YIELD INCREASES NEEDED TO JUSTIFY SUBSURFACE DRAINAGE IN SUGARCANE FIELDS

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ABSTRACT

A study was conducted to determine the cost of installing subsurface drainage in Louisiana and to determine if the increase in sugar yields attributed to subsurface drainage was sufficient to justify installation costs. Drain system costs ranged from \$170.00/A for systems with drains spaced 160 feet with a gravity drain outlet and no interest payments to \$2158.00/A for systems with drains spaced 18 feet with a pumped outlet and 10 percent loan interest. Sugar yield increases needed to pay for these drainage systems, assuming the land owner/grower's share of the market price of sugar is \$0.132/lb, ranged from 161 lb/A for systems with 160 ft drain spacing to 2044 lb/A for systems with 18 ft drain spacing. The cost of installing subsurface drainage systems, including payments with 10 percent interest for 10 years, was justified by increased sugar yields for Commerce (*fine-silty, mixed, nonacid, thermic Aeric Fluvaquents*) silt loam with 80 ft drain spacing and Jeanerette (*fine-silty, mixed, thermic Udollic Ochraqualfs*) silty clay loam with 90 ft and 135 ft drain spacings. Sugar yield increases resulting from subsurface drainage on Baldwin (*fine, montmorillonitic, thermic Vertic Ochraqualfs*) silty clay and Sharkey (*very-fine, montmorillonitic, nonacid, thermic Vertic Haploquepts*) clay were not sufficient to justify the cost of installing subsurface drains. The value of enhanced trafficability benefits, due to subsurface drainage, was not included in this study.

INTRODUCTION

Annual rainfall during the past 30 years has ranged from 40 to 90 inches in the sugarcane growing area of Louisiana with yearly averages of 55 inches in the northern part of the sugar belt and 65 inches in the south (16). Annual evapotranspiration (ET) is only about 42 inches. However, average annual rainfall exceeds ET by 13 to 23 inches and may exceed ET by as much as 48 inches in high rainfall years. The excess rainfall either runs off the land or infiltrates the soil and causes the water table to rise. High fluctuating water tables can inhibit crop growth, reduce yield, reduce stubble longevity, and prevent timely field operations.

Louisiana sugarcane fields are generally crown-shaped with lateral drains 1.5 to 3 feet deep spaced 150 to 250 feet apart (14, 15). Quarter drains are constructed from low places in each field to the lateral drains with the number of quarter drains depending on the number of low places that require drainage.

Little effort is devoted to draining the soil profile. Lateral surface drains provide some soil profile drainage but their effectiveness is limited because of shallow depth and wide spacing. Research in Louisiana has shown that subsurface drainage lowers the water table, particularly in silt loam and silty clay loam soils (6, 8, and 9). By lowering the water table, yields and stubble longevity were increased and the delay in entering fields after rains was shortened.

Sugarcane farmers have shown an interest in subsurface drainage but are reluctant to install drains. The primary reasons for this reluctancy are unfamiliarity with subsurface drainage in general, unfamiliarity with the many variables involved in determining costs, and the uncertainty as to whether yield increases caused by subsurface drainage are sufficient to justify the installation cost. The purposes of this paper were to 1) determine the cost of subsurface drainage for various drain spacings with and without a pumped outlet; 2) determine the increases in sugar yield needed to justify the cost of subsurface drain installation, and 3) determine if increased sugar yields resulting from subsurface drainage were sufficient to justify drain installation.

MATERIALS AND METHODS

Subsurface drainage sites

Subsurface drainage experiments with sugarcane were initiated in small plots in 1966 and in field plots in 1972 (4, 5). Since 1972, sugarcane responses to subsurface drains spaced 18, 20, 36, 40, 45, 60, 80, 90, 120, 135, and 160 feet apart have been evaluated at various field locations in Louisiana.

The first experiment was located on the Crescent farm in Terrebonne Parish. Subsurface drains were installed with a wheel-type trencher in 1972 with drains spaced 20, 40, and 80 feet, all without filters, on Mhoon (*Fine-silty, mixed, nonacid, thermic, Typic, Fluvaquents*) silty clay loam soil. Sugarcane (cultivar CP 52-68) was planted in the fall of 1973 and three crops were harvested (2).

In 1976, subsurface drains were installed on the Graugnard farm in St. James Parish on Commerce (*fine-silty, mixed, nonacid, thermic Aeric Fluvaquents*) silt loam. The ARS drain tube plow equipped with a laser grade control system (12) was used to install the drains 80, 120, and 160 feet apart (6, 8). All drains were installed without filters. Yields from 11 sugarcane crops were measured from 1977 to 1990. Sugarcane cultivar CP 48-103 was planted in 1976 for the first cropping cycle: CP 70-321 was planted in 1981 and 1986 for the other two cropping cycles.

