Level Pan Construction for Diverting and Spreading Runoff

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THE prevalence of extended droughts, unfavorable distribution of precipitation, high winds and hail are major problems of dryland agriculture in the west-central Great Plains. Approximately 60 to 70 percent of the annual precipitation is lost in evaporation and less than 5 percent in runoff. Success or failure in dryland agriculture is dependent on effectiveness of management practices used in conserving the precipitation that does occur.

Summer fallow is the common practice used to provide for water needs of crops on most farms. However, efficiency of water storage by this practice is relatively low. Various land-forming techniques have been developed to improve distribution and storage of precipitation on sloping cropland. The water-spreading technique utilizes flood runoff from natural watercourses for spreading on leveled or over inclined areas. Design criteria have been developed for flow and detention-type spreader systems (6)*.

Some of the earliest research on flow-type, water-spreading systems was conducted at Spur, Texas (2). This practice involved the use of dikes to force flood runoff from a water course to cross and recross land of ½ to 1 percent slope before draining back into the main channel. Results showed that 16 percent more water was stored than fell on the area, with a resultant two to three-fold increase in crop yields. In the detention-type spreader systems, runoff is diverted from a watercourse, spread over a sloping area from a spreader ditch, and impounded above a contoured dike. The system allows greater time for infiltration. Contour ridge terraces are a version of the detention-type system where water is intercepted, spread and stored in the channel above the ridge. However, stored water is not uniformly distributed over a large area in either system.

A detention-type spreading system with improved water distribution was developed by Burnett and Fisher (1). The level areas collected and stored runoff from a contributing area. Yields of cotton lint from the leveled land receiving runoff were increased 59 percent over those from adjacent unleveled areas. At Bushland, Texas, grain sorghum yields on contoured level benches receiving runoff from sloping areas were about 300 pounds per acre higher than those from a wheat-sorghum-fallow rotation on the contributing watershed (3).

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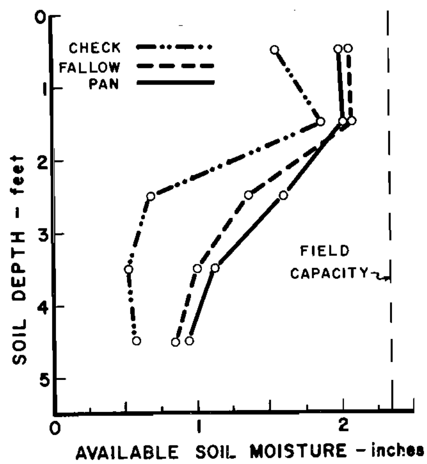

FIG. 1 Available soil moisture distribution to a depth of 5 ft at seeding time in level pans receiving runoff and in unlevel areas after 19 months of fallow and continuous cropping.

The spreader system used in the experiment described here was developed at Akron, Colorado, and involved leveled areas (pans) constructed in natural drainageways to intercept, spread and store the runoff that normally flowed through them (5). The experiment was initiated in 1958 to evaluate the economic feasibility of utilizing watershed runoff on dryland leveled areas for annual cropping, to study management problems, and to observe response of different crops to intermittent flooding. Crops tested were millet hay, hybrid sudan, alfalfa, grain and forage sorghums. Results reported in 1962 showed that yields of most crops tested in leveled pans were nearly doubled from the 4 to 7 in. of extra water received as compared with yields on the unleveled check areas.

TABLE 1. ACREAGE INVENTORY OF CONTRIBUTING WATERSHED AND PAN AREAS IN THE WATER-SPREADING SYSTEM

Pan No.	Pan size, acres	Watershed size, acres	Ratio
1	6.4	357.3	56/1
2	6.6	18.4	3/1
3	3.0	138.3	46/1
4	2.5	63.5	26/1
5*	2.8	......	......
Total	21.3	577.5	27/1

* Pan 5 has no contributing watershed, but receives excess runoff from pans 3 and 4.

