DRAINAGE SYSTEM IMPACTS ON SURFACE RUNOFF, NITRATE LOSS, AND CROP YIELD ON A SOUTHERN ALLUVIAL SOIL

B. C. Grigg, L. M Southwick, J. L. Fouss, T. S. Kornecki

ABSTRACT. *Excess rainfall and subsequent surface runoff is a challenge to farmers of the Lower Mississippi River Valley region. In 1993, we established an experimental field site in Baton Rouge, Louisiana, consisting of 16 hydraulically isolated plots (0.2 ha) on a Commerce soil (Aeric Fluvaquents). Our objective was to determine drainage system impacts on surface runoff, subsurface drainage effluent, nitrate loss, and corn (Zea mays L.) yield. We evaluated the following drainage systems (four replications) in 1995 and 1996: surface drainage only (SUR), controlled subsurface drainage at 1.1 m below the soil surface (DCD), and shallow water table control at a 0.8 m depth via controlled-drainage/subirrigation (CDSI). Planting date, fertility management, and minimum tillage were consistent across treatments. When compared to SUR, DCD and CDSI did not reduce surface runoff or nitrate loss in runoff. This is in contrast to previous research showing that subsurface drainage systems decreased runoff on this soil, the difference being that we did not use deep tillage. Our results suggest that subsurface drainage systems should be coupled with deep tillage to reduce nutrient loss in runoff from this alluvial soil. DCD and CDSI controlled the shallow water table, but the increased annual effluent from subsurface drainage increased nitrate loss compared to SUR. DCD and CDSI had no affect on corn yield under these rainfall conditions. With respect to nitrate loss and crop yield in this region, typical SUR drainage may be the best management practice (BMP) in the absence of effective runoff mitigation, such as deep tillage.*

Keywords. *BMP, Controlled drainage, Deep tillage, Humid region, Shallow water table, Subirrigation, Subsurface drainage.*

Excess nutrient application has caused widespread eutrophication of rivers, lakes, estuaries, and coastal waters in the U.S. The role of production agricultural systems as a non-point source of these nutrients in surface waters has come under increasing scrutiny in recent years. Fertilizer N input regularly exceeds N output in agricultural products in the U.S. and other nations; mobile, surplus N then leaches from many soils to downstream aquatic ecosystems (Carpenter et al., 1998). Gross residual N from agricultural production is greatest in the Upper Mississippi River and Ohio River basins; however, contributions from the Tennessee River, Arkansas/Red River, and the Lower Mississippi River basins are also significant (Burkart and James, 1999).

Subsurface drainage of agricultural lands in the midwestern U.S. is common and was initially installed to provide suitable soil conditions for seedbed preparation in the spring, and to make the best use of the available growing season. Benefits of subsurface drainage include removal of excess soil water and increased crop yield. These benefits have also been shown for corn (*Zea mays* L.) and sugarcane (*Saccharum* spp.) in the Lower Mississippi River Valley (Bengtson et al., 1984a; Carter, 1987). While the benefits to crop production are evident, recent reports indicate that subsurface drainage systems have primarily negative environmental impacts with respect to fertilizer nutrients.

Nitrogen-flux from the upper Midwest region, between 15 and 35 kg ha^{-1} year^{-1} (Goolsby, et al., 2001), is ultimately transported to the Gulf of Mexico. Turner and Rabalais (1994) reported a linkage between the N load in the Mississippi River and hypoxia in the Northern Gulf of Mexico, and between increased fertilizer N use and changes in the hypoxic zone in coastal waters. Thomas et al. (1992) concluded that in most cases, subsurface drainage systems (including controlled drainage) increased the transport of soluble nitrate to surface receiving waters, even though subsurface drainage reduced sediment transport and loss of sediment-borne nutrients. A study in North Carolina by Gilliam and Skaggs (1986) showed that nitrate losses with a subsurface drainage system were up to ten times that of surface drained-only systems.

In some situations, however, subsurface drainage systems have reduced the negative impacts of agricultural production. Bengtson et al. (1995) reported that subsurface drainage of a Commerce clay loam soil (fine-silty, mixed, non-acid, thermic, Aeric Fluvaquents) reduced surface runoff (35%), sediment (31%), and total nitrogen (17%) when compared to surface drainage alone. Controlled drainage-subirrigation (CDSI) has generally reduced nitrate effluent from agricultural watersheds (Drury et al., 1996; Gilliam et al., 1979). Gilliam et al. (1979) attributed the decrease in nitrate effluent

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to dilution of nitrate into the elevated water table, as well as denitrification of nitrate that migrated deeper into the water table. Gilliam and associates developed controlled-drainage practices for reducing nitrogen and phosphorus levels in surface/subsurface effluent from agricultural lands (Gilliam and Skaggs, 1986; Gilliam et al., 1979; Skaggs and Gilliam, 1986). These practices are in use on soils in eastern and southern coastal plains, where controlled drainage is an accepted best management practice (BMP) to reduce nitrogen loss.

