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Furrow diking in conservation tillage☆

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ABSTRACT

Crop production in the Southeastern U.S. can be limited by water; thus, supplemental irrigation is needed to sustain profitable crop production. Increased water capture would efficiently improve water use and reduce supplemental irrigation amounts/costs, thus improving producer's profit margin. We quantified infiltration (INF), runoff (*R*), and sediment (*E*) losses from furrow diked (+DT) and non-furrow diked (−DT) tilled conventional (CT) and strip tillage (ST) systems. In 2008, a field study (Tifton loamy sand, Typic Kandiudult) was established with DT, ST, and CT systems. In 2009, a field study (Faceville loamy sand, Typic Kandiudult) was established with DT and ST systems. Treatments (6) included: CT − DT, CT + DT, ST_1 (1-year old) − DT, ST_1 + DT, ST_{10} (10-year old) − DT, and ST_{10} + DT. Simulated rainfall (50 mm h^{-1} for 1 h) was applied to each 2-m × 3-m plots (n = 3). Runoff and *E* were measured from each 6-m^2 plot. ST_1 + DT plots had 80–88% less *R* than ST_1 − DT plots. Any disturbance associated with DT in ST_1 systems did not negatively impact *E* values. For both soils, CT − DT plots represented the worst-case scenario in terms of measured *R* and *E*; ST + DT plots represented the best-case scenario. Trends for *R*, *E*, and estimated plant available water (PAW) values decreased in order of CT − DT, CT + DT, ST_1 − DT, ST_1 + DT, ST_{10} − DT, and ST_{10} + DT treatments. From a hydrology standpoint, ST_1 − DT plots behaved more similarly to CT plots than to other ST plots; from a sediment standpoint, ST_1 − DT plots behaved more similarly to other ST plots than to CT plots. DT had no effect on ST_{10} plots. CT − DT and ST_{10} + DT plots resulted in 5.9 (worst-case) and 8.1 (best-case) days of water for crop use, a difference of 2.2 days of water for crop use or 37%. Compared to the CT − DT treatment, an agricultural field managed to CT + DT, ST_1 − DT, ST_1 + DT, ST_{10} − DT, and ST_{10} + DT would save a producer farming the CT − DT field \$5.30, \$9.42, \$13.55, \$14.14, and \$14.14 ha^{-1}, respectively, to pump the amount of water lost to *R* and not saved as INF back onto the field. The most water/cost savings occurred for CT and ST_1 plots as a result of DT. Savings for CT + DT, ST_1 − DT, and ST_1 + DT treatments represent 27%, 47%, and 68% of the cost of DT (\$20 ha^{-1}) and 37%, 67%, and 96% of the savings a producer would have if managing the field to ST for 10 years without DT (ST_{10} − DT) in a single 50-mm rainfall event. For row-crop producers in the Southeastern U.S. with runoff producing rainfall events during the crop growing season, DT is a management practice that is cost-effective from a natural resource and financial standpoint for those producers that continue to use CT systems and especially those that have recently adopted ST systems into their farming operations.

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1. Introduction

Highly weathered, Coastal Plain soils of Georgia and the Southeastern U.S. have been intensively cropped under conventional tillage (CT) systems, have relatively sandy surfaces, tend to be drought-prone, and are susceptible to compaction, runoff, and erosion. Rainfall in the region is ∼1250 mm annually, tends to be bi-modal in nature, and characteristically has short duration-high intensity, runoff producing storms with extended periods of drought during the crop growing season. Thus, crop production can be limited by water, and supplemental irrigation is often needed to prevent yield-limiting water stress. Management practices are needed to increase water (rainfall, irrigation) capture and infiltration, improve water use, reduce supplemental irrigation costs, conserve natural resources, and sustain profitable crop production. Furrow diking creates a series of surface depressional storage micro-catchments between crop rows with small earthen dams over short intervals to more effectively catch and retain rainfall and/or irrigation, thus promoting infiltration and preventing runoff and erosion.

Agricultural and urban demand for water in Georgia and the Southeast, along with rising fuel costs, continue to place great

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importance on water conservation. Sustainable crop production demands more efficient water use as the amount of irrigated land has increased steadily (~610,000 ha in 2004, Harrison, 2005), while farm diesel costs increased 3+ times from 2002 to 2009. Water conservation in agricultural settings is essential, including accurate quantification of how well management practices conserve water.

