Effectiveness of Post-Harvest Sugarcane Residue and Polyacrylamide on Reducing Soil Deposition in Quarter-Drains

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

Abstract. *Each spring, small ditches perpendicular to sugarcane rows (quarter-drains) that are responsible for transferring runoff from furrows to main ditches have to be re-conditioned to be effective. Bare soil surfaces in quarter-drains and furrows are exposed to intense rainfalls. Raindrop energy from rainfall causes detachment of soil particles and sediment transport from furrows through quarter-drains to main ditches. In time, sediment transported from furrows that accumulates in main ditches diminishes the capacity of these structures, thus requiring frequent and costly sediment cleanup. On average, yearly cost of sediment cleanup from surface ditches is $293/ha. Present practice in managing post-harvest residue is burning. However, burning is a questionable management practice and has a negative effect on the environment and human health due to discharging toxic gases into the atmosphere. An alternative to burning is to leave sugarcane residue on the surface after harvest. This practice could provide multiple benefits such as reducing soil sediment, enhancing soil quality in terms of increasing soil organic carbon, and decreasing cost for cleanup of surface ditches. To evaluate these benefits, an experiment was conducted to study effects of sugarcane post-harvest residue and Polyacrylamide (PAM) applied directly to quarter-drains in spring 2003. Twelve plots (0.1 ha each) were planted to sugarcane. For the residue treatment, residue was left on site after harvest and swept to furrows. Comparison was made with similar quarter-drains on six plots where residue was removed by burning. Treatments were: (1) residue left on the field; (2) no residue; (3) residue + PAM applied; and (4) no residue + PAM applied. Following each rainfall event, which produced runoff (four events), measurements of erosion/sedimentation depths were obtained. Based on the data, soil deposition in quarter-drains was the main process and the measurements represent the combined effect of treatments on the field and sediment transport through the quarter-drains. The sediment deposited in quarter-drains originated both from furrows and from side walls of quarter-drains. Sediment deposition rather than typically expected soil erosion in quarter-drains was related to unusually dry weather during the experiment. The sediment was measured at four locations along the length of the quarter-drain. A custom-made portable device was used to determine cross-sectional area of each semicircular quarter-drain at selected grid points. Based on four rainfall events with a cumulative depth of 105 mm, sugarcane residue left on the field significantly reduced soil deposition by 28% in quarter-drains compared to residue removed by burning. Results also show that, in addition to residue left on the field, applying an aqueous PAM solution to quarter-drains further reduced soil deposition by 34%; however, no significant difference in soil deposition was found between residue only and residue + PAM treatments. Data suggest that PAM effectiveness was likely inhibited by abnormally dry and hot weather in spring, 2003, and might be related to the polymer's chemical, photo, and mechanical degradation. Leaving sugarcane residue on the field after harvest instead of burning could reduce soil loss from furrows and surface drains by 4.2 tons per year. This type of residue management might also provide economical benefits due to reducing reformation cost of surface drainage ditches within the field with an average yearly savings of $106/ha.*

Keywords. *Sugarcane residue, PAM, Soil erosion, Soil deposition, Quarter-drain.*

Alluvial soils in Southern Louisiana contain significant amounts of clay in the top layer which are susceptible to significant soil erosion and sediment transport downslope to surface drainage ditches. Schwab et al. (1993) stated that soil transport in runoff increases as soil particle size decreases, thus on bare soil up to 200,000 kg/ha of soil is splashed into the air by falling rain drop energy. Sediment from eroded soils, which is transported with runoff water downslope through the field, is proportional to flow velocity with finer particles deposited further downslope than larger particles (Haan et al., 1994). Appelboom et al. (2002) reported that sediment has been identified as one of the most important non-point source pollutant that affects water quality including degradation of surface water for irrigation and drinking purposes. Long (1991) stated that agriculture accounts for up to two-thirds of the non-point source pollution. Introduction of sediment and absorbed pollutants such as pesticides, metals and nutrients to streams and lakes threatening the nation's water resources (Erman and Ligon, 1988). According to Lichatowich et al. (1999) in the U.S. Pacific Northwest, high sediment in runoff from agriculture is responsible for the deterioration of aquatic life in rivers of that region.