In Louisiana, 60% of cropland is drained; however, only 1% of this total is accomplished via subsurface drainage systems (USDA-ERS, 1987). The Lower Mississippi River Valley (LMRV) region is typified by intense rainfall events and up to 1600 mm of annual rainfall. As with many of the alluvial soils of this region, the Commerce soil association is poorly drained. These climate and soil factors, frequently in combination with shallow water tables, result in a high potential for transport of agrochemicals in surface runoff to surface receiving waters.

A need for improved drainage of southern alluvial soils has been expressed, and improved crop yields have been reported (Bengtson et al., 1984a; Carter, 1987). Only Bengtson et al. (1984a, 1984b, 1995) have quantified the impacts of subsurface drainage on surface runoff quantity and quality in this region. In these reports, however, it is difficult to partition the effects of drainage from deep tillage management. Moreover, the majority of southern Louisiana alluvial soils are planted to sugarcane, and regular deep tillage is not currently recommended (Faw, 1999). Thus, the objective of this research was to determine the impact of water table management on the volume of surface runoff, soluble nitrate loss in drainage effluent, and crop yield under minimal tillage practices more common to the region.

MATERIALS AND METHODS

For the two years beginning in April 1995, research was conducted at the USDA-ARS Ben Hur Field Site (fig. 1). The fully instrumented site was established in 1993 and is made up of 16 hydraulically isolated plots (0.2 ha). The soil is a Commerce silt loam (fine-silty, mixed, non-acid, thermic, Aeric Fluvaquents). The Commerce soil occurs extensively throughout the LMRV region and is found in parts of Arkansas, Louisiana, Mississippi, Missouri, and Tennessee (National Cooperative Soil Survey, 2002). This soil is moderately to poorly drained. Infiltration of rainfall can be limited, with the surface soil (0 to 0.3 m deep) characterized by a saturated hydraulic conductivity of 0.6 to 0.7 mm h^{-1}, as determined by Rogers et al. (1985). Saturated hydraulic conductivity increases with depth, from 11 mm h^{-1} (0.3 to 0.6 m depth) to 40 mm h^{-1} (1.2 to 1.5 m depth) (Rogers et al., 1985).

Each plot was isolated using both 0.3 m high berms and 1.5 m deep plastic sheeting, starting at 0.3 m below the soil surface to facilitate cultivation. Plots were precision leveled (0.2% slope) in the direction of the row, and surface runoff was directed through an H-flume at the downslope end of each plot. Three subsurface drain lines were installed in each plot at 1.2 m below the soil surface and were spaced 15 m apart. The outer two drain lines were used as buffer drains in conjunction with vertical plastic sheeting between plots. As such, drainage volume and nutrient content were determined from the center drain line only, which accounted for 50% of subsurface drainage from each plot. In the case of surface drainage only (SUR), all subsurface drain lines were plugged to prevent drainage of these plots. Field instrumentation enabled automated control of water management, automated recording of water table depth between drain lines, automated measurement and sampling of runoff and subsurface drainage effluent, and refrigerated on-site storage of collected water samples. A detailed description of the site design, layout, and field instrumentation was previously published (Willis et al., 1991).

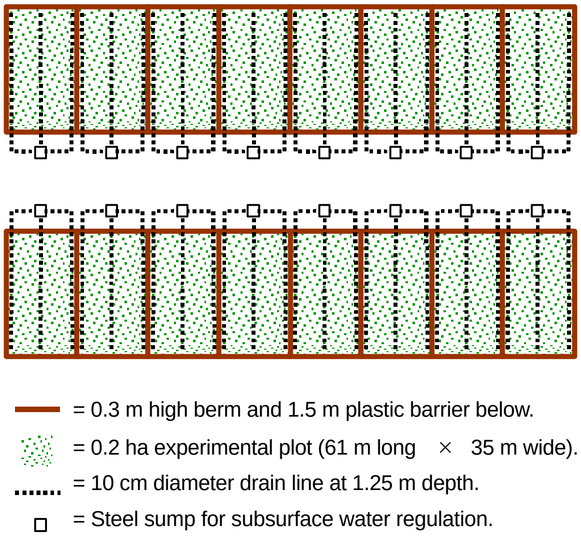

Figure 1. Layout of the Ben Hur Field Site located at the Louisiana Agricultural Experiment Station in Baton Rouge, Louisiana. Construction of this site was completed in 1993, and data collection began in 1995.