Flume construction and instrumentation on all the pan areas were not completed until 1962. This paper presents results for three consecutive years of cropping grain and forage sorghums on two of the leveled pans. Crop yields and moisture data are compared with fallow and continuous cropping on unleveled dryland areas.

Procedure

The plains of eastern Colorado are dissected by broad natural waterways which provide good drainage to well-defined, intermittent streams. The waterways vary in width from 500 to 1000 ft, with slopes that vary from nearly level to about 3 percent. Within a waterway on the experiment station near Akron, Colo. a series of five level pans were each constructed to zero grade and smoothed with a land plane. Table 1 gives the size of pan areas leveled and the contributing watershed.

Each of the pans was equipped with Parshall or type H runoff flumes and FW-1 waterstage recorders at its upper and lower ends to measure inflow and outflow. Dikes were constructed around each pan to divert runoff through the flume from outside areas. A 6-in. plank

TABLE 2. ANNUAL AND MONTHLY PRECIPITATION AND RUNOFF DURING THE GROWING SEASON AT THE CENTRAL GREAT PLAINS FIELD STATION, AKRON, COLO.

Month	57-year mean*	1962		1963		1964	
	Rainfall, inches	Rainfall, inches	Runoff,† inches	Rainfall, inches	Runoff,† inches	Rainfall, inches	Runoff,† inches
May	2.94	5.08	0.04	1.01	0	2.23	Trace
June	2.41	4.83	0.08	2.08	Trace	3.97	0.40
July	2.67	2.80	0.07	2.91	0.07	0.71	Trace
August	2.08	0.84	0.01	3.75	0.15	1.47	Trace
September	1.37	0.49	......	3.23	0.03	0.13	0
October	0.97	0.29	......	0.70	Trace	0.16	0
Calendar year	16.65	16.29	0.20	15.96	0.25	12.27	0.40

* Runoff for years 1908 through 1961 is not available.
† Runoff measured from 23 contributing watershed ranging from ¼ to 357 acre in size. No runoff occurred during November through April.

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was installed above each outflow flume to impound 6 in. of water in the pan. Water in excess of this depth overflowed through the flume onto a pan at a lower elevation. Planks could be removed to drain the pan if water exceeded crop needs.

Grain and forage sorghums in pans 1 and 4, respectively, received 50 lb of nitrogen annually. Check areas were not fertilized. Unpublished research results at Akron have indicated that crops do not respond to nitrogen in hardland soils under dryland conditions.

Soil moisture was measured to a depth of 5 ft at seeding and harvest times. Rainfall was measured from a recording rain gage which was centrally located among all of the level pans.

RESULTS

Precipitation and Runoff

Annual and monthly precipitation and runoff during the growing season are shown in Table 2 for the long-term mean and the years of 1962 through 1964. Average annual precipitation for 1962 through 1964 was 1.81 in. below the 57-year mean of 16.65 in. Approximately 80 percent of the total precipitation occurred in April through August. Rainfall during this period usually originates from convective-type storms of short duration and high intensity.

Long-term runoff records are not available for this area. Runoff was measured from 23 watersheds and plots varying in size from ¼ acre to 357 acres. Annual runoff for the years reported herein averaged 0.3 in. All runoff occurred in May through October. None was observed from snowmelt which is evident only in certain years.

Stored Water

Available soil moisture in the top 5 ft at seeding time is summarized in Table 3, and distribution within the profile is shown in Fig. 1. About the same amount of available soil moisture was stored in the top 5 ft in the level pan after 7 months as was stored in fallow after 19 months. Available moisture content in unleveled continuously cropped areas was about half of that in level pans, with the greatest differences occuring in the third through the fifth foot. The increase in storage efficiency was due to the pans retaining all precipitation and runoff, whereas some moisture was lost in runoff from unleveled areas. Quantity of water stored also was affected by the amount of crop residue and its ability to trap blowing snow during the winter.

Amount of water stored in any year depended on the precipitation and runoff received during the storage period. In most years runoff does not occur before seeding time in June; however, in 1962 some runoff was measured in May. Precipitation during the first 5 months of 1963 was far below normal, but was above normal later in the season. As a result, much of the water stored in the pans in spring of 1964 was residual water which was surplus to crop needs the previous year.

