Runoff Water-Spreading On Leveled Cropland

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Storm runoff is a potential source of additional moisture for crop production in the dryland areas of the high plains located in the west central part of the Great Plains. This article describes a level pan system constructed in broad natural drainageways to intercept, spread, and store such storm runoff. It also sets forth information about the response of different crops to the 4 to 7 inches of additional moisture available in 1962 in the level pans.

PRECIPITATION in the high plains area of the west central Great Plains is highly variable and inadequate for annual crop production. Normal annual precipitation is slightly less than 17 inches and about 60 percent of this occurs during the intense rainstorms that take place from May through August.

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Approximately 30 to 35 percent of the precipitation during the growing season is available for use by crops (*4*). Of the remainder, 60 to 65 percent is lost in evaporation and 5 to 10 percent is lost in the form of runoff. However, storm runoff can be collected, spread over leveled dryland areas, and used for crop production.

Several water-spreading practices have been developed for retaining and utilizing runoff. In early research at Spur, Texas, Dickson, Langley, and Fisher (*2*) used large level terraces in a syrup-pan, spread-and-spill system across a flat valley. This design forced runoff to cross and recross the field several times before it was discharged into a natural drainageway. Later work by Burnett and Fisher (*1*) at the Spur, Texas, location revealed that land leveled for uniform moisture distribution exhibited a 24 percent increase in crop yield. Leveled areas with contributing areas of the same size exhibited increases in crop production of 50 percent. The Zingg conservation bench terrace recently was developed to conserve moisture by distributing and storing runoff received from a contributing area above the bench (*3, 6*).

A system for diverting waste runoff from agricultural watersheds to leveled areas for spreading and storage on cropland has been developed at the Central Great Plains Field Station near Akron, Colorado. The primary objectives of this experimental work are (a) to evaluate the automatic water-spreading system for utilizing watershed runoff, (b) to collect information on the ratio of size of watershed to leveled area, and (c) to evaluate the performance of different annual crops under the conditions of intermittent flooding on the leveled water-storage areas.

Characteristics of Runoff

In the central high plains, runoff-producing storms vary in number from none during some years to as many as 10 or more during years of high rainfall. One or more runoff events can be expected in 3 out of 5 years. On the average, between four and five storms produce 0.1 inch or more of runoff each year.

Annual runoff, estimated from rainfall according to procedures outlined in the hydrology section of the Soil Conservation Service's National Engineering Handbook, is about 1.5 inches for the central high

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plains area. Rainfall-runoff correlations on 5 years of measurements from half-acre watersheds at Akron, Colorado, indicate average annual runoff is about 2 inches. Approximately 20 percent of the annual runoff comes from storms yielding less than 0.1 inch of runoff. During a normal rainfall year, 50 to 60 percent of the runoff may come from one to two storms having 60-minute intensities of 1 or more inches per hour. Snowmelt runoff is not an annual occurrence and represents a small part of potential runoff.

Runoff in the central high plains accumulates in broad, natural drainageways in the upper reaches of the watershed. These drainageways frequently are 500 to 1000 feet wide and have slopes that range from slightly more than 0 to 3 percent. Such areas have deep productive soils well suited for leveling in small tracts designed to intercept, spread and retain the runoff normally flowing through the channels.

The basic principle of the water-spreading technique is illustrated in figure 1. Small volumes of runoff from a relatively large area can provide a significant amount of water when concentrated on a relatively small leveled area. For example, if 0.1 inch runoff from a 100-acre watershed were concentrated on a leveled area of 5 acres, the leveled area would receive 2 inches of water.

Water Spreading Versus Summer Fallow

Summer fallow generally is necessary for successful dryland farming in the central high plains. Moisture storage efficiencies for an 18-to-21-month fallow period can vary from 20 to 30 percent, which means that from 3 to 5 inches of moisture are conserved annually through fallowing. Most of the precipitation during the fallow period is lost through evaporation and some is lost in the form of runoff.