Three water management treatments were evaluated on these plots: surface drainage only (SUR), surface drainage + controlled subsurface drainage at a 1.1 m depth (DCD), and surface drainage + water table control at a 0.8 m depth via controlled subsurface drainage and subirrigation (CDSI) during the 150-day growing season. It was thought that DCD would remove excess soil waters from the crop root zone, increase the capacity for rainfall infiltration, and reduce surface runoff, as previously reported (Skaggs et al., 1994; Thomas et al., 1992). The CDSI treatments were included to determine if reduced fluctuation of the shallow water table (comparable to that of SUR) during the growing season would improve crop yield. This in an attempt to prevent both excess and deficit water stress to the growing crop. During the remainder of the year, the water table in the CDSI plots was lowered to the 1.1 m depth. A more detailed description of the automated drainage and water table control systems was presented by Fouss et al. (1999a, 1999b).

Corn was selected as an indicator crop, even though sugarcane is the principle crop grown in southern Louisiana. This was done because: (1) corn is produced throughout the LMRV, (2) corn and sugarcane fertilization schedules are similar in this region, (3) annual sugarcane planting costs are more than five times that of corn, and (4) annual replanting of the sugarcane crop would have been required to compare yield between consecutive years. Unlike corn, sugarcane is grown in a 4- to 5-year cycle with harvest of multiple ratoon crops, each with different growth and yield characteristics.

Thus, growing corn allowed comparison of management practices similar to those of sugarcane, while also facilitating comparison of consecutive years of data for a time-compressed study. Corn was planted approximately April 1 in both 1995 and 1996. This was 30 days later than the optimal planting date in both years and was the result of wet field conditions for some of the treatments, and the desire to plant all plots on the same day. Corn yield is reported on a 15.5% moisture basis.

Fertilizer N was applied at 224 kg N ha^{-1} $year^{-1}$ as a three-way split, based on soil test recommendations. The first split of N-fertilizer was applied at planting, with the subsequent two splits applied prior to June 10 of each year. Fertilizer N was applied as a 32% N solution (43.3% ammonium nitrate: 35.4% urea: 20.3% water) and was injected 5 cm deep into the soil adjacent to the crop row. It was assumed that N in the ammonium or urea forms was readily oxidized to nitrate form, as the zone of application was aerated. While the plots were planted to corn, split application of fertilizer-N was also common in sugarcane production, with all sugarcane fertilizer applications occurring by early June, corresponding to the final pass of field equipment prior to canopy closure.

All plots were minimally tilled. In previous studies by Bengtson et al. (1984a, 1984b, 1995), it is difficult to separate the effects of subsurface drainage from deep chiseling. The research site for these previous studies was deep-chiseled to a depth of 0.5 m every one to two years (R. L. Bengtson, personal communication). At the time of this study, minimum tillage operations were recommended. As minimum tillage was practiced, routine deep tillage operations were not conducted. Moreover, deep tillage is infrequently practiced in corn and sugarcane production in the LMRV.

Water and nitrate data are reported on both a 150-day growing season (GS) and a crop year (annual) basis, beginning with the first nitrogen fertilizer application at approximately April 1 each year. Flow-proportional samples of surface runoff and subsurface drainage effluent were collected on a storm-event basis and refrigerated in the field and laboratory prior to analysis. Nitrate concentration in effluent water samples was determined using ion chromatography (model DX-500, Dionex Corp., Sunnyvale, Cal.) and USEPA method 300.1 (Pfaff et al., 1997).

The experiment was established as a completely randomized design with four replications. The ANOVA procedure was used to analyze these data, and when means were statistically different (α = 0.05), mean separations were accomplished using the Fisher's least significant difference (LSD) test at the same level of significance. The p-value resulting from the ANOVA procedure is also reported: a p-value less than 0.05 is considered significant, and a p-value less than 0.01 is considered highly significant. Data from the two years were treated as replications in time, and data are presented as a 95-96 average. The software used for statistical analysis of data was SAS v.8 (SAS Institute, Inc., Cary, N.C.).