In Georgia and the Southeast, a major effort has been undertaken to conserve soil resources and reduce water and energy requirements for row-crop production, mainly through conservation tillage. Conservation tillage (strip tillage, ST) adoption in the region has steadily increased; yet, a significant portion of the land continues to be managed to CT. Also, studies have reported that the impact of conservation-till on rainfall partitioning was nonexistent in year one of conservation-till adoption or that less runoff (more infiltration) occurred from CT compared to conservation-till systems, especially 1–3 years after conservation-till adoption (Soileau et al., 1994; Cassel and Wagger, 1996; Truman and Rowland, 2005). On-farm management practices are needed by producers that have recently converted to conservation-till to take better advantage of water (rainfall, irrigation) available to them.

The world-wide use of furrow diking (DT), or some form thereof (tied ridge, basin tillage, basin listing, micro-basin tillage), and its agronomic, economic, and environmental benefits have been documented (Truman and Nuti, 2009; Nuti et al., 2009). To date, few studies have demonstrated DT applications in the humid Southeastern U.S. (Hackwell et al., 1991; Bader and Wilson, 1996; Truman and Nuti, 2009; Nuti et al., 2009), especially in conservation tillage systems. In Georgia, Truman and Nuti (2009) found that DT in CT systems had 84% more infiltration, 3.2 days more estimated plant available water, 2.8 times less runoff, and 2.6 times less soil loss than traditional CT systems.

Current agricultural water issues and the need to reduce input costs in farming operations add importance to making sound management decisions to ensure efficient water use, natural resource conservation, and on-farm profitability. The success of DT will depend on rainfall characteristics, intrinsic soil properties, and cropping/tillage systems used in any given region. We hypothesize that DT systems in Georgia and the Southeastern U.S. can not only improve economic returns by improving water capture, crop yield/quality, reducing supplemental irrigation inputs, and fuel/energy consumption in CT systems, but also in ST systems. Ultimately, DT coupled with ST should allow for more efficient use of rainfall and/or irrigation, especially just after ST adoption; thus giving producers in this region a management tool that takes better advantage of rainfall and/or irrigation and extends the time between supplemental irrigations during this tillage transition to improve yield potential and profit margins. We quantified runoff and sediment losses from furrow diked (+DT) and non-furrow diked (−DT) ST systems (1, 10 years old), and compared results to those for corresponding CT systems.

2. Materials and methods

2.1. Experimental Sites

Field site 1 was located near Tifton, GA (N 31°26′, W 83°35′). The soil studied was a Tifton loamy sand (fine, kaolinitic, thermic Typic Kandiudult; 82% sand, 7% clay), which represents over 762,000 farmable ha in the Coastal Plain region of Georgia. Prior to this study, site 1 has been managed under CT and ST systems in a cotton–peanut rotation since 1998 (Potter et al., 2006; Truman et al., 2007). CT consisted of fall disking, winter rye (Secale cerale) cover, followed by spring disking and cultivator leveling. Rye surface cover was incorporated 10–15 cm. Site 1 (2008) was cropped to peanuts (planting date = 15 May, row spacing = 0.9 m).

Field site 2 was located near Dawson, GA (N 31°24′, W 84°31′). The soil studied was a Faceville loamy sand (fine, kaolinitic, thermic Typic Kandiudult; 71% sand, 16% clay), which represents over 87,000 farmable ha in the Coastal Plain region of Georgia. Prior to this study, site 2 has been managed under CT and ST systems in a cotton–corn–peanut rotation since 2008; it was conventional tilled in a cotton–corn–peanut rotation from 2002–2008 (Truman and Nuti, 2009). At both field sites, ST consisted of planting a winter rye cover just after crop harvest in the fall and killing the rye chemically 30 days before planting the next year's row crop. With ST, a 10-cm wide strip was tilled and used to plant the crop into. Site 2 (2009) was cropped to peanuts (planting date = 15 May, row spacing = 0.9 m).

At both sites, DT was conducted just after planting (spring), and created surface depressional storage basins between non-traffic crop rows 1.5-m long, 30-cm wide, and 20-cm deep (Fig. 1). All DT treatments had a ripper shank (1.6-cm × 10.5-cm steel; 45-cm from tip to point parallel to the back of the shank) operated at 18-cm depth.

2.2. Treatments

Treatments consisted of furrow diked (+DT) and non-furrow diked (−DT) conventional (CT) and strip (ST) tillage. Six treatments were evaluated. In May 2008, four treatments were established (site 1): conventional (freshly) tilled seedbed without furrow diking (CT − DT); conventional (freshly) tilled seedbed and with

Fig. 1. Conventional- (CT) and strip-tillage (ST) under furrow dike tillage (DT).

furrow diking (CT + DT); established (10-year old) strip tilled seedbed without furrow diking (ST_{10} − DT); established (10-year old) strip tilled seedbed and with furrow diking (ST_{10} + DT). In May, 2009, two treatments were established (site 2): newly established (1-year old) strip tilled seedbed without furrow diking (ST_1 − DT); newly established (1-year old) strip tilled seedbed with furrow diking (ST_1 + DT).