Unlike fallowing, the level pan spreading system permits annual cropping on the limited level areas. The spreader system conserves more water than fallowing because it eliminates the fallow period with its high evaportion losses, utilizes otherwise wasted runoff from contributing watersheds, promotes better distribution of rainfall, and minimizes runoff losses from the leveled area. With the spreader system, tillage operations usually necessary on fallowed areas are eliminated.

Water Spreading System Constructed

In 1958-1959, construction was started on a series of five level pans in a broad natural drain. These pans, designed to intercept, spread and retain the runoff that flowed through the natural drainageway, ranged in size from 2.5 to 6.6 acres. The total area leveled was 21 acres and the potential contributing area was 490 acres.

The pans were constructed with scrapers and track-type tractors and were smoothed with land planes. The volume of earth moved averaged 360 yards per acre, with maximum cuts of 2.2 feet and maximum fills of 1.7 feet. Less than 5 percent of the total area leveled was subjected to this excessive cutting and filling. All pans were diked to retain runoff. Diversion structures were constructed to funnel all runoff through flumes equipped with recorders to measure the actual quantities that flowed from the watersheds into individual leveled pans. The pans were constructed to allow runoff in excess of a predetermined depth to flow on through one pan to the next pan at a lower elevation.

As is shown graphically in figure 2, potential runoff from about 356 acres of mixed crop watershed is diverted to the first leveled pan. Runoff that accumulates in this pan in excess of a depth of 4

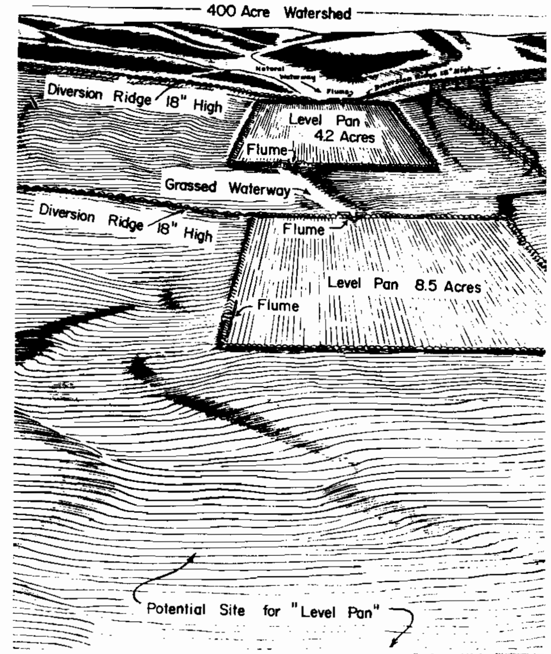

Figure 1. Schematic illustration of the use of level pans to intercept and store runoff.

inches spills over into a grassed waterway leading to pan 2, which also receives runoff from an additional 36 acres. An automatic shutoff gate operated by a float is located at the entrance to pan 2. When 4 to 5 inches of water are impounded in the pan, the float trips the gate to close off the water supply and the runoff is diverted to pan 4. This pan receives runoff from an additional 62 acres of watershed. Any runoff impounded in pan 4 in excess of a depth of 4 inches flows through a flume to pan 5. The excess water from pan 4 is the only source of supplemental runoff to pan 5. Pan 3 receives its runoff through a diversion canal from a separate watershed of 35 acres.