RESULTS AND DISCUSSION

RAINFALL AND SUBSURFACE IRRIGATION

Rainfall during 1996 was equivalent to the 30-year average and exceeded that of the 1995, during both the growing season and crop year (fig. 1). There was significant difference between years for volume of surface runoff ($p < 0.01$ for GS; $p < 0.01$ for annual) and subsurface drainage ($p < 0.01$ for GS; $p < 0.01$ for annual); these differences were wholly a function of rainfall volume, not water management treatment. This is substantiated by the fact that there were no significant differences in treatment × year interactions for surface runoff ($p = 0.56$ for GS; $p = 0.98$ for annual) or subsurface drainage ($p = 0.78$ for GS; $p = 0.1$ for annual). Moreover, there were no significant year impacts on nitrate-N loss in either surface runoff ($p = 0.28$ for GS; $p = 0.86$ for annual) or subsurface drainage ($p = 0.08$ for GS; $p = 0.13$ for annual). Nor were there any significant year × treatment interactions for nitrate-N loss in surface runoff ($p = 0.21$ for GS; $p = 0.21$ for annual) or subsurface drainage ($p = 0.34$ for GS; $p = 0.80$ for annual) for the period of observation. As a result, data is presented as an average for the 1995 and 1996 growing seasons (95-96 average) and will be discussed in terms of averaged data.

Annual rainfall (95-96 average) was 1420 mm for the crop year (April 1 to March 31). This represents an 8% departure from the 30-year average of 1540 mm for the Baton Rouge area. Average rainfall during the growing season (41% of the year) accounted for 565 mm (40% of annual rainfall), and the distribution is representative of this warm, humid climate (fig. 2). Significant rainfall, coupled with low hydraulic conductivity of the surface soil, contributes to proportionally large surface runoff events. As such, mitigation of surface runoff is important in southern Louisiana and the LMRV region, particularly following agrochemical application during the growing season.

CONTROL OF THE SHALLOW WATER TABLE AND MITIGATION OF SURFACE RUNOFF

During the growing season, the SUR water table varied considerably, between 0.4 and 1.1 m below the soil surface (fig. 3), with an average depth of 0.8 m (table 1). While maintaining the same average depth as SUR (table 1), CDSI stabilized the depth to water table (fig. 3), an observation supported by the reduced standard deviation (table 1). The water table depth for both SUR and DCD (no subirrigation) declined during the later portion of the growing season, while CDSI maintained a relatively consistent depth (fig. 3). This corresponds with the expected period maximum leaf area and

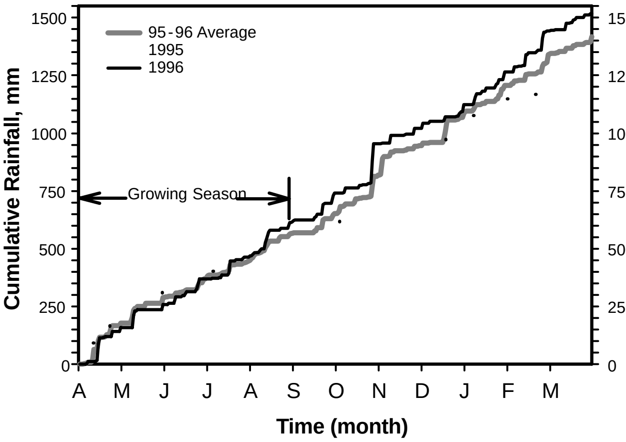

Figure 2. Cumulative rainfall for the 1995, 1996, and 95-96 average crop years. The duration of the growing season (April 1 through August 31) is also indicated.

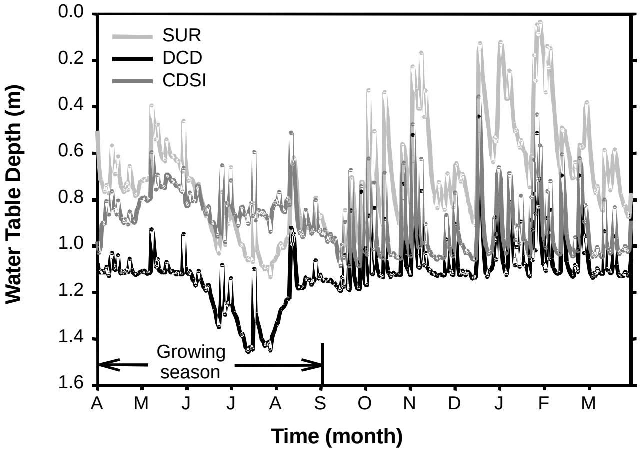

Figure 3. Average daily water table depth (95‑96 average) for the surface drainage only (SUR), controlled drainage at a 1.1 m depth (DCD), and controlled drainage‑subirrigation at a 0.8 m depth (CDSI) treatments.