Submitted for review in January 2006 as manuscript number SW 6284; approved for publication by the Soil & Water Division of ASABE in August 2006.

The use of trade names or company names does not imply endorsement by USDA-ARS.

The authors are **Ted S. Kornecki, ASABE Member,** Agricultural Engineer, USDA–ARS, National Soil Dynamics Lab., Auburn, Alabama; **Brandon C. Grigg,** Soil Scientist, USDA–ARS Soil and Water Research Unit, Baton Rouge, Louisiana; **James L. Fouss, ASABE Fellow,** Agricultural Engineer, Research Leader, and **Lloyd M. Southwick,** Soil Chemist, USDA–ARS Soil and Water Research Unit, Baton Rouge, Louisiana. **Corresponding author:** Ted S. Kornecki, USDA–ARS, National Soil Dynamics Lab., 411 S. Donahue Dr., Auburn, AL 36832; phone: 334-844-4741; fax: 334-887-8597; e-mail: tkornecki@ars.usda.gov.

Post-harvest residue has been shown to significantly reduce rainfall energy, which is largely responsible for soil erosion, by protecting the soil surface from raindrop impact. The primary benefits of crop residues are reduction of soil erosion, improvement of soil properties, and reduction of soil surface sealing effects (Schwab et al., 1993). Dickey et al. (1986) reported that crop residue was increasingly being used as a major tool to reduce the loss of topsoil. Conservation practices encourage the use of residue as a protective blanket from rainfall and to enrich soil structure by increasing organic matter content.

Blough et al. (1990) used countered slit treatment to determine soil erosion from residue cover and bare soil. They concluded that 30% of residue cover with slit treatment produced 25% less runoff and 50% less erosion than the bare soil. According to Brown and Norton (1994), who examined the residue effect on erosion from consolidated ridges in a poorly drained silt loam soil, the average detachment rate and average flow velocity decreased 92% and 71%, respectively, with 45% corn residue cover. Gilley et al. (1986) stated that even small amounts of crop residue substantially reduced soil erosion.

Another method in controlling soil erosion has been an application of polymers to the soil surface. Polyacrylamide (PAM) has been a focus technology for reducing soil erosion due to environmental concerns related to negative impacts of soil erosion from irrigated agriculture. Sojka et al. (1998) reported that PAM, when applied to irrigation water, nearly eliminated soil erosion caused by irrigation. For more than a decade, PAM has effectively controlled soil erosion induced by irrigation water flowing in surface channels in the Northwestern region of the United States (Lentz et al., 1992; Sojka and Lentz, 1994; Trout et al., 1995). Peterson et al. (2003), who studied PAM effect on sediment yield in small experimental earthen waterways, reported that PAM solution applied to the channel's surface reduced sediment yield ranging from 93% to 98% in comparison to untreated channels. Lilleboe (1997) reported that in 1996 approximately 150,000 ha were successfully treated by PAM in the western United States. According to the USDA-NASS (1998) over 140,000 ha were treated with PAM nationally, mostly in the western states with Idaho having the maximum treatment area of 35,500 ha.

The new family of high molecular weight anionic PAM exhibits low toxicity to mammals and has a low content of residual monomer acrylamide, typically less than 0.05% (Stephens, 1991). PAM degradation in soil systems occurs over time via chemical and biological hydrolysis, sunlight, temperature, and physical breakdown (Wallace et al., 1986; Tolstikh et al., 1992) at a rate of 10% per year (Azzam et al., 1983). Bjorneberg et al. (2000) studied combined effects of residue cover and PAM on soil erosion. They stated that applying PAM to straw-covered soil controlled runoff, erosion, and phosphorus losses better than using either PAM or straw residue alone.

