and seeding times.
† Average precipitation during period of storage was 19.7 in. for 19 months of fallow and 6.1 in. for 7 months on benches.
‡ Available soil water in top 5 ft of profile at seeding time.

TABLE 4. EFFECT OF CUT-AND-FILL ON GRAIN SORGHUM YIELD AND AVAILABLE SOIL WATER AT SEEDING (1961-1964)

Bench location	Years 1961	1962	1963	1964
Grain sorghum yield, pounds per acre				
Cut	1071	1655	2382	1292
Fill	1274	1765	1420	1321
Soil water at seeding, inches†				
Cut	5.88	7.91	4.15	7.38
Fill	5.36	9.04	3.37	6.50

* Grain yield at 12.5 percent moisture content.
† Available soil water to a depth of 5 ft.

or with a ratio of contributing area to level bench area of 1:1, costs would be reduced to 11 cents per lineal foot and would decrease with increased spacing between benches. Costs would increase with construction on steeper slopes.

Increased production on level benches on an annual basis over that on fallow every two years could pay for level-bench construction within ten years if precipitation were normal.

Summary

Conservation bench terraces in eastern Colorado have increased water supplies 0.7 to 1.7 in. more than that in fallow during a period of below normal precipitation. Water storage in benches during 7 months over winter was almost the same as storage in fallow over 19 months. Annual grain sorghum yields in benches receiving runoff were 400 lb more per acre than biannual yields on fallow.

Maximum production of grain sorghum was obtained on ratios of contributing to level bench areas of 2:1. More research is needed to determine response by other crops and the effect of sandy soils in the conservation bench system.

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