Table 1. Treatment impacts (95‑96 average) on depth of water table for both the growing season and crop year (annual) periods.

	Water Table Depth (m)			
	Growing Season		Annual	
Treatment[a]	Average	S.D.	Average	S.D.
SUR	0.8	0.2	0.7	0.3
DCD	1.2	0.2	1.1	0.2
CDSI	0.8	0.1	0.9	0.2

[a] SUR = surface drained only, DCD = deep controlled drainage at 1.1 m depth, and CDSI = water table controlled at 0.8 m depth via subsurface drainage/irrigation.

Table 2. Treatment impacts on surface runoff, subsurface drainage, and total (runoff + drainage) presented as both a growing season (GS) and crop year (annual) basis.

	Effluent (mm)[b]					
	Surface Runoff		Subsurface Drainage		Total	
Treatment[a]	GS	Annual	GS	Annual	GS	Annual
SUR	244 a	384 a	0 c	0 b	244 b	384 b
DCD	245 a	417 a	68 a	432 a	313 a	849 a
CDSI	256 a	433 a	39 b	396 a	295 a	829 a
LSD[c]	23	50	15	57	27	68
p‑value[d]	0.67	0.22	<0.01	<0.01	<0.01	<0.01

[a] SUR = surface drained only, DCD = deep controlled drainage at 1.1 m depth, and CDSI = water table controlled at 0.8 m depth via subsurface drainage/irrigation.

[b] Values followed by the same letter are not significantly different, and comparisons are only valid within a column.

[c] LSD = Fisher's least significant difference at the $\alpha = 0.05$ level of significance.

[d] p‑value from ANOVA procedure: $p < 0.05$ is considered significant; $p < 0.01$ is considered highly significant.

reproductive growth for the corn crop, and reflects evapotranspirative water loss in excess of rainfall, thus the decline in the shallow water table of SUR and DCD, where subirrigation was not applied.

For the remainder of the year, CDSI was operated in controlled drainage mode, with a target 1.1 m water table depth, the same as the DCD treatment. While there were numerous rainfall events, the corresponding peaks in the shallow water table depth for DCD and CDSI were sharp and of limited duration (fig. 3), indicating rapid decline of the water table to the target depth, as facilitated by the installed drainage systems. In contrast, the peaks in the depth of the shallow water table for SUR were broader and slower to return to a basal level (fig. 3). This is likely a result of both reduced evapotranspirative water loss during the non‑crop portion of the year and restricted deep or lateral seepage.

Compared to SUR, CDSI provided a potential benefit of maintaining a more consistent water table depth near the crop root zone during the growing season. Moreover, when compared to SUR, CDSI also rapidly removed excess soil waters during the remainder of the year. The winter control of the shallow water table, as demonstrated by both the DCD and CDSI treatments, would likely benefit sugarcane production. With sugarcane, the growing season is considerably longer, and yield from the subsequent ratoon crop can be negatively impacted by shallow water tables. This is a result of degradation of the rootstock, and of slower warming of the soil in the spring caused by elevated soil water content (Richard, 1999).

While controlling the water table at the desired levels, DCD and CDSI did not significantly impact surface runoff, either during the growing season or annually (table 2). The DCD treatment removed an additional 68 mm of soil water as subsurface drainage effluent during the growing season (table 2). Likewise, CDSI removed 39 mm of water as subsurface drainage during the growing season. The difference between DCD and CDSI is primarily a result of differing depths of water table control during the growing season.

Subsurface drainage effluent from DCD and CDSI treatments during the 150‑day growing season was only 16% and 10% of annual subsurface effluent, respectively. This occurred during 40% of the year (table 2). Crop water uptake and transpiration were greater during the growing season and helped reduce excess soil‑water and subsurface drainage effluent. During the remainder of the year, when the CDSI treatment was in controlled‑drainage mode, drainage effluent from DCD and CDSI were almost identical, with 368 and 356 mm of subsurface drainage effluent outside of the growing season, respectively.