There have been many reports related to PAM application rates and methods. Shainberg et al. (1990) concluded that applying 20 kg/ha was most effective in maintaining a high infiltration rate, thus minimizing sealing and runoff. Addition of small amounts of polymers (10-20 kg/ha), either sprayed directly on the soil surface or added to the applied water, stabilizes and cements together aggregates at the soil surface and thus increases their resistance to seal formation (Shainberg and Levy, 1994). According to Letey (1994), PAM adsorption occurs mainly on the external surface of clay particles because the high molecular weight of PAM does not penetrate soil aggregates. PAM adsorption on soil particles is related to soil aggregate size and molecular conformation of PAM rather than whole soil surface area. Because of many reports related to high effectiveness of PAM in reducing soil erosion in western states, we used a high molecular weight of anionic PAM to determine if spray applying an aqueous solution of PAM directly to quarter-drain can also be effective in reducing soil erosion in these structures.

Historically, sugarcane residue has been removed by burning, which eliminated the benefits of maintaining residue cover, to reduce soil erosion. In addition, burning of residue increases the loss of organic carbon from these naturally low organic matter (<1.0%) alluvial soils. In Louisiana, 7 to 24 tons/ha of sugarcane residue is lost due to burning each year (Boopathy, 2004). In recent years, however, burning cane has become objectionable to the general public because of health issues related to inhalation of smoke. Increasingly, it is difficult to justify this method as a Best Management Practice (BMP) of residue management. Environmental concerns about burning and public concerns for clean air, especially in newly developed suburban areas adjacent to sugarcane plantations, has also moved the sugar industry toward green cane harvesting that leaves all residue on the surface. Because of these concerns, there is a need to find economical alternatives for its management and to identify benefits from residue with respect to reducing soil erosion and improving soil quality.

Each year in early spring, quarter-drains are installed or refurbished perpendicular to the furrows in sugarcane fields to provide drainage of runoff water from furrows and route it to main surface drainage ditches. The installation of a new quarter-drain requires removal of about 0.065 m^3 of soil per linear meter of length, which is discharged (airborne) by the installation equipment over the adjacent field surface. Based on an average bulk density of 1.45 Mg/m^3 for clay loam soil, the mass of soil removed is about 90 kg/m (Kornecki et al., 2005). Intense rainfall events during spring in Southern Louisiana commonly have rainfall energies that can severely erode topsoil in sugarcane fields, including the quarter-drains. Without adequate protection, sediment is eroded from the soil surface and is carried with surface runoff waters causing sedimentation to quarter-drains, culverts, and main ditches. The sediment build-up diminishes capacity and functionality of the surface drainage system within the field, thus requiring frequent cleanup and sediment deposit removal from surface ditches. This is especially important in the Lower Mississippi River Valley where flat agricultural land (slopes from 0 to 0.5%) provides only a limited outflow of runoff waters from sugarcane fields.

Residue protects the soil surface from raindrop impact, thus reducing soil particle detachment. In addition, transport capacity is reduced because crop residue forms a complex series of small dams that slow the runoff's velocity. Therefore, maintaining good functionality of the surface drainage system including quarter-drains is essential to provide adequate drainage for optimum sugarcane growth.

To address erosion/sedimentation in quarter-drains, two different sugarcane post-harvest residue management practices and PAM treatment to quarter-drains were investigated to determine benefits from sugarcane residue and PAM under

Southern Louisiana weather conditions. The objective of this study was to evaluate the effectiveness of sugarcane residue left on the soil surface after harvest and PAM effectiveness applied as a water solution directly to quarter-drains in reducing soil loss/deposition from quarter-drains under natural weather conditions.