2.3. Rainfall simulations

Rainfall simulation plots (6-m^2, 2-m wide by 3-m long) were established on each treatment (6) (n = 3). Therefore, 18 6-m^2 rainfall simulation plots were evaluated. Each plot had a slope of 2%. An area surrounding each 6-m^2 simulator plot was treated like the test area to allow soil material to be splashed in all directions. Soil water content was determined gravimetrically (Gardner, 1986) from samples taken from three areas around each rainfall simulation plot just prior to each simulated rainfall event (0–1 and 1–15 cm depths). Each 6-m^2 simulator plot, oriented lengthwise with the row, had either a furrow diked row (centered) with two half beds (one peanut row per half bed) on either side of the furrow diked middle or a wheel track (centered) with two half beds on either side of the wheel track middle (non-diked plots). Simulated rainfall was applied to each 6-m^2 plot at a target intensity (I) of 50 mm h^{-1} for 60 min (ave. I for the 18 runs/plots = 50.2 mm h^{-1}; CV = 5%). Thirty-five year average monthly rainfall for May was 83.8 mm; and 35-years average maximum rainfall intensity for Spring (March, April, May) was 163 mm h^{-1}. Rainfall was applied with an oscillating nozzle rainfall simulator (Potter et al., 2006; Truman et al., 2007) that used 80150 Veejet nozzles (median drop size = 2.3-mm). The simulator was placed 3 m above each 6-m^2 plot. Well water was used in all simulations, and had an average pH of 7.7 (CV = 0.6%) and EC of 0.002 S cm^{-1} (CV = 2%).

Runoff (R) and sediment yields (E) from each 6-m^2 plot were measured continuously at 5-min intervals during each simulated rainfall event. Runoff and E were collected in 1-L Nalgene (autoclaveable) bottles. Each bottle was weighed (bottle + water + sediment), dried at 105 °C for 24 h, then weighed again (bottle + sediment). Runoff and E were determined gravimetrically; infiltration (INF) was calculated by difference (rainfall-runoff). The parameter d INF was calculated by difference (INF_{max} − INF_{min}). Water for crop use estimates were calculated from INF values (30-min totals and 60-min totals) for each treatment and an assumed ET value.

2.4. Data analysis

Means, coefficient of variations (CV, %), and standard error bars are given for measured data (n = 3). We performed unpaired t-tests (two-tailed distribution) to determine significance among treatment means using SigmaStat 3.1 (Systat, 2004). All test statistics were evaluated at P = 0.05 unless otherwise noted. All other data analysis was conducted with Microsoft Office Excel 2003.

3. Results and discussion

We quantified water capturing and erosional characteristics of DT in ST systems by measuring infiltration, runoff, and sediment delivery. We specifically wanted to address the following questions: What general trends or differences occur in infiltration, runoff, and soil loss from ST, DT, and CT systems when rainfall is simulated at planting on a freshly tilled seedbed condition? Is DT effective in improving infiltration–runoff relationships in ST system without having any negative impacts on sediment delivery, especially ST systems less than three years old?

3.1. ST_{10} − DT vs. ST_{10} + DT

For the Tifton loamy sand, DT had little to no effect on infiltration, runoff, or sediment yields on the mature ST system (ST_{10} − DT vs. ST_{10} + DT; Table 1). DT did impact CT systems as CT + DT plots had 11% more INF (% of rainfall applied) (P = 0.0313), 33% less R (mm h^{-1}; P = 0.0169), and 62% less soil loss (P = 0.0262) than CT − DT plots. Others have reported similar runoff reductions, water conservation, and soil loss trends with DT in CT systems (Rawitz et al., 1983; Gerard et al., 1983, 1984; Jones and Clark, 1987; Truman and Nuti, 2009).

Runoff rates for the four treatments are given in Fig. 2A. No differences in runoff rates occurred between ST_{10} − DT and ST_{10} + DT plots, as rates increased to 3–4 mm h^{-1} in the first 5-min and remained at that rate for the remaining 60-min duration. Runoff rates for CT − DT plots steadily increased throughout the 60-min duration, while rates for CT + DT plots increased to 3–4 mm h^{-1} during the first 25 min, then steadily increased for the remaining duration. CT − DT plots had 21% higher maximum runoff rates (R_{max}) than CT + DT plots (Table 1) (P = 0.0135). DT had no effect on R_{max} values on the mature ST10 system.