For both DCD and CDSI, total effluent was over two times greater than SUR, solely a result of water table control and discharged soil waters for DCD and CDSI (table 2). This difference in annual soil water removed was 396 to 432 mm greater for DCD/CDSI when compared to SUR management. Only 20 to 30 mm of this can be accounted for by the difference in the depth of water table control between SUR and DCD or CDSI, when considering the drainable porosity of the soil profile between the 0.7 and 1.1 m depth, as reported by Fouss et al. (1987). A portion of this difference is likely due to deep seepage. It is possible that with less‑than‑normal annual rainfall, the SUR system was not stressed with regards to potential deep seepage of infiltrating rainwater. Although, with no impact of water management treatment on surface runoff, and thus on infiltration, the remaining 400 mm of the difference seems to be a considerable amount of water to be lost as solely deep seepage in this poorly drained soils. However, we estimate that 200 mm of this difference in soil water removed was actually due to greater evapotranspiration (ET) with SUR when compared to DCD or CDSI water management.

We estimated ET using DRAINMOD (v. 5.1, North Carolina State University, Raleigh, N.C.). Input data for the model include climatological (rainfall from gauges on site and temperature and pan evaporation from the nearby weather station maintained by LSU), crop, and drainage system parameters. DRAINMOD also utilizes monthly potential ET adjustment factors established for this location by Bengtson et al. (1985), previously used in DRAINMOD simulations for this site (Fouss et al., 1987). We selected SUR and DCD, rather than CDSI, because of their reduced management complexity. Brief drainage system parameters for DCD include 1.2 m drain depth, 5 cm radius drain lines, and 15 m spacing. Design information for SUR was set such that drainage was zero (5 cm drain depth, 2 cm radius, 200 m drain spacing). For SUR, the simulation predicted 730 mm and 890 mm of ET for the 1995 and 1996 crop years, respectively, with 810 mm of ET for the 95-96 average. In contrast, DCD resulted in 560 mm and 660 mm for the 1995 and 1996 crop years, and 610 mm for the 95-96 average. We assume that the primary reason for increased ET under SUR management is closer proximity of the water table to the soil surface and to the crop root zone.

The 200 mm greater ET, along with the 30 mm from shallower drainage depth for SUR, accounts for over half of the total difference in soil water loss between SUR and DCD. The unaccounted for remainder of water losses from SUR were most likely a result of deep seepage, as well as lateral seepage below the plastic barriers between plots. This lateral seepage would have been intercepted by the buffer drains of adjacent plots, where subsurface drainage lines were actively drained. Loss as lateral seepage to adjacent buffer drains was quantified; however, we could not accurately determine the source of this buffer subsurface drainage water, as this soil water could have come from within the plot, from adjacent plots, or the land area surrounding our site.

Increased subsurface drainage discharge was an expected result of DCD and CDSI, although we expected a corresponding decrease in surface runoff. Subsurface drainage generally decreases runoff volume and increases percolation of rainwater through the soil profile as it moves to the drain lines (Baker et al., 1975; Baker and Johnson, 1976; Bengtson et al., 1995). However, in this study, DCD and CDSI did not result in increased rainfall infiltration in comparison to the SUR, as indicated by no treatment effects on surface runoff (table 2). These data suggest that surface and subsurface waters are largely decoupled in this soil profile. This is in contrast to previous reports of a 35% decrease in surface runoff in response to similar subsurface drainage practices on this same Commerce soil association where deep chiseling was regularly practiced (Bengtson et al., 1995). Our water table control treatments effectively control the shallow water table at the desired depth; however, in the absence of deep tillage, these water table control systems do not mitigate surface runoff.

NITRATE LOSS

All fertilizer-N was applied before June 10 of each year. For all treatments, 87% to 95% of the annual nitrate loss in surface runoff waters occurred during the 150-day growing season (table 3). This trend in surface effluent-borne soluble N would likely be repeated for sugarcane culture. While the plots were planted to corn, split application of fertilizer-N is also common in sugarcane production, with all sugarcane fertilizer applications occurring by early June, the final pass of equipment through the sugarcane field prior to canopy closure.

Table 3. Treatment impacts on nitrate transported in surface runoff, subsurface drainage, and total (runoff + drainage) effluent waters are presented as both a growing season (GS) and crop year (annual) basis.