Subsurface drains were installed at the Louisiana Agricultural Experiment Station in Iberville Parish on Sharkey (*very-fine, montmorillonitic, nonacid, thermic Vertic Haploquepts*) clay soil in 1977. The ARS drain tube plow was used to install drains 18 and 36 feet apart. All drains were installed without filters. Yields from four crops of sugarcane (cultivar CP 65-357) were measured from 1978 to 1981.

Subsurface drains were installed on the Patout farm in Iberia Parish in 1978 on Jeanerette (*fine-silty, mixed, thermic Udollic Ochraqualfs*) silty clay loam (9). The ARS drain tube plow was used to install drains 45, 90, and 135 feet apart. All drains were installed with filters. Sugar yields from nine crops were measured from 1980 to 1990. Sugarcane cultivar NCo-310 was planted in 1979 for the first cropping cycle. CP 70-321 was planted in 1983 and 1988 for the other two cropping cycles.

Subsurface drains were installed on the Sterling farm in St. Mary Parish in 1978 on Baldwin (*fine, montmorillonitic, thermic Vertic Ochraqualfs*) silty clay. The ARS drain tube plow was used to install drains 45 and 90 feet apart. All drains were installed with filters initially. After yields were measured from two crops in 1979 and 1980, the drains were replaced in 1981 with drains that had no filters. A chain-type trencher was used to install the drains in 1981. Sugar yields from seven more crops were measured from 1982 to 1990. Sugarcane cultivar CP 65-357 was planted in 1978 for the first cropping cycle. CP 70-321 was planted in 1981 and 1984 for the second and third cropping cycles, and CP 70-330 was planted in 1988 for the fourth cropping cycle.

Subsurface drains were installed on the USDA Sugarcane Laboratory's farm in Terrebonne Parish on Commerce (*fine-silty, mixed, nonacid, thermic Aeric Fluvaquents*) silt loam (13, 7). A chain-type trencher was used to install drains spaced 60 feet apart. All drains were installed with filters. Sugar yields were measured from three crops (cultivar CP 65-357) beginning in 1980.

In each field experiment, a laser system was used on the trencher or plow to control the slope of the drain tubes which was parallel to the soil surface. Drain slopes varied from approximately 0.2 percent to 0.3 percent among locations. Drain depth varied from 3 feet to 4 feet among locations.

The cultivars planted for these experiments were selected by the respective sugarcane growers. In general, the cultivars were selected from a list of varieties recommended by the LSU Extension Service personnel (11). Before varieties are placed on the recommended list they are tested for responses to light-textured and heavy-textured soils but not for responses to subsurface drainage.

Drain Material Costs

The materials required to provide subsurface drainage for fields 1000 feet long were determined and converted to cost per acre. The materials required for each drain line were: 1000 feet of 4-inch drain tubing, one 4-inch by 6-inch tee adapter, three drain tube couplers, one end cap, and enough main drain line to reach the adjacent drain line or the drain outlet. The area served by one drain was determined by multiplying drain length and drain spacing. The number of drains required in each field was determined from the total field area divided by the area served by one drain line.

The cost of subsurface drainage materials used in this report was based upon 1993 prices quoted by a representative from a plastic drain tubing manufacturing company. The costs of drain materials were: $0.29/foot for 4-inch perforated, corrugated, plastic drain tubes wrapped with filter fabric ($0.22/foot for drain tube without a filter); $4.80 each for 4-inch by 6-inch tee adapter; $0.70 each for 4-inch drain tube coupler; $0.80 each for 4-inch end cap and $0.45/ft for 6-inch main non-perforated tubing with no filter. Thus, the cost of materials for each 1000 feet of drain line without a filter would be $227.70 ($220.00 for the tubing and $7.70 for the fittings). Materials for each drain line with a filter would cost $297.70 ($290.00 for the tubing and $7.70 for the fittings). In both cases, connecting the main line, the length of which equals the drain spacing, is an additional cost.

Example calculations for determining the cost of materials for a drain spacing of 90 feet are as follows: The area served by one drain line was determined by multiplying the drain spacing (90 ft) and drain length (1000 ft) = 90,000 ft^2 or 2.07 acres. The cost of a drain line without a filter (from previous paragraph) is $227.70 and main line costs $40.50 (90 feet at $0.45/ft). Total material cost is ($227.70 + $40.50)/2.07 A = $130/A. For drains with the same spacing but with a filter on the drain, the total material cost is ($297.70 + $40.50)/2.07 = $164/A.