Soil loss rates for the four treatments are given in Fig. 2B. Small differences occurred in soil loss rates from ST_{10} − DT and ST_{10} + DT plots (rates were <0.05 kg m^{-2} h^{-1}). Soil loss rates for CT − DT plots increased sharply during the first 15-min, then remained at a quasi-steady-state rate (range = 0.20–0.28 kg m^{-2} h^{-1}). Soil loss rates for CT + DT plots remained <0.10 kg m^{-2} h^{-1} during the first 30-min, then increased to a quasi-steady-state rate (0.18–0.26 kg m^{-2} h^{-1}) for the remaining duration. DT had little effect on E_{max} values for CT or ST_{10} plots.

Table 1
Hydrology and erosion parameters for each treatment studied.

Treatment	AWC[a] 1 cm	AWC 15 cm	Int	INF	INF	R	R	R_{max}	E	E_{max}
	%	%	mm h^{-1}	mm h^{-1}	%	mm h^{-1}	%	mm h^{-1}	g	kg m^{-2} h^{-1}
Tifton loamy sand										
CT − DT	1.2	8.3	54 (03)[b]	36 (04)	66 (03)	18.3 (07)	34 (07)	34 (06)	1197 (14)	0.31 (06)
CT + DT	1.0	8.5	51 (04)	37 (07)	73 (04)	13.8 (11)	27 (11)	28 (05)	740 (21)	0.30 (32)
ST_{10} − DT	2.4	6.9	53 (03)	49 (02)	93 (01)	3.6 (07)	7 (06)	4 (18)	176 (32)	0.05 (38)
ST_{10} + DT	2.8	7.5	55 (03)	51 (03)	93 (01)	3.6 (11)	7 (09)	4 (08)	133 (63)	0.03 (57)
Faceville loamy sand										
CT − DT[c]	2.6	8.2	52 (05)	39 (04)	72 (01)	15 (07)	28 (09)	29 (04)	1563 (10)	0.67 (07)
CT + DT[c]	1.3	8.9	51 (05)	42 (09)	83 (05)	9 (16)	17 (21)	19 (08)	552 (14)	0.17 (17)
ST_1 − DT	1.9	6.6	49 (02)	42 (04)	87 (06)	7.2 (10)	15 (09)	12 (07)	274 (24)	0.07 (11)
ST_1 + DT	1.8	9.0	48 (02)	44 (02)	92 (01)	4.0 (05)	8 (05)	5 (11)	278 (21)	0.07 (12)

[a] AWC = antecedent water content (%); Int = rainfall intensity (mm h^{-1}); INF = infiltration (%, values is % of simulated rainfall); R = runoff (%, value is % of simulated rainfall); R_{max} = maximum 5 min runoff rate (mm h^{-1}); E = soil loss (g); E_{max} = maximum 5 min soil loss rate (kg m^{-2} h^{-1}).
[b] x (cv).
[c] Published data (Truman and Nuti, 2009).

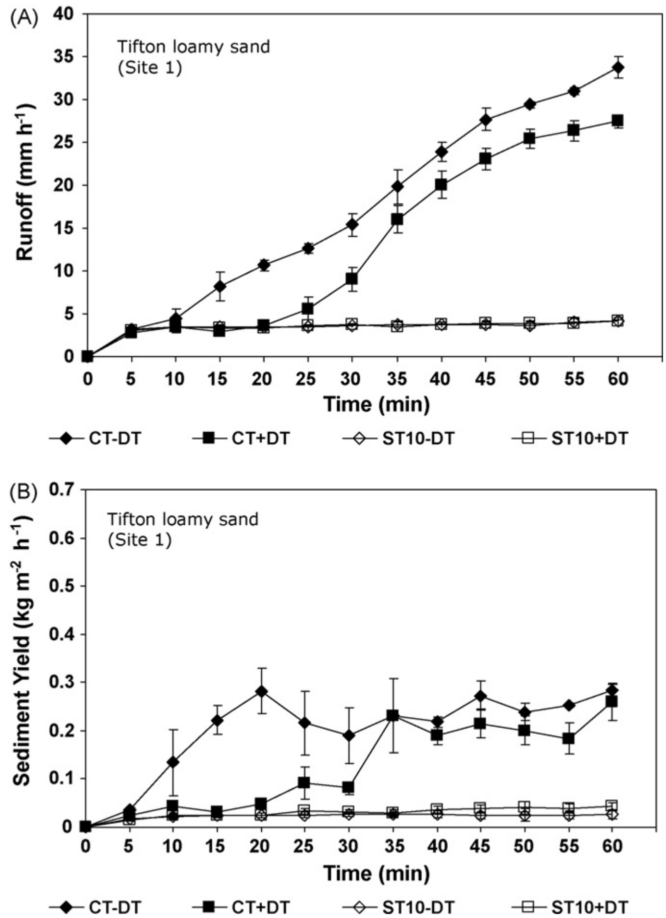

Fig. 2. Runoff and sediment rates from each treatment on the Tifton loamy sand during the 1 h of simulated rainfall ($I = 50$ mm h^{-1}; Bars = standard error, S.E.).