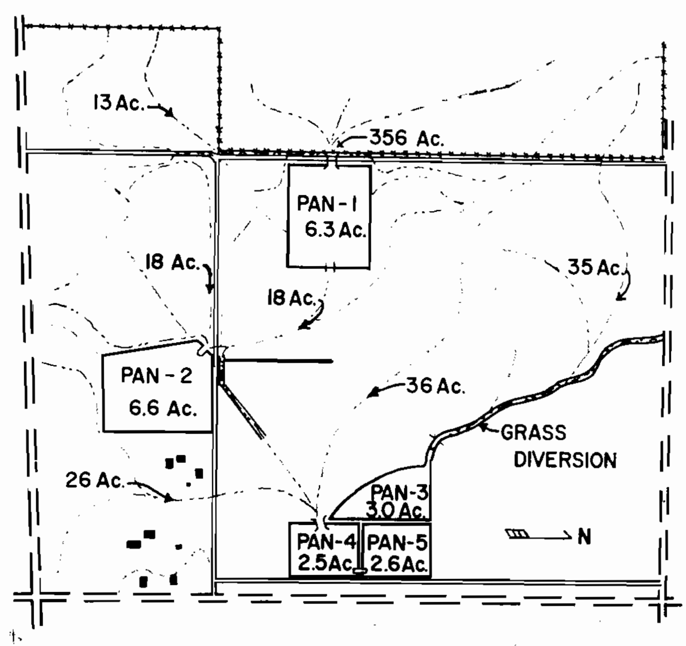

Figure 2. (Left) Diagram of the level pans and portions of the contributing watersheds contained in the runoff diversion and water spreading facilities at the Central Great Plains Field Station near Akron, Colorado.

Figure 3. (Below) Snowmelt runoff, though it seldom occurs more often than once in 3 years, is a potential source of additional moisture for crop production in moisture-deficient areas. Pan 1 is shown here as it appeared after receiving snowmelt runoff in 1960.

The ratio of watershed area to level pan area varies from 55:1 to 5:1 for individual pans. The four leveled pans that lie within the main drainage system have a combined watershed area to level pan area ratio of 25:1. Pan 3 has a contributing area-leveled area ratio of approximately 10:1.

The soil-cover condition of the contributing watershed varies from year to year; it is influenced primarily by the acreage devoted to wheat, sorghum, and fallow on this privately owned land. Watershed slopes range from 1 to 8 percent and portions of them are capable of high detention storage.

Description of Soils

Soils on the leveled areas are representative of the region's predominantly brown, well drained upland soils (*5*). During dry periods, these soils become extremely hard —a condition that retards the movement of air, water, and crop roots through them. However, when moist, the soils are friable and have a high to moderate capacity to absorb and retain moisture.

Goshen, Sligo, Rago, Weld, and Platner loams are the soils that occur on the level pans. The Goshen and Sligo loams are typical of the soils in the slightly concave upland portions of the drainageway. Well drained, these soils developed either in a thin loess overlying a Paleosol or in locally transported parent materials derived largely from aeolian sources.

To a depth of 18 inches the Goshen soils consist of dark grayish brown loam. Below 18 inches and to a depth of 48 inches they consist of fine to coarse clay loam, which grades into fine sandy loam at a depth of 5 feet. Shallower than the Goshen soils, the Sligo soils consist of loam to a depth of 6 inches. From 6 to 28 inches they are composed of fine to coarse clay loam. At a depth of 28 inches, sandy clay loam and sandy loam begin to appear in the Sligo profile. Both the Sligo and Goshen soils are well suited for leveling.

The Weld and Rago soils generally begin along the edges of the drainageway and continue up the slopes; the Rago soils occur at higher elevations than the Weld soils. Both soils have a 6-inch deep A horizon of loam, which grades into clay loam in the B horizon. The B horizon is 10 to 14 inches deep in the Weld soils and 30 inches deep in the Rago soils. Below the B horizon in both soils are sandy loams that are deficient in nitrogen and some minor elements. These sandy loams frequently are exposed in leveling Weld soils when cuts are greater than 1.5 to 2.5 feet.

The Platner soils generally are shallower and less productive than the other soils. They require more care if the maximum amount of moisture is to be conserved. Among the predominant soils in the area, Platner occurs on the steeper slopes and has an irregular surface. It has a shallow loam A horizon that grades into clay loam at a depth of 12 inches. Unlike other soils, it is not uncommon for Platner to have sand and water-worn granite pebbles intermixed with it in many places, especially below the 12-inch depth. In isolated areas, Platner soils are underlain by coarse sand and gravelly material at a depth of 2.5 to 3 feet. These areas should not be leveled for they have low water-holding capacities and are not suitable for growing many crops.