Sump cost

Sumps with float-activated electric pumps were used as drain outlets in each experiment. Sumps, however, may not be needed in every case. Many fields in Louisiana have surface drainage ditches that are more than 4 feet deep and could be used as subsurface drain outlets. Therefore, the costs of installing subsurface drainage systems both with and without sumps were determined. The cost of a sump and pump was estimated at $2000. This cost was based on 1992 charges for sumps provided by a metal fabricating contractor in Baton Rouge. One sump should serve at least 20 acres, thus the cost per acre for a sump was estimated at $100.

Sumps used at the various subsurface drainage sites were usually 4 by 4 by 10 feet deep. Many were made in farm shops from scrap materials. One sump, at the Iberia site, was an old 5 ft diameter boiler tube 10-feet long. Sumps at the USDA site in Terrebonne Parish were 5 ft diameter legs from off-shore oil drilling platforms. Metal plates were welded on the bottom of each sump. The plates extended out from the sumps to form a one ft lip around the perimeter. After each sump was in place, approximately 1.5 $yards^3$ of concrete were poured onto the lip to prevent the sump from floating. Metal pipes through which the plastic perforated drain tubes entered the sumps were welded into the sides of the sumps at a height of approximately 2.5 feet above the bottom. The metal pipes extended outward from the sumps approximately 10 feet to provide support for the drain tubes where the area around the sump was backfilled and to avoid a potential reversal in grade of the drain tubes should the backfill settle. The cost of providing power to the sumps was not included in the total cost of subsurface drainage systems. Electric companies usually provide power to the sites without charge unless the sites are a great distance from their main power line. The monthly cost of electricity to operate the sump pump varies, depending upon the amount of water pumped. In most cases approximately $1/A/month would be sufficient to cover the operating cost of the pump (10).

Drain installation costs

Installation involves opening trenches, installing lateral drains, connecting lateral drains to main drains, and backfilling the trenches. The cost of installing subsurface drains was difficult to determine because no subsurface drainage contractors routinely operate or conduct business in the lower Mississippi Valley. Installation charges in the mid-western United States vary from less than $0.15/ft to more than $0.50/ft. Using the $0.15/ft to $0.50/ft range as a guide, we estimated the cost of drain installation at $0.28/ft.

Amortization Period and Payment Estimates

Drainage systems installed by the authors in East Baton Rouge Parish in 1975 are functioning as well today as they did when installed (1). This means that the life of drainage systems in Louisiana is at least 19 years. Amortization periods frequently selected for investment-type practices, such as subsurface drainage, is the life of the system. However, if lending institutions provide financing for a practice, an amortization period less than the life of a practice is usually required. For this study, we chose 10 years as the amortization period and determined payback periods for cases with and without an interest rate of 10 percent. For sugarcane, the value of the average yield increase in eight crops during a 10-year period must be sufficient to pay for a drainage system because only three crops are produced in a four-year period. The fourth year is required to destroy the sugarcane stubble, fallow the land for several months, and replant for the next three crops.

Determining actual sugar yield increases attributed to subsurface drainage

At each of the subsurface drainage sites an adjacent area of the same soil type that had no subsurface drains was used for comparisons. Differences in sugar yields between the two areas were attributed to subsurface drainage because the areas were treated identically. The value of the increase in sugar yields, because of subsurface drainage, was determined by multiplying the yield increase in lbs/A by $0.132/lb, the price the grower who owns his land receives for sugar after milling costs have been paid. The value of the measured yield increase was compared to the calculated yield increases needed to justify the cost of installing subsurface drainage. If the value of the actual yield increase exceeded the calculated increase needed to pay for the drain installation, then installation of subsurface drainage was justified.

Statistics

Except for the experiment at the USDA site in Terrebonne Parish, the field experiments were not replicated. They were, however, repeated for several years. Therefore, tests for statistical differences between drained and non-drained treatments were made using the paired t-test with years as replicates.

RESULTS AND DISCUSSION

Subsurface drainage system installation costs

The costs to install subsurface drainage systems for drains spaced from 18 to 160 feet are shown in Table 1. These drain spacings were those used in field tests in south Louisiana during 1974 through 1990. Some drains were installed with filters and some were installed without filters, as noted in Table 1. Total costs ranged from $170.00/A for a drainage system with drains spaced 160 feet, no sump, and no interest payments to $2158.00/A for a drainage system with drains spaced 18 feet, a sump, and 10 percent interest payments for 10 years (Table 1).