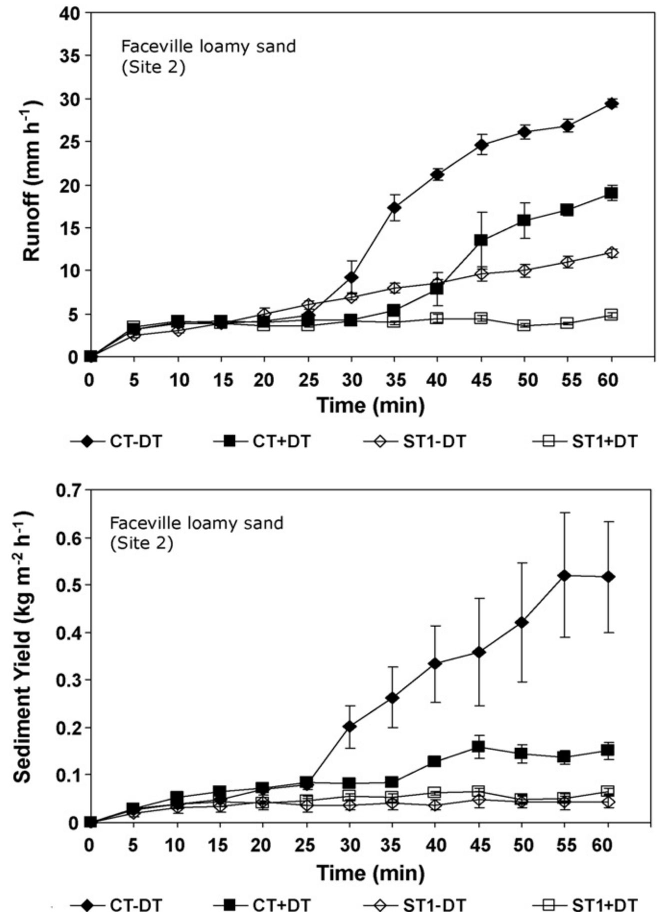

Fig. 3. Runoff and sediment rates from each treatment on the Faceville loamy sand during the 1 h of simulated rainfall ($I = 50$ mm h^{-1}; Bars = standard error, S.E.).

3.2. *$ST_1 - DT$ vs. $ST_1 + DT$*

For the Faceville loamy sand, DT influenced infiltration, runoff, and sediment yields on the CT (previously published, Truman and Nuti, 2009) and newly established ST systems ($ST_1 - DT$ vs. $ST_1 + DT$; Table 1). CT results will not be discussed fully and will only be used to make new comparisons to ST treatment results. $ST_1 + DT$ plots had 5–6% (numerically greater; NS) more infiltration (%, mm h^{-1}) and 80–88% less runoff ($P = 0.0017$ for R, mm h^{-1}; $P = 0.0014$ for R, %) than $ST_1 - DT$ plots. DT had no affect on sediment yields (E, E_{max}) for ST_1 treatments.

Runoff rates for the four treatments are given in Fig. 3A. Runoff rates for all treatments were <5 mm h^{-1} for the first 25-min of simulated rainfall. From 25 to 60 min, runoff rates for $ST_1 - DT$ plots steadily increased (12 mm h^{-1} at 60 min); whereas, runoff rates for $ST_1 + DT$ plots remained <5 mm h^{-1} for the entire 60-min rainfall (4.9 mm h^{-1} at 60-min). In comparison, runoff rates for corresponding CT treatments increased sharply from 25 to 60 min (CT − DT plots = 29.5 mm h^{-1}; CT + DT plots = 25.9 mm h^{-1}). Note that $ST_1 - DT$ plots had 2.4 times higher R_{max} values than $ST_1 + DT$ plots (Table 1) ($P = 0.0002$).

Soil loss rates for the four treatments are given in Fig. 3B. Small, non-significant differences occurred in soil loss rates with $ST_1 - DT$ and $ST_1 + DT$ plots (rates were <0.07 kg m^{-2} h^{-1} for the 60-min duration). Soil loss rates for both CT treatments did not deviate from ST rates during the first 20–25-min of rainfall. Soil loss rates for CT − DT plots increased sharply for the 25–60-min duration (0.52 kg m^{-2} h^{-1} at 60-min). Soil loss rates for CT + DT plots increased to 0.20 kg m^{-2} h^{-1} during the 25–60-min duration, then reached a quasi-steady-state rate (0.16 kg m^{-2} h^{-1} at 60-min). DT had little effect on E_{max} values for ST plots (DT had a significant effect on E_{max} values for CT plots, $P = 0.0001$).