Cropping of Leveled Areas

After they were completed in 1960, the level pans were cropped every year. Grain and forage sorghum, millet, hybrid sudan, and alfalfa were grown in the individual pans. All crops except alfalfa were fertilized at the rate of 40-60 pounds of nitrogen per acre. In order to evaluate the effects of the additional moisture in the level pans, small check strips were established on adjacent nonleveled areas in 1962. Cropped each year, the check strips were subjected to the same cultural practices as the leveled areas.

Available Moisture

Only the findings for the crop year 1962 are reported in this article. During 1962, rainfall was near normal and for the first time runoff was received by four of the five leveled pans.

The moisture in the top 5 feet of soil on each pan and on each check strip was measured at seeding time and again at harvest. Data on the available moisture at seeding time, growing season rainfall, and amount of runoff received by the leveled pans are given in table 1 along with comparable information about the corresponding check strips. The amounts of rainfall and runoff given in table 1 are for the period between planting and harvest of the different crops grown on the individual pans. Runoff lost from the check areas was estimated on the basis of average runoff from the contributing watershed above pan 1.

At seeding time, there was from 1 to 3.5 inches more water in the profiles of three of the pans than there was in the profiles of the corresponding check strips. No check area was established for alfalfa (pan 2) or for sudan (pan 5). Soil moisture under the alfalfa on pan 2 was measured in April; because of abnormally low precipitation prior to the time of sampling, there was very little moisture in the soil profile. With the exception of pan 5, all pans received runoff as a result of the above-normal rainfall during May and the first week in June; this was prior to the measurement of initial soil moisture on pans 1, 3, 4 and 5.

In some years, part of the water stored in the soil profile comes from snowmelt runoff. Figure 3 shows snowmelt runoff spread uniformly over pan 1 in the spring of 1960. Such an event, however, may occur only once in 3 years.

During 1962, growing season runoff supplied 1 to 2.7 inches of supplemental water on four of the five level pans. Impounded runoff in pan 4 was never sufficient to overflow into pan 5. Total available moisture was 4 to 7 inches greater on pans 1, 3, and 4 than on the corresponding check areas.

Pan 1 was flooded once and pan 4 was flooded twice with an inch or more of water from runoff in 1962. Each of five storms yielded runoff that supplied more than 0.1 inch of supplemental water to

TABLE 1. Moisture Available During the 1962 Growing Season On Leveled Pans and On Unleveled Check Strips

Pan Number	*Initial Soil Moisture*[a]	*Rainfall*[b]	*Collected Runoff*[c]	*Total Available Moisture During Growing Season*
	inches	*inches*	*inches*	*inches*
1	8.76	6.92	2.72	18.40
Check	5.46	6.92	−0.77	11.61
3	7.87	4.83	0.98	13.68
Check	4.36	4.83	−0.77	8.42
4	7.53	6.32	2.57	16.42
Check	6.63	6.32	−0.77	12.18
5	4.78	4.84	0.00	9.62
2	2.30	11.46	1.42	15.18

[a] In the top 5 feet of the soil profile. [b] During the growing season of the specific crop on the pan. [c] Water lost in the form of runoff from check areas was estimated on the basis of runoff recorded from the watershed above pan 1.

TABLE 2. Yields and Water-Use Efficiencies of Crops Grown During 1962 On Leveled Pans and On Unleveled Check Strips

Pan Number	*Crop*	*Water-Use*	*Yield*[a]	*Water-Use Efficiency*
		inches	*per acre*	*lbs./acre inch*
1	Grain sorghum	15.66	43.8 bu.	157
Check	(RS-610)	10.05	0.0	000
1	Sorghum residue	15.66	3.14 tons	401
Check	(RS-610)	10.05	1.30 tons	259
3	Siberian millet	6.53	1.86 tons	570
Check		7.50	1.23 tons	328
4	Forage sorghum	13.79	6.38 tons	925
Check	(FS-22)	10.63	2.58 tons	486
5	Hybrid sudan	6.82	2.63 tons	771
2	Ranger alfalfa			
	1st cutting	6.02	1.16 tons	385
	2nd cutting	8.68	.66 tons	152

[a] Grain yield determined at 12.5 percent moisture content; forage yields determined as oven-dry weights.

some of the leveled pans. The impounded water usually infiltrated into the soil within 24 to 36 hours after each storm. Frequent storms resulting in runoff in early June delayed the seeding of sorghum a week to 10 days. Extremely wet conditions delayed sorghum growth and maturity 6 to 8 days on parts of the leveled areas.

