Lagoon leveling to permit annual cropping in semiarid areas

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ABSTRACT - Lagoon leveling converted a non- to low-productive area to a moderately productive area by providing more uniform distribution of impounded water over a larger surface area. Water supplies were adequate to permit annual cropping of forage crops in the leveled lagoon, and dry matter yields were increased 25 percent over those on unleveled dryland areas. A farmer can expect to recover an investment of $90 to $100 per acre in leveling costs within a period of 4 to 6 years, given normal rainfall and good management practices.

On the west-central Great Plains lie numerous irregularly shaped basins commonly referred to as lagoons, potholes, swales, or playas. These small depressions are usually 2 to 5 feet below the surrounding land and collectively comprise less than 1 percent of the region's total land area. They have no natural drainage outlets and intermittently become shallow ponds.

The lagoons on rangeland serve as natural livestock watering ponds during peak rainfall periods. On cropland, farmers often attempt to grow crops in the lagoons during dry periods. They are frequently forced to abandon the crops, however, because of flooding. Flooding is most common during May, June, and July, when nearly 50 percent of the annual precipitation normally occurs. Within the lagoons, small grain crops either grow so rank that they lodge or standing water prevents their being harvested at the proper time. In the case of row crops the lagoons are occasionally too wet to plant at the proper time or to permit timely cultivation.

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Various land forming or leveling practices improve the distribution and utilization of precipitation and runoff in some semiarid areas (*1*, *2*, *3*, *4*, *5*, *6*). In these areas cropping has been intensified and crop yields increased. Leveling lagoons to improve the distribution of impounded water should achieve similar results. Therefore, we undertook an evaluation of the effect of leveling on water storage and crop yields in a lagoon at the Central Great Plains Field Station near Akron, Colorado.

Methods

Leveling Prodecure

The original area of the lagoon, an elongated, bowl-shaped depression, was 2.1 acres. Water was usually impounded to a depth of 8 to 12 inches from one to three times a year. A 22.6-acre area in wheat and fallow contributed to the runoff.

An area three times the size of the lagoon was surveyed and staked on a 50-foot grid in October 1962 (Figure 1). The leveled area is 4.0 acres. Edges of the leveled lagoon were backsloped to about 5-percent grade. Soil removed in backsloping was uniformly distributed over the leveled area.

Nineteen hundred yards of earth were moved on the 4.0 acres, with a maximum cut and fill of 1.9 and 0.9 feet, respectively. Less than 15 percent of the area had cuts exceeding 1.5 feet (subsoil exposed). Leveling with a track-type tractor and scraper cost approximately $90 per acre.

Soil Description

Soil in the lagoon area is a Scott loam developed in lacustrine materials washed from adjacent areas of loess and Ogallala beds. The surface loam

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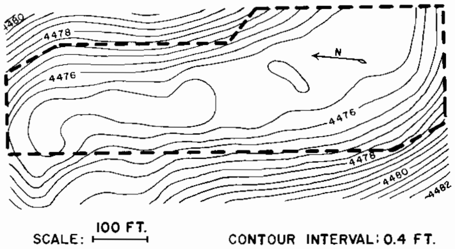

Figure 1. Topographic map of the original lagoon (heavy line delineates the area leveled to zero grade).

grades into a clay or clay loam at the 7-inch depth. The clay, about 4 feet thick, is underlain by a lighter colored sandy loam. The soil is slowly permeable, noncalcareous throughout the profile, and has a pH of 6.5 or higher.

Soil along the edge of the lagoon is Ascalon fine sandy loam. It is shallower, more permeable, and becomes calcareous at about 24 inches. Sandy loam was exposed in leveling the Ascalon soil when cuts exceeded 18 inches. Subsoil of the Ascalon soil is generally deficient in nitrogen, phosphorus, and iron.