3.3. *Impact of furrow diking*

From hydrology and sediment data measured from ST, DT, and CT plots (seedbed conditions), we quantified four trends/characteristics of DT in two major agricultural soils in the Coastal Plain region of Georgia. First, DT did not significantly impact mature

Table 2
Surface sealing and water for crop use parameters for each treatment studied.

Treatment	d INF[a]	PAW 25 mm days	PAW 50 mm days
Tifton loamy sand			
CT − DT	31 (08)[b]	3.7[c]	5.9
CT + DT	24 (04)	3.9	6.2
$ST_{10} - DT$	1 (66)	4.1	8.3
$ST_{10} + DT$	1 (18)	4.3	8.5
Faceville loamy sand			
CT − DT[d]	33 (05)	3.9	6.3
CT + DT[d]	16 (12)	3.9	7.0
$ST_1 - DT$	10 (03)	3.8	7.1
$ST_1 + DT$	2 (49)	3.7	7.3

[a] d INF = $INF_{max} - INF_{min}$; PAW = estimated available water (days) for 25 and 50 mm rainfall amounts.
[b] x (cv).
[c] Assumed ET = 6 mm day^{-1}.
[d] Published data (Truman and Nuti, 2009).

conservation tillage systems (ST_{10} – DT, ST_{10} + DT; Table 2) in terms of runoff or soil loss. In these 10-year-old systems, surface soil conditions or properties have improved in such a way that rainfall partitioning into infiltration and runoff and sediment yields have been optimized with ST alone, with no further environmental or economic benefit of DT.

Second, DT does improve rainfall partitioning into infiltration and runoff for recently adopted (1-year old) conservation tillage systems (ST_1 – DT, ST_1 + DT; Table 2). Also, DT did not negatively impact sediment delivery or sediment loss rates for these conservation tillage systems. These findings are important because ST systems used in Coastal Plain soils of Georgia typically yield soil loss benefits (reductions) immediately after adoption, yet often do not yield hydrological benefits (improved infiltration, reduced runoff) (Truman, unpublished data). Other studies have reported similar findings in that conservation tillage had no effect on rainfall partitioning in year one of conservation tillage adoption or that less runoff (more infiltration) occurred from CT compared to conservation tillage systems that were less than 3-years old (Soileau et al., 1994; Cassel and Wagger, 1996; Truman and Rowland, 2005). Furthermore, a concern with using DT in ST systems 1–3 years old to improve water (rainfall, irrigation) partitioning is that the disturbance associated with DT would cause sediment delivery to increase. This was not the case in this study.

For both soils, CT – DT plots represented the worst-case scenario in terms of measured runoff and sediment yields (ST + DT plots represented the best-case scenario). Subsequently, if one combines runoff and sediment yield data for CT – DT and CT + DT plots from these two similar surface-textured soils, trends for runoff (range = 3.6–17 mm h^{-1}), R_{max} (range = 4–32 mm h^{-1}), E (range = 133–1380 g), and E_{max} (range = 0.03–0.49 kg m^{-2} h^{-1}) decreased in order of CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT treatments. The soil surface of both loamy sand soils under CT conditions is significantly altered due to rainfall (and/or irrigation) impact compared to ST and DT surface conditions, resulting in differences in INF, R, and E. This is evident by the fact that runoff values (combined CT – DT and CT + DT plot data) from CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 17, 11, 7.2, 4, 3.6, and 3.6 mm h^{-1}, respectively. Also, R_{max} values from the CT – DT, CT + DT, ST_1 – DT, DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 32, 24, 12, 5, 4, and 4 mm h^{-1}, respectively. Residue accumulation and/or DT change the amount and rate of change in the soil's surface due to rainfall. To further illustrate surface alteration effects on R from CT, ST, and DT treatments, the change in infiltration (d INF) was calculated for each treatment (Table 2). Values of d INF (INF_{max} – INF_{min}) have been used as an indicator of surface sealing/crusting, resulting in alterations of the soil surface (Truman and Bradford, 1993; Truman et al., 2005; Truman and Nuti, 2009). The greater the d INF value, the greater the change in the soil surface of a respective treatment. Values of d INF (range = 1–32) for CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 32, 20, 10, 2, 1, and 1, respectively.