Growing Season Moisture

Rainfall and runoff received in level pans and lost from unleveled areas during the growing season are shown in Table 4. Rainfall in 1962 through 1964 averaged about 2.2 and 1.5 in. below the long-term mean for the growing season of grain and forage sorghum, respectively. During the same period, pans received an extra 4 to 6 in. of water as impounded runoff.

Runoff from the unlevel check areas in continuous sorghum and after fallow was estimated by the method developed by the SCS hydrologists (7). Runoff losses from less than 1-acre areas on 1-percent slope in row crop were estimated at 1.2 to 1.5 inches annually over a 3-year period.

Total water supplies in level pans were more than 9.0 and 5.0 inches higher than those in unlevel areas in continuous cropping and fallow, respectively. The difference in available water between the level pans and unlevel fallow was due to differences in runoff received or lost during the growing season. The greater difference on areas of continuous cropping resulted from differences in runoff during the growing season and in amount of water stored at seeding time.

Crop Yield and Moisture Relationships:

Grain and forage sorghum yields are summarized in Table 5. The relationship with total water supplies is shown in Fig. 2. Grain sorghum yields from level pans averaged 2700 lb per acre annually. This was about 1500 lb more than that harvested from plots in fallow the previous year, and 2400 lb greater than yields obtained from continuous cropping on unleveled areas. Oven-dry forage yields from the leveled pan averaged almost 4 tons per acre which was 2.8 times greater than the yields from unleveled areas.

Crop yields were significantly related to the amounts of water stored at seeding time and received during the growing season. Fallowing increased yields

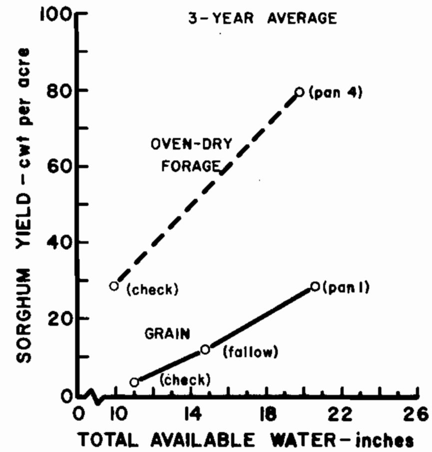

FIG. 2 Relationship between yields and total available moisture (initial soil moisture, growing-season rainfall and runoff) for forage and grain sorghum grown in level pans and in unlevel areas after 19 months of fallow and continuous cropping.

TABLE 3. AVAILABLE SOIL MOISTURE IN 5 FEET AT SEEDING FOR GRAIN AND FORAGE SORGHUM ON CONTINUOUS CROPPING IN LEVELED AND UNLEVELED AREAS AND ON FALLOW

	Available soil moisture, inches			
	1962	1963	1964	Mean
		Grain sorghum		
Continuous, not level	4.56	2.71	4.79	4.02
Fallow, not level	8.50	6.73	7.15	7.46
Continuous, level pan	8.76	5.48	9.06	7.77
Precipitation*	9.5	3.7	6.2	6.5
		Forage sorghum		
Continuous, not level	6.63	2.80	5.84	5.10
Continuous, level pan	7.53	5.81	8.79	7.38
Precipitation*	11.3	4.4	10.2	8.6

* Precipitation occurring between harvest and seeding times for grain sorghum (Nov. 1 to June 8) and forage sorghum (Sept. 5 to June 14).