Cropping Procedure

In 1964 the lagoon area was divided into 9 plots, each having three replications of corn (Colo. 152) and two forage sorghums (FS-IA and RS-301). A single replication of these crops was established on an adjacent upland unleveled area. Corn was planted annually about May 15 from 1964 through 1966. The forage sorghums were seeded about June 1 each year. In 1965 three replications of hybrid sorghum-sudan (Sudax) were added in the lagoon and one in the check. Thirty pounds of nitrogen per acre as ammonium nitrate were topdressed annually before seeding. Phosphate was applied only on exposed subsoils the first year of cropping at the rate of 30 pounds of phosphorus per acre as treble superphosphate. All crops were harvested for forage about mid-September. Soil water content at 1-foot increments to a depth of 6 feet was measured at various times throughout the growing season.

Results and Discussion

Climate

The long-term average annual precipitation for the area is 16.7 inches, with extremes of 9.9 to 26.5 inches.

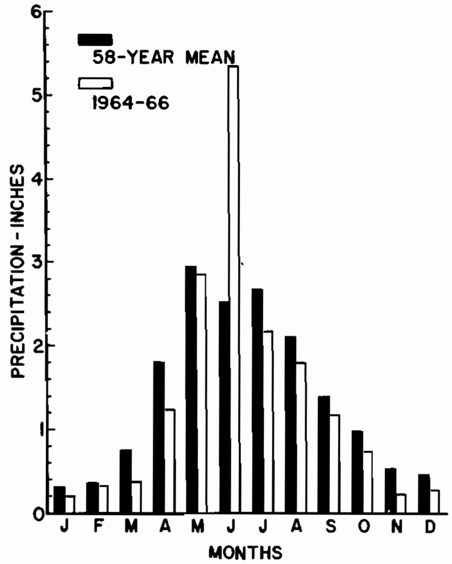

Figure 2. Monthly distribution of annual precipitation for a 58-year period and for 1964-1966.

Annual precipitation for 1964, 1965, and 1966 was 12.3, 22.8, and 14.3 inches, respectively. Monthly distribution of annual precipitation is shown in figure 2 for the 58-year period and for the 1964-1966 experimental period.

Average monthly precipitation during the 3 years was below the long-term mean each month except June, when precipitation averaged more than twice the normal. Since June is the usual time for seeding forage crops, the excess rainfall during this period made seedbed preparation difficult and delayed seeding in 1965 and 1966.

Soil Water Storage at Seeding

Available soil water at seeding time represents water held in the soil above wilting point. The average wilting point of these soils is about 1.3 inches of water per foot.

At seeding time, the leveled lagoon averaged 4.4 inches more available soil water than was found on the unleveled check area (Table 1). Soil water in the lagoon also increased during the crop season as a result of more incoming runoff water than was being consumed by the crops. Thus, stored water at seeding time gradually increased each succeeding year. In 1966 soil water at seeding time was also partially the result of rainfall and runoff received before seeding time.

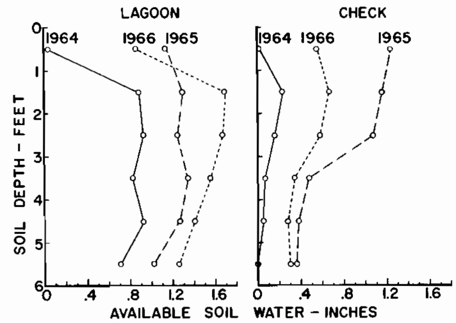

Figure 3. Available soil water distribution to a depth of 6 feet at harvest time.

Growing Season Water Supplies

Growing season rainfall averaged 9.1 inches. In 1965 it was twice this amount; in 1964 and 1966 it was about 2.0 inches below and 1.0 inch above average, respectively (Table 1).

Runoff was impounded in the leveled lagoon each year. In 1964 and 1965 all runoff occurred after seeding. In 1966 nearly all runoff occurred prior to seeding. Runoff was not measured, but the amounts impounded were assumed to be similar to that measured from crop and fallow plots on 1.5 percent slopes from another experiment.