Finally, from a hydrology (R, R_{max}, d INF) standpoint, ST_1 – DT plots behaved more similarly to CT plots than to other ST plots. The increased values of R, R_{max}, and d INF for ST_1 – DT plots were less different to corresponding values for CT plots than other ST plots. Conversely, from a sediment (E, E_{max}) standpoint, ST_1 – DT plots behaved more similarly to other ST plots than CT plots. Sediment yields (combined CT – DT and CT + DT plot data) from CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 1380, 646, 274, 278, 176, and 133 g, respectively. Also, E_{max} values from CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 0.49, 0.24, 0.07, 0.07, 0.05, and 0.03 kg m^{-2} h^{-1}, respectively. The decreased values of E and E_{max} for ST_1 – DT plots were less different to corresponding values of other ST plots than for CT plots. Again, these results support the finding of DT improves rainfall partitioning into infiltration and runoff for recently adopted (1-year old) conservation tillage systems, while not negatively impacting sediment delivery or sediment loss rates.

DT and/or ST systems capture and retain more water and lose less water as runoff compared to CT systems. The question remains for producers as to whether CT and ST systems, especially for recently adopted (1-year old) conservation tillage systems, coupled with DT will translate into more plant available water, less supplemental irrigation, and improved profit margins. To address this, we used data from this study and two assumptions to calculate estimated plant available water (PAW). We assumed all INF was plant available and evapotranspiration (ET) was 6 mm day^{-1}. Plant available water estimates, expressed in days of water for crop use, for 25-mm (1-in.) and 50-mm (2-in.) and for each treatment studied is given in Table 2. Infiltration values (combined CT – DT and CT + DT plot data) from CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 36, 39, 42, 45, 48, 49 mm h^{-1}, respectively. Dividing the amount of water that infiltrated for each treatment during the 1 h simulated rainfall duration by ET gives plant available water estimates (days) for each treatment based on our assumptions. Thus, PAW (50-mm) values from CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 5.9, 6.6, 7.1, 7.5, 8.0, and 8.1 days, respectively. DT increased PAW (50-mm) values up to 11.9% for CT plots. DT only increased PAW (50-mm) values by 5.6% for ST_1 plots, and had little to no effect on ST_{10} plots. The 36-mm and 49-mm of water infiltrating into the combined CT – DT plots and ST_{10} + DT plots resulted in 5.9 (worst-case) and 8.1 (best-case) days of water for crop use. This difference (2.2 days of water for crop use or 37%) is important for low water holding capacity (loamy sand) soils in the Coastal Plain during extended drought conditions that often occur during the growing season. Also, based on these calculations of worst-case and best-case scenarios and using combined 25 mm (1-in) PAW estimates from Table 2, Coastal Plain producers utilizing ST_{10} – DT (mature ST system only) or ST_{10} + DT systems would irrigate 8 and 13% less than those using CT – DT systems. Note that in the Coastal Plain region of Georgia, 20–25 mm (0.8–1.0 in.) is a common irrigation volume per irrigation.

To further illustrate water and financial savings with DT, we assumed a field size of 49 ha (120 A), a 50 mm rainfall event, and cost to pump irrigation water is \$1.17 ha mm^{-1}. A 50 mm rain over a 49 ha field is 24,666,694 L of water. Percentages (combined CT – DT and CT + DT plot data) of the rainfall amount applied that was lost to runoff from CT – DT, CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT plots were 31, 22, 15, 8, 7, and 7%, respectively. Compared to the CT – DT treatment, the difference between INF and R for the 49 ha field managed to CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT would have saved the producer farming the 49 ha CT field \$259, \$461, \$663, \$692, and \$692, respectively, to pump the amount of water lost to R (not saved as INF) back onto the 49 ha field. This equates to \$5.30, \$9.42, \$13.55, \$14.14, and \$14.14 ha^{-1}, respectively. Note that no water/cost savings occurred for the mature ST treatment (ST_{10}) as a result of DT. These dollar values per hectare represent the water/cost saving a producer would obtain if utilizing the CT + DT, ST_1 – DT, ST_1 + DT, ST_{10} – DT, and ST_{10} + DT management treatments (and not CT – DT) on the same field. Furthermore, the most water/cost savings occurred for the CT and recently adopted ST (ST_1) treatments as a result of DT. The \$5.30, \$9.42, and \$13.55 ha^{-1} savings for the CT + DT, ST_1 – DT, and ST_1 + DT treatments represents 27%, 47%, and 68% of the cost of DT (\$20 ha^{-1}) and 37%, 67%, and 96% of the savings a producer managing the 49 ha field in ST for 10 years without DT (ST_{10} – DT) in a single 50-mm rainfall event. For row-crop producers in Georgia and Southeastern U.S. with runoff producing rainfall events during the crop growing season, DT is a management practice that is cost-effective from a natural resource conservation and financial standpoint for those producers that continue to use CT systems and especially those that have recently adopted ST systems into their farming operations.