Methods and Materials

Soil at the research site was a Commerce silt loam (fine-silty, mixed, nonacid, thermic, Aeric Fluvaquents). Following the 2002 fall harvest of sugarcane, residue in the amount of 8600 kg/ha was discharged by the chopper harvester and left on the entire study area. The residue mainly contained pieces of leaf parts chopped to 10-15 cm in length and finer pieces of sugarcane stalk. The residue was swept from the row-tops to the furrows spaced every 1.8 m using a three-row mechanical rotating brush. Sweeping of residue from the top of rows was required to provide adequate soil moisture and temperature conditions for the next growing season in 2003 (early spring) to optimize emergence of sugarcane. The width of sweeping from the row-tops was 0.4 m. Swept residue formed a band in furrow 1.3 m wide and maintained residue coverage of 71%.

An experiment was initiated to determine the effectiveness of residue cover and PAM on stability of freshly constructed quarter-drains on plots (0.2 ha) planted to sugarcane. A total of 12 identical (0.1 ha each) experimental units (6 plots) were used. For the residue treatment, residue was left on site after harvest and swept to furrows providing approximately 71% of residue cover. Comparison was made with similar quarter-drains on six experimental units where residue was removed by burning. The experiment was a split block design with two main treatments: (1) residue left on the field (Residue); (2) residue removed through burning (No-Residue). Within each residue treatment, two sub-main treatments were assigned: (3) PAM applied to quarter-drain (Residue + PAM) and (4) No Residue + PAM applied (PAM) treatment. Each treatment was replicated three times with measurements of cross-sectional area of the quarter-drain following each rainfall event. Statistical analyses were performed by (SAS, 2001) using appropriate GLM procedure. Treatment means were compared using Fisher's Least Significance Difference (LSD) (Steel and Torrie, 1980) at $\alpha = 0.1$ significance level. To determine treatment effects for the whole experiment, statistical analyses were done across all rainfall events. Data were also analyzed on an individual rainfall event basis to illustrate cumulative treatment effects for the duration of the experiment.

The cross-sectional area of each quarter-drain was measured to determine soil erosion/deposition. Measurements were obtained at the same four locations (every 1.78 m) on each quarter-drain. The experimental design for each plot is shown in figure 1. The main ditch was located in the middle of each plot and two perpendicular 13.5-m long quarter–drains were constructed at the end of the plot with the opposite slope of 0.2% toward the main ditch. The initial cross-sectional area was measured immediately after quarter-drains were constructed or refurbished.

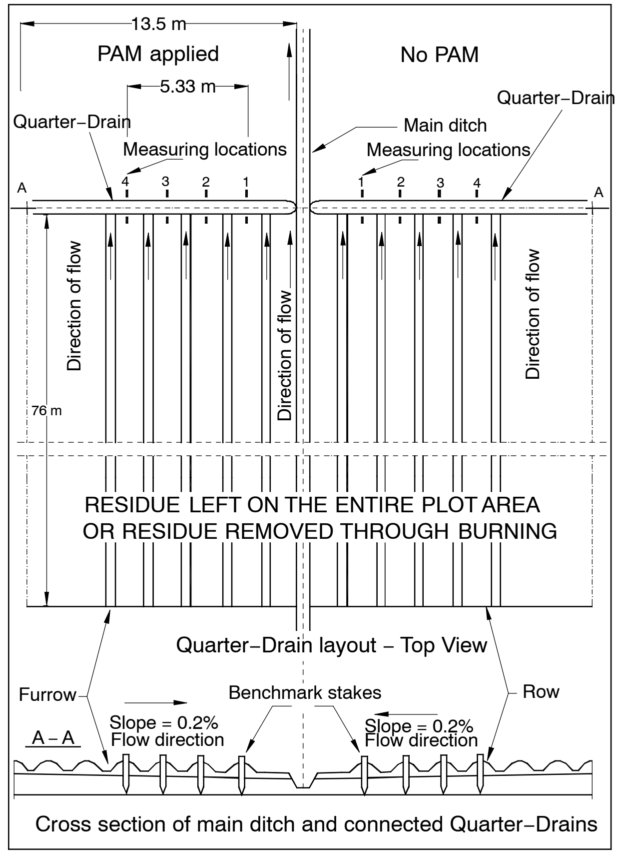

Figure 1. Experimental plot (0.2 ha) layout design. Sugarcane residue was main-plot effect and left on/removed from the whole area (two experimental units). PAM was applied directly to the 13.5-m length of quarter-drain.