Yield increases needed to pay for subsurface drainage system

For each $100.00/A spent to install subsurface drainage systems an increase of 758 lbs/A of sugar is needed for repayment by a grower who owns his land, assuming the grower receives a net $0.132/lb for sugar. In a 10-year repayment period, eight crops of sugarcane are usually grown. Hence, an average increase of 94.75 lb/A of sugar is needed for each harvest to justify subsurface drain installation.

Drainage systems without sumps and without interest payments were the least expensive while systems with sumps and with interest payments were the most expensive (Table 1). The needed yield increases ranged from 161 lb/A/crop for the 160 ft spacing with no sump and no interest payments to 2044 lb/A/crop for 18 ft spacing with a sump and 10 percent interest payments (Table 2).

Table 1. Drain installation costs both with and without sumps and interest charges.

Drain space	Filter	Soil texture[1]	Location	Drain Cost[2] tube	Drain Cost[2] install	Total Cost, no interest, sump: no	Total Cost, no interest, sump: yes	Total Cost, interest, sump: no	Total Cost, interest, sump: yes
ft	y/n		Parish	$/A	$/A	$/A	$/A	$/A	$/A
18	no	c	Iberville	571	690	1261	1361	1999	2158
20	no	sicl	Terrebonne	516	622	1138	1238	1805	1963
36	no	c	Iberville	296	351	646	746	1025	1184
40	no	sicl	Terrebonne	268	317	585	685	928	1086
45	no	sic	St. Mary	240	283	523	623	830	989
45	yes	sicl	Iberia	308	283	591	691	938	1096
60	yes	sil	Terrebonne	236	215	451	551	716	874
80	no	sil	St. James	144	164	308	408	489	648
80	no	sicl	Terrebonne	144	164	308	408	489	648
90	no	sic	St. Mary	130	147	278	378	440	599
90	yes	sicl	Iberia	164	147	312	412	494	653
120	no	sil	St. James	103	114	216	316	343	502
135	no	sicl	Iberia	116	102	218	318	346	505
160	no	sil	St. James	82	88	170	270	270	429

[1] Abbreviations used for soil texture are: c = clay; sic = silty clay; sil = silt loam; and sicl = silty clay loam.

[2] Drain tube cost includes drain tubing, connectors, end-caps, and tees. Drain installation cost includes opening the trench on grade, laying drain tubes in the trench, making connections, and back-filling trench.

The increase in yields needed to justify the cost of installing closely spaced drains where interest payments are required is almost prohibitive with the present crop varieties and cropping practices. For example, to justify installing drains 18 feet apart requires an increase in sugar yield of 1893 lb/A/crop for drainage systems with no sump and 2044 lb/A/crop for drainage systems with sumps (Table 2). Consequently, the yields would have to be 34 and 36 percent greater than the Louisiana state average yield of 5647 lb/A. Drains spaced less than 36 feet would probably be on clay soil, where increasing average sugar yields by 30 percent is unlikely.

Yield increases due to subsurface drainage

The measured crop yield increases, attributed to subsurface drainage, are shown in the last column of Table 2. The highest sugar yield increases were obtained from the Jeanerette silty clay loam soil in Iberia Parish. Areas of Jeanerette soil, with drains spaced 45, 90, and 135 feet, yielded significantly more sugar per acre than did the non-drained area. In St. James Parish, only the area with drains spaced 80 feet apart yielded significantly more than the non-drained area on Commerce silt loam. In Terrebonne Parish, the area with drains spaced 60 feet apart on Commerce silt loam yielded significantly more sugar per acre than did the non-drained area.

Table 2. Sugar yield increases needed to justify subsurface drain installation costs and the actual yield increases attributed to subsurface drainage.

			--- Total drain cost ---				Yield increases needed to justify drain costs[2]				
			no interest		interest		no interest		interest		Actual
Drain	Soil		-- sump --		-- sump --		-- sump --		-- sump --		yield in-
Space	texture[1]	Location	no	yes	no	yes	no	yes	no	yes	crease[3]
ft		Parish	$/A	$/A	$/A	$/A	lb/A	lb/A	lb/A	lb/A	lb/A
18	c	Iberville	1261	1361	1999	2158	1194	1288	1893	2044	109
20	sicl	Terrebonne	1138	1238	1805	1963	1077	1172	1709	1859	178
36	c	Iberville	646	746	1025	1184	612	707	971	1121	575
40	sicl	Terrebonne	585	685	928	1086	553	649	878	1029	449
45	sic	St. Mary	523	623	830	989	496	590	786	936	365
45	sicl	Iberia	591	691	938	1096	**560**	**655**	**888**	1038	938a
60	sil	Terrebonne	451	551	716	874	**427**	**522**	678	828	535a
80	sil	St. James	308	408	489	648	**292**	**387**	**463**	**613**	706a
80	sicl	Terrebonne	308	408	489	648	292	387	463	613	230
90	sic	St. Mary	278	378	440	599	263	358	417	567	0
90	sicl	Iberia	312	412	494	653	**295**	**390**	**468**	**618**	928a
120	sil	St. James	216	316	343	502	**205**	**300**	**325**	475	376
135	sicl	Iberia	218	318	346	505	**207**	**302**	**328**	**478**	713a
160	sil	St. James	170	270	270	429	**161**	**256**	**256**	406	264