4. Summary and conclusions

In May, 2008 and 2009, we simulated rainfall to quantify rainfall partitioning and sediment delivery (*E*) from the Tifton loamy sand and Faceville loamy sand managed under conventional (CT) and strip tillage (ST) systems with and without dike tillage (DT) at planting. Treatments (6) established on field plots (2-m wide, 3-m long) received simulated rainfall ($50\,\mathrm{mm\,h^{-1}}$ for 60 min). Runoff (*R*) and *E* were measured continuously.

DT did not significantly impact (positively or negatively) mature conservation tillage systems (ST_{10}) in terms of *R* and *E*. In these 10-year-old systems, rainfall partitioning and sediment yields have been optimized with ST alone, with no further environmental or economic benefit of DT.

DT improves rainfall partitioning into infiltration (INF) and *R* for recently adopted (ST_1) ST systems. ST_1 + DT plots had 80–88% less *R* than ST_1 − DT plots. Any disturbance associated with using DT in ST_1 systems to improve rainfall and/or irrigation partitioning did not negatively impact *E* values. These findings are important because conservation tillage systems used in Coastal Plain soils of Georgia and the Southeastern U.S. typically yield soil loss benefits (reductions) immediately after adoption, yet often do not yield hydrological benefits (improved infiltration, reduced runoff) until 3–5 years after adoption.

For both soils, CT − DT plots represented the worst-case scenario in terms of measured *R* and *E*; ST + DT plots represented the best-case scenario. Combining *R* and *E* data for CT − DT and CT + DT plots from the two soils studied yields trends for *R* (3.6–17 $\mathrm{mm\,h^{-1}}$), R_{max} (4–32 $\mathrm{mm\,h^{-1}}$), *E* (133–1380 g), and E_{max} (0.03–0.49 $\mathrm{kg\,m^{-2}\,h^{-1}}$) that decrease in order of CT − DT, CT + DT, ST_1 − DT, ST_1 + DT, ST_{10} − DT, and ST_{10} + DT treatments. From a hydrology standpoint, ST_1 − DT plots behaved more similarly to CT plots than to other ST plots. Conversely, from a sediment standpoint, ST_1 − DT plots behaved more similarly to other ST plots than to CT plots. Results support the finding of DT improves rainfall partitioning into INF and *R* for ST_1 systems, while not negatively impacting sediment delivery.

Plant available water (PAW) estimates (50-mm) (combined CT − DT and CT + DT plot data) from CT − DT, CT + DT, ST_1 − DT, ST_1 + DT, ST_{10} − DT, and ST_{10} + DT plots were 5.9, 6.6, 7.1, 7.5, 8.0, and 8.1 days, respectively. DT had no effect on ST_{10} plots. The 36-mm and 49-mm of water infiltrating into the combined CT − DT and ST_{10} + DT plots resulted in 5.9 and 8.1 days of water for crop use. This difference (2.2 days of water for crop use or 37%) is important for low water holding capacity (loamy sand) soils in the Coastal Plain during extended drought conditions that often occur during the growing season.

Water and financial savings occurred with DT. Compared to the CT − DT treatment, an agricultural field managed to CT + DT, ST_1 − DT, ST_1 + DT, ST_{10} − DT, and ST_{10} + DT would save the producer farming the CT − DT field \$5.30, \$9.42, \$13.55, \$14.14, and \$14.14 $\mathrm{ha^{-1}}$, respectively, to pump the amount of water lost to *R* and not saved as INF back onto the field. No water/cost savings occurred for the mature ST_{10} treatment as a result of DT. The most water/cost savings occurred for the CT and ST_1 treatments as a result of DT. The \$5.30, \$9.42, and \$13.55 $\mathrm{ha^{-1}}$ savings for the CT + DT, ST_1 − DT, and ST_1 + DT treatments represents 27%, 47%, and 68% of the cost of DT (\$20 $\mathrm{ha^{-1}}$) and 37%, 67%, and 96% of the savings a producer would have if managing the agricultural field in ST for 10 years without DT (ST_{10} − DT) in a single 50-mm rainfall event. For row-crop producers in Georgia and Southeastern U.S. with runoff producing rainfall events during the crop growing season, DT is a management practice that is cost-effective from a natural resource and financial standpoint for those producers that continue to use CT systems and especially those that have recently adopted ST systems into their farming operations.

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