	Nitrate-N in Effluent (kg ha^{-1})[b]					
	Surface Runoff		Subsurface Drainage		Total	
Treatment[a]	GS	Annual	GS	Annual	GS	Annual
SUR	7.0 a	7.5 a	0.0 b	0.0 b	7.0 a	7.5 b
DCD	5.0 a	5.7 a	2.4 a	7.2 a	7.4 a	12.9 a
CDSI	6.2 a	6.7 a	2.3 a	7.0 a	8.5 a	13.7 a
LSD[c]	2.6	2.5	1.3	4.2	2.9	4.8
p-value[d]	0.43	0.50	<0.01	<0.01	0.72	0.05

[a] SUR = surface drained only, DCD = deep controlled drainage at 1.1 m depth, and CDSI = water table controlled at 0.8 m depth via subsurface drainage/irrigation.

[b] Values followed by the same letter are not significantly different, and comparisons are only valid within a column.

[c] LSD = Fisher’s least significant difference at the $\alpha = 0.05$ level of significance.

[d] p-value from ANOVA procedure: $p < 0.05$ is considered significant; $p < 0.01$ is considered highly significant.

Less than 1 kg ha^{-1} of nitrate-N was lost in surface runoff during the 215-day period outside of the growing season, regardless of water management treatment. Thus, with respect to soluble nitrate, mitigation of surface runoff is most important during the growing season for corn, and probably for sugarcane. However, when considering overall N-loss in surface runoff, including soluble + sediment-bound N, reduction of surface runoff would likely be important on an annual basis, as 50% of runoff, and associated soil erosion and sediment loss, occurs outside of the growing season. This study did not quantify the loss of soil sediment, or sediment-associated nutrients in surface runoff waters. Under these rainfall conditions, however, we would not estimate a significant treatment impact on sediment loss or sediment-bound nutrient loss.

Nitrate transported in subsurface drainage effluent was the same for the DCD and CDSI treatments, with approximately 7 kg ha^{-1} of nitrate-N lost from each of these treatments (table 3). As the DCD and CDSI treatments did not alter the infiltration of rainwater, it is likely that the same quantity of nitrate that was delivered to surface waters via subsurface drainage was transported to shallow groundwater under SUR management. Groundwater containing high concentrations of nitrate and discharging to streams may still pose a serious threat to stability and diversity of biota in some ecosystems (Cooper, 1993). While not monitored, SUR could still deliver additional nitrate to nearby surface waters through deep and lateral seepage, although this nitrate would also be subject to denitrification and subsequent loss to the atmosphere.

In contrast to nitrate loss in surface runoff, only one-third of annual nitrate lost in subsurface drainage effluent occurred during the corn-growing season (table 3). The remaining 67% of nitrate lost in subsurface drainage from the DCD or CDSI treatments occurred during the remainder of the year, outside of the growing season. Although more of the near-surface soil profile was drained by DCD in comparison to CDSI, the same amount of nitrate was transported beyond the edge of the field in subsurface drainage effluent (table 3).

DCD and CDSI significantly increased total annual nitrate losses (surface runoff + subsurface drainage) when compared to SUR (table 3). Nitrate in subsurface drainage waters makes up over 50% of the total nitrate lost from DCD and CDSI plots on an annual basis (table 3). This increased nitrate loss resulting from subsurface drainage has been observed in other research (Thomas et al., 1992). Moreover, previous research has also shown that the majority of annual nitrate loss through subsurface drainage occurred during period of non-crop production (Bjorneberg et al., 1996; Drury et al., 1996).

Leaching of nitrate is less likely during the summer growing season, as evapotranspiration removes much of infiltrating waters and the rate of plant uptake is high (Allison, 1965). Furthermore, because of the longer growing season, sugarcane would likely result in greater potential crop uptake of N in soil waters, reducing the potential for nitrate loss in subsurface drainage effluent. Drury et al. (1993) showed that full-season crops developed extensive root systems, increasing nitrate uptake and reducing nitrate movement below the root zone.

While shown to be ineffective for corn production in the LMRV, de-watering using systems such as DCD or CDSI will likely become more important for sugarcane production in the near future. Sugarcane farmers are under increasing pressure to cease burning of post-harvest residue, leaving significant quantities of this low-value plant residue in the field. This new residue management strategy has been shown to increase the water-holding capacity of soil, slowing spring germination and reducing sugarcane yield (Richard, 1999). The DCD or CDSI systems could be used to manage soil water content during the cool, wet months between December and April.