In 1964 and 1966 more than 90 percent of the annual runoff occurred from one or two major storms. In 1965, however, the number of closely spaced storms contributed significant runoff in June and July. No more than 4 to 6 inches of runoff water ever accumulated in the lagoon from any given storm. The water infiltrated the soil in about 2 days.

Total available water (soil water at seeding time, growing season rainfall, and runoff) for crop use in the leveled lagoon averaged 10.3 inches more annually than that on the adjacent unleveled check. Approximately 60 percent or 5.9 inches of this increase was attributed to runoff received by the lagoon and lost from the check area. The remaining portion was due to the difference in soil water storage at time of seeding.

Residual Soil Water

As mentioned before, the forage crops did not use all the available water in the leveled lagoon during the growing season. Residual soil water increased to a depth of 6 feet each year after harvest in the leveled lagoon (Figure 3). Some of the water may have been lost to deep percolation. Hail damage in 1966 reduced growth potential so that the crops did not use as much available water as in 1964 and 1965.

On the check area nearly all available soil water was used after the first year of cropping. In 1965, when precipitation was considerably above normal, there was a significant buildup of residual soil water in the top 3 feet, but only minor increases occurred in the lower part of the 6-foot profile. After the third year of annual cropping, residual soil water at harvest had decreased throughout the soil profile from the previous year. Little, if any, soil water was lost below the root zone depth.

Crop Yields

Corn responded most dramatically to the effects of leveling (Table 2). Dry matter yields averaged nearly 3,500 pounds per acre, about 2,000 pounds more than on the unleveled check. Sorghum dry matter production was greater than corn, but the differences between the lagoon and check were less. Sorghum yields in the lagoon averaged 4,030 pounds or about 610 pounds more per acre than check yields. Sudax yields averaged 4,620 pounds, the highest of any crop grown, but the Sudax yield in the lagoon was only 40 pounds more than that on the check. Dry matter production for all crops in the leveled lagoon averaged 830 pounds more per acre per year than production on the unleveled check.

Annual dry matter yields for each crop are summarized in table 3. Yield variability was due to the amount of available water each year. In 1964 corn grew well throughout the season in the lagoon, while corn on the check area showed moisture stress late in the season. Flooding hindered the growth of sorghums in June 1964, but they recovered rapidly in July.

Although the lagoon area produced more forage, yields were still low by irrigation practices. In dryland areas where crops depend solely on natural precipitation, yields are frequently limited by untimely distribution of rainfall and hail.

Yields obtained in this study were considered optimum for the prevailing climatic conditions. The application of 30 pounds of nitrogen normally fulfills forage crop requirements in this dryland area. More fertilizer may increase yields in years when rainfall and runoff are distributed properly, but crops do not respond to fertilizer in years of low rainfall.

Corn yield potential was reduced by hail in August 1966, and the crop never did recover. Delayed planting and poor stands due to prolonged soil wetness were responsible for lower sorghum yields in the lagoon than on the check area in 1965 and 1966. Sudax, having a slightly shorter season and lower water requirement, was planted later and, therefore, was not affected by excess water in the early stages of plant growth.

Results show that in years of above normal precipitation, such as 1965, it is difficult to establish a good stand of

Table 1. Water available for crop growth in the leveled lagoon and unleveled check, 1964-1966.

Year	*Available Soil Water at Seeding (in)*[a]	*Crop Season Rainfall (in)*	*Estimated Runoff (in)*[b]	*Total Water (in)*[c]
		Leveled Lagoon		
1964	7.2	5.2	4.1	16.5
1965	9.2	14.1	10.4	33.7
1966	10.7	8.1	.4	19.2
Mean	9.0	9.1	5.0	23.1
		Unleveled Check		
1964	4.1	5.2	−0.7	8.6
1965	5.5	14.1	−1.8	17.8
1966	4.2	8.1	−0.1	12.2
Mean	4.6	9.1	−0.9	12.8

[a]Available soil water is that held in the soil above wilting point to a depth of 6 feet.
[b]Runoff assumed to be similar to that measured from wheat and fallow plots on 1.5 percent slopes for the period between planting and harvest.
[c]Available soil water at seeding, growing season rainfall, and runoff.