TABLE 4. RUNOFF RECEIVED OR LOSS AND RAINFALL DURING GROWING SEASON OF GRAIN AND FORAGE SORGHUM

	Runoff received or lost, inches			
	1962	1963	1964	Mean
		Grain sorghum		
Continuous, not level	−0.8	−1.5	−2.3	−1.5
Fallow, not level	−0.6	−1.2	−1.8	−1.2
Continuous, level pan	2.1	6.1	4.8	4.3
Growing season rainfall,* inches	6.9	12.4	6.3	8.5
		Forage sorghum		
Continuous, not level	−0.7	−1.5	−1.9	−1.4
Continuous, level pan	2.6	6.2	9.8	6.2
Growing season rainfall,* inches	6.2	8.5	4.1	6.2

* Rainfall occurring between seeding and harvest for grain sorghum (June 8 to October 28) and forage sorghum (June 14 to September 7).

TABLE 5. GRAIN AND FORAGE SORGHUM YIELDS FROM LEVELED AREAS AND FROM UNLEVELED AREAS FOLLOWED AND CONTINUOUSLY CROPPED

Treatment	Crop yield, pounds per acre			
	1962	1963	1964	Mean
	Grain sorghum*			
Continuous, not level	358	297	370	308
Fallow, not level	1400	1372	773	1182
Continuous, level pan	2454	4051	1609	2705
	Forage sorghum†			
Continuous, not level	5162	1486	1922	2857
Continuous, level pan	12756	6350	4860	7989

* Grain sorghum yields at 12.5 percent moisture.
† Forage sorghum yields oven-dried at 70 degrees Centigrade.

230 lb per in. of water stored. Runoff into the pans increased yields 260 lb per in. Forage sorghum yields responded more significantly to the extra water supplies, with an average increase of 520 lb of forage per in. of water received. Pounds of dry-matter produced per in. of water used (water-use efficiency) increased with increasing water supplies.

Discussion

The level pans increased crop yields each year as a result of extra water supplies; however, the magnitude of the increase depended on timely distribution of rainfall. In 1963, most of the runoff-producing rains occurred during the period of maximum water use by the crops. The yields that year were the highest produced in the pans. In 1964, excessive water at seeding time made seedbed preparation difficult and delayed planting time a week to 10 days. When the crop was planted, severe crusting occurred, causing non-uniform emergence and survival.

Pans were flooded once or twice each year. The impounded runoff usually infiltrated the soil within 36 to 48 hr. Approximately 90 percent of the annual runoff resulted from one or two intense storms.

Runoff was sometimes heavily laden with sediments, but deposition within the pans was not a serious problem. Runoff approached most pans through grassed waterways at nonerosive velocities. Amount of runoff and sediment from any given storm depended on surface treatment of the contributing area.

Soils on sites where leveling is anticipated should be examined to determine their depth and water-holding capacities. Deep, medium to moderately fine-textured soils over moderately permeable subsoils are desired. Shallow or coarse-textured soils are less desirable because of their low water-holding capacities.

Soils in these level pan areas were the deep Goshen loams in the center of the natural waterways and the shallower Weld, Rago, and Platner loams and silt loams toward the edges of the main channel. These soils are friable when moist, but hard when dry, and have good water-holding capacities (4). They constitute most of the productive soils in this area and lend themselves to greater diversification of crops when water is available.

Nutrient deficiencies were evident on subsoils exposed by leveling in pans during the first two years of cropping. However, annual application of nitrogen fertilizer has restored the soil fertility to near its original level.

Costs of pan construction by contractor were estimated between $90 and $100 per acre, which included detention dikes at lower ends. These costs could be offset by the increased yield in 4 to 6 years of normal precipitation.

The level pans were large enough to permit use of ordinary farm equipment for all cultural operations. Approximately 5 percent of the land in this area is suitable for level pan construction. The inclusion of this type of spreader system in an overall farm program with livestock will give some insurance against complete crop failures in dryland areas in most years. It may also permit use of some crops that are not normally grown in the area.

Summary

Level pans constructed in broad natural waterways increased water supplies by intercepting and storing the runoff that normally flows through them. Pans have conserved and utilized the moisture more efficiently than fallow or annual cropping on unleveled areas. The additional water stored in the pans has been sufficient to permit annual cropping with increased yields. Data obtained to date indicates that return on the investment would be great enough to offset costs in 4 to 6 years of normal precipitation.

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