However, any use of subsurface drainage must be part of an overall BMP that reduces nutrient inputs and prevents loss of these nutrients to receiving surface and ground waters. Surface runoff waters from agricultural production areas in southern Louisiana and the LMRV have typically been routed through our abundant wetlands, where nutrients and suspended sediments are captured. This practice reduces potential eutrophication of open bodies of water, including the Gulf of Mexico, but can alter the nutrient balance in the wetlands, impacting native biota and promoting the establishment of invasive species. This “clean-up” option will not be available in the near future as total maximum daily loads (TMDL) are established for these waters.

CROP YIELD

On average, corn was planted about 30 days after the optimum planting date for the region. According to previous research, delayed planting in each year resulted in an approximately 30% reduction in yield potential (Morrison et al., 2000), regardless of water management treatment. There were no significant differences in corn yield resulting from water management treatment (fig. 4). However, there was a trend for increased corn yield with DCD and CDSI treatments (fig. 4). This would suggest that there might be a benefit derived from controlling the shallow water table. With the longer growing season of sugarcane, and considering the negative impacts of a cool-season shallow water table, water table control may also increase sugarcane yield, particularly when rainfall exceeds the 30-year average. Treatment differences might have been greater in conjunction with earlier planting, particularly earlier planting facilitated by water table control. However, in light of these reasonably modest gains in corn yield, DCD and CDSI would not be recommended. Yield differences between DCD/CDSI and SUR may also have been greater had we received rainfall in excess of the 30-year annual average.

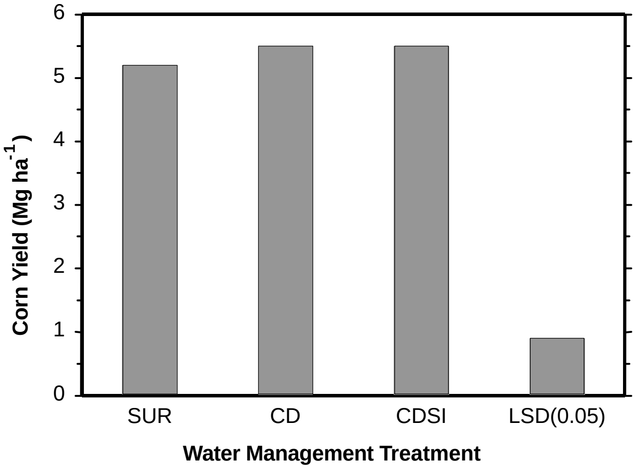

Figure 4. Corn yield as impacted by water management treatment. Treatments include surface drainage only (SUR), controlled drainage at a 100 cm depth (DCD), and controlled drainage-subirrigation at a 75 cm depth (CDSI).

CONCLUSION

The DCD and CDSI treatments effectively controlled the shallow water table at or near the target depth. However, on this alluvial soil, these treatments did not reduce surface runoff or improve crop yield under these rainfall conditions. With no deep tillage, surface and subsurface waters were largely independent of one another, explaining the lack of subsurface drainage systems impacts on surface runoff or nitrate loss in runoff. However, under these rainfall conditions and considering (1) the expense of installing such drainage systems, (2) marginal increases in corn yield, (3) increased nitrogen loss, and (4) infrequent practice of deep tillage, the commonly used SUR management may be considered the best management practice (BMP) for corn production on these alluvial soils. With respect to fertilizer and tillage management in this southern alluvial soil, practices used in this study were consistent with those of sugarcane for the same period (Faw, 1999).

These findings differ from those of Bengtson et al. (1984b, 1995), the only difference being tillage (deep chiseling) management. No direct comparison of tillage impacts on effluent water quantity and quality has been conducted on this alluvial soil. However, these findings suggest that previously reported decreases in surface runoff and nitrate loss from this alluvial soil were likely a result of tillage management, rather than improved subsurface drainage.

When compared to SUR, the DCD and CDSI treatments increased nitrate transport from these agricultural fields to surface receiving waters by approximately 40%, most of which occurred during the off-season when no crop was grown. Nitrate transport in removed subsurface drainage waters might not be as great with sugarcane, with a longer growing season, increased ET and associated reduction in subsurface drainage, and greater potential for nitrogen uptake.

It will become more important to control nutrient and sediment transport from agricultural fields as new regulations, such as TMDL standards, are set for surface receiving waters. For alluvial soils of the LMRV region, subsurface drainage is unlikely to reduce surface runoff, unless coupled with reduced fertilizer inputs or deep-tillage operations. However, carefully managed subsurface drainage could be an effective part of integrated management approaches to reduce surface runoff and transport of nutrients and sediments to receiving waters and to increase crop yield.

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