[1] Abbreviations used for soil texture are: c = clay; sic = silty clay; sil = silt loam; and sicl = silty clay loam.

[2] The needed yield increases, shown in bold type and underlined, were justified by the actual sugar yield increases shown in the last column.

[3] The letter "a" in the actual-yield-increase column indicates those yields that were increased significantly by subsurface drainage (probability at the 95 percent level).

Yield increases measured in the field were then compared to yield increases needed to justify subsurface drain installation costs. The needed yield increases that were exceeded by the measured yields are indicated by bold type and underlining in Table 2. Increases in sugar yield on Jeanerette silty clay loam in Iberia Parish with drains spaced 90 and 135 feet and on Commerce silt loam in St. James Parish with drains spaced 80 feet justified the cost of installing drainage systems in all four situations, even where interest payments are made. The yield increase from the area with drains spaced 60 feet in Commerce silt loam in Terrebonne Parish justified installing the drainage system for the two situations (sump and no sump) where no interest payments were required. The experiment with Commerce soil in Terrebonne Parish lasted for only 3 years (one cycle). The drain spacing of 60 feet may be closer than is needed for Commerce silt loam soil. This soil type is the same as that in the experiment at the St. James Parish site where drains spaced 80 feet were effective in lowering the water table and increasing sugar yields.

Sugar yield increases were not sufficient to justify subsurface drainage of Baldwin silty clay in St. Mary Parish and Sharkey clay soil in Iberville Parish (Table 2). The value of enhanced trafficability was not included in this study but it could be a major benefit of subsurface drainage on a clay soil. In the sub-tropical climate of south Louisiana where the interval between rainfall events is small, being able to conduct machinery operations in fields at the proper time may mean the difference between a good crop and a poor one. However, estimating the value of trafficability is difficult and was not attempted in this study.

The experiment on Mhoon silt loam soil in Terrebonne parish resulted in data which may be misleading. Unusually dry weather conditions during 2 years of the 3-year study in Terrebonne parish prevented the collection of representative data. In 1974, annual rainfall was only 41.7 inches, which was 23.6 inches below normal. In 1976, annual rainfall was 45.7 inches which was 19.7 inches below normal. Extremely low rainfall, like that in 1974 and 1976, is rare. In the past 42 years, annual rainfall at Houma, Louisiana was less than 47 inches only twice. In 1975, sugarcane responded in a very positive manner to subsurface drainage where annual rainfall was 71.6 inches, and yields from the subsurface drained areas were 20 percent greater than those from the non-drained area (3). Mhoon soil is similar to Commerce except the Mhoon has a very distinct 12-inch layer of silt located approximately 4 feet below the soil surface whereas layers of silt in the Commerce soil are not always connected and their depths vary. The distinct silt layer in Mhoon silty clay loam soil enhances subsurface drainage so that it drains more readily than Commerce soil. If subsurface drainage is justified for Commerce soil by increased sugar yields, it also may be justified for Mhoon soil.

CONCLUSIONS

The cost of installing subsurface drainage systems, including payments at 10 percent interest for 10 years, was justified by increased sugar yields for Commerce (*fine-silty, mixed, nonacid, thermic Aeric Fluvaquents)* silt loam with 80 ft drain spacing and for Jeanerette (*fine-silty, mixed, thermic Udollic Ochraqualfs*) silty clay loam soil with 90- and 135 ft drain spacings. The cost of installing subsurface drains was also justified by increased sugar yields for Commerce silt loam soil with 60 ft drain spacing if interest payments were not included. Crop yield increases resulting from subsurface drainage of Baldwin (*fine, montmorillonitic, thermic Vertic Ochraqualfs*) silty clay and Sharkey (*very-fine, montmorillonitic, nonacid, thermic Vertic Haploquepts*) clay were not sufficient to justify the cost of installing subsurface drainage systems.

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