Table 2. Average water use, dry matter yields, and water use efficiencies of crops grown in the leveled lagoon and unleveled check.

Crop[a]	*Water-Use (in)*	*Dry-Matter Yield (lb/a)*	*Water Use Efficiency (lb/a-in)*
		Leveled Lagoon	
Corn, Colo. 152	16.6	3,460	210
Forage Sorghum, FS-1A	15.9	3,900	245
Forage Sorghum, RS-301	16.4	4,170	270
Sudax	18.7	4,620	250
Mean	16.9	4,040	240
		Unleveled Check	
Corn, Colo. 152	10.6	1,430	135
Forage Sorghum, FS-1A	10.2	3,170	310
Forage Sorghum, RS-301	10.4	3,670	355
Sudax	12.7	4,580	360
Mean	11.0	3,210	290

[a]Average data for 3 years of corn and sorghum and 2 years of sudax.

Table 3. Annual dry matter yields of forages grown in the leveled lagoon and unleveled check.

	Dry Matter Yield (lb/a)		
Crop	*1964*	*1965*	*1966*
		Leveled Lagoon	
Corn, Colo. 152	3,560	5,390	1,430
Forage Sorghum, FS-1A	3,080	4,760	3,850
Forage Sorghum, RS-301	3,960	5,390	3,160
Sudax	—	5,180	4,060
		Unleveled Check	
Corn, Colo. 152	1,460	2,080	770
Forage Sorghum, FS-1A	2,060	5,080	2,370
Forage Sorghum, RS-301	2,220	6,700	2,100
Sudax	—	6,340	2,830

sorghum on leveled areas receiving extra water. In such years sorghums will yield as well on unleveled dryland areas. Corn, however, responded favorably to increased water supplies whenever a good stand was established.

Water use efficiencies (pounds of dry matter produced for each acre-inch of water used) were higher for sorghums on the check area but higher for corn on the lagoon area. The efficiency values seemed realistic for crops on the check area but were less than expected on the lagoon area, probably because of loss of total available water to deep percolation.

Exposing the Ascalon subsoil on the edges of the lagoon by leveling reduced fertility and, therefore, plant vigor and yield potential. However, unpublished results from other research at this station show that the subsoil can be amended with proper fertilization to obtain full crop production within a short period. Leveling improved soil tilth over most of the lagoon bottom by mixing the coarser textured Ascalon soil with the finer textured Scott soil. This mixing improved infiltration which reduced the time water was ponded.

Conclusion

Leveling the lagoon provided more uniform distribution and efficient use of impounding runoff water. In doing so, a non- to low-productive lagoon area was converted to a moderately productive area, eliminating it as a hindrance to normal farming operations.

The leveled lagoon was managed separately from surrounding cropland area. Isolating a small area for intensive cropping may not be economically feasible in areas where extensive farming operations prevail and large equipment is used; however, leveling can permit normal farming operations to proceed through, rather than around, the lagoon and enable the area to be treated the same as the surrounding cropland area.

The ratio of contributing area to leveled area, about 5:1, provided more water than the annual forage crops could use. Better use of available water might be achieved by planting deep-rooted crops, such as alfalfa or bromegrass. The size of the contributing area could also be reduced by constructing a division terrace upland from, and surrounding, the leveled lagoon.

In areas of variable rainfall it is difficult to determine what size the contributing area should be because runoff is a function of watershed treatment. This study indicated that the ratio of contributing area to leveled area should be about 3:1 and no greater than 5:1.

Lagoon leveling is a practice for which federal cost sharing is currently available through the Agricultural Conservation Program. Many farmers in the vicinity of the study have observed the merits of the practice and have incorporated it into their normal farming operations with favorable results.

Leveling costs averaged between $90 and $100 per acre. With proper management and normal rainfall, a farmer could recover such an investment in 4 to 6 years.

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