Crop Yields

The increased supplies of moisture on the leveled pans had a significant effect on crop yields and water-use efficiencies. Data on the yields of the various crops, total water use, and water-use efficiencies of crops on the individual pans and check areas are given in table 2. The yields reported in table 2 are averages from 15 to 18 sub-samples collected in each pan at the same sites as those at which the soil moisture samples were taken. In all cases, crop yields were substantially higher on the leveled pans than on the corresponding check areas, and the crops on the pans were nearly twice as efficient as those on the checks in utilizing the available moisture.

The difference between pan 1 and the check of 6.8 inches of total moisture available during the growing season effected a difference of 43.8 bushels per acre in yield of grain sorghum. The grain sorghum on the check area exhibited some vegetative growth but drought late in the season prevented the crop from maturing. Analysis of residue samples collected from the sites on which grain samples were taken revealed that the additional 6.8 inches of available moisture on pan 1 produced an amount of residue more than double that produced on the check.

The low yield of the alfalfa on pan 2 was attributed to lack of initial moisture and supplemental runoff. The pan was not entirely level, which precluded uniform spreading of rainfall and runoff, and there was a great deal of variation in the size and number of plants on various areas of the pan.

The yield of millet hay was increased 0.63 tons per acre by the 5.2 inches of additional moisture available on pan 3. Forage sorghum exhibited the greatest response to an increase in the supply of moisture. Oven-dry forage yield was increased 3.8 tons per acre by the 4.2 inches of additional water received on pan 4. The green ensilage yield was 20 tons per acre while the yield from the unleveled check area was only 6.7 tons per acre.

Because of moisture stresses and possible nutrient deficiencies on the cut areas, the stand of hybrid sudan on pan 5 was not uniform. The pan received no supplemental runoff in 1962. Although the initial soil moisture in pan 5 was considerably lower than that in pan 3, the yield per acre and the pounds of dry matter produced per inch of water used were greater on pan 5 with sudan than they were on pan 3 with millet.

Yield reductions due to cuts and fills were noted during the first 2 years of cropping. However, the annual applications of nitrogen fertilizer have diminished the yield depressing effects of the cuts and fills.

Deviations from level, due to the settling of fill areas, affected moisture storage and yields. It was necessary to smooth the pans with a land plane every 2 years. Sediment deposition was not a problem.

Conclusions and Cost Information

Runoff water-spreading on leveled cropland has shown considerable potential as a moisture conservation practice. The retention and uniform distribution of rainfall alone have especially beneficial results in moisture-deficient regions. During 1962, supplemental runoff resulted in crop yields on the pans being nearly double those on the unleveled check areas.

Dryland leveling costs ranged from $90 to $100 per acre on areas recently leveled by a local contractor. In some cases, these costs included the amount charged for construction of the dikes. With the increases in crop yields that were attained in 1962 on the level pans described in this article, it may be possible to repay construction costs for a water-spreading system within a period of 3 to 5 years. Of course, the yield increases obtained with such a system depend on the amount and the time of occurrence of annual rainfall.

Summary

A runoff water-spreading system involving land-forming to conserve moisture for annual crop production has been developed at the Central Great Plains Field Station near Akron, Colorado. The system consists of level pans constructed in broad natural drainageways to intercept, spread, and retain runoff normally flowing through the waterways. In 1962, the spreader system provided 4 to 7 inches of additional available water on the leveled areas and this additional moisture effected substantial increases in crop yields. Due to the additional available amounts and uniform distribution of water, water-use efficiencies of crops on the leveled areas were double those of crops on unleveled check strips. The gross return from increased crop yields may pay for construction of level pans within a period of 3 to 5 years.

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