Soil Deposition Measurements

Following each rainfall event which produced runoff, soil deposition was measured in all quarter-drains. A custom-made portable device was used to determine cross-sectional area of each semicircular quarter-drain selected grid points. The device, consisting of 19 equally spaced 6-mm diameter aluminum rods, was placed on the bench-marks (wooden stakes) and the rods carefully lowered until making contact with the soil surface of the quarter-drain (fig. 2). Overall, the device performed very well, requiring only occasional wiping of soil from the aluminum rods. This device could be scaled up in size to measure soil erosion or deposition in larger surface ditches especially in situations when runoff and sediment measurement data were not available.

Determination of the initial cross-sectional area was based on calculating areas of 18 trapezoids and summing them. Since the spacing between centers (b) of all rods is a constant, the initial cross-sectional area was calculated as a sum of trapezoidal areas (fig. 3):

$$A1 = (H1 + H2) \times b/2;\ A2 = (H2 + H3) \times b/2;$$

$$A3 = (H3 + H4) \times b/2;\ ...\ A18 = (H18 + H19) \times b/2;$$

By adding sections of areas between each rod the total area of the quarter-drain was calculated:

$$At = A1 + A2 \ldots + A18 = b/2 \times (H1 + H2 + H2 + H3 + H3 + \ldots + H18 + H18 + H19)$$

Figure 2. Portable device to measure soil erosion/deposition in quarter-drain.

At = b/2 × (H1 + 2* × H2 + 2 × H3……..+ 2 × H18 + H19)

The cumulative eroded/deposited area was calculated by subtracting the initial cross-sectional area from consecutive measurements following a rainfall event. The net eroded/deposited area was calculated by subtracting previous rainfall area from last rainfall event. A negative number of the cumulative/net area indicates erosion and a positive number-indicates deposition of soil. Next, the average void/deposition area was calculated for the full length of quarter-drain (sum of all voids/depositions from the full length of quarter-drain divided by number of measuring locations). The soil loss/deposition volume was calculated as:

Net soil deposited = Avg Net Area × length of quarter-drain;

Cum. Soil deposited = Avg Cum area × length of quarter-drain.

The average soil bulk density of 1.45 g/cm^3 for these plots was multiplied by the void volume to obtain the mass of soil erosion.

A plastic container (890 L) and a submersible low pressure 3.2-L/s water sump-pump were used to prepare an aqueous PAM solution. The equivalent of 18-kg/ha anionic PAM was added to the circulating water. The mixing was done in minimum time and stopped as soon as PAM granules were not visible to provide a smooth solution without forming clusters which would otherwise plug the nozzles and inhibit the discharge.

On 23 April 2003, a high molecular weight (14 millions), having 30% anionic charge density with 100% active ingredient PAM (Floeger AN 934 SH, Chemtall Inc., Riceboro, Ga.) was mixed with water and sprayed directly on the bare soil in the quarter-drains at a rate of 18 kg/ha in one application (four nozzles at 4.5 kg/ha per one nozzle) with a concentration of 250 mg/L of water mixed by mechanical water pump. This was the maximum PAM concentration in terms of viscosity that could be handled by the nozzle and still provide an optimum coverage spray pattern. A three-point-hitch 115-L sprayer was used to spray PAM into quarter-drains. The sprayer had four nozzles (discharge of 5.5 L/min per nozzle) mounted on two opposite sides at the end of a square steel boom.

Results and Discussion

Treatment Effects

Soil deposition in quarter-drains was the main process observed in this experiment, and measurements represent the combined effect of treatments on the field (sediment transported from field and furrows) and sediment which originated in quarter-drains from side walls and transported through the quarter-drains. Sediment deposition in quarter-drains was related to unusually dry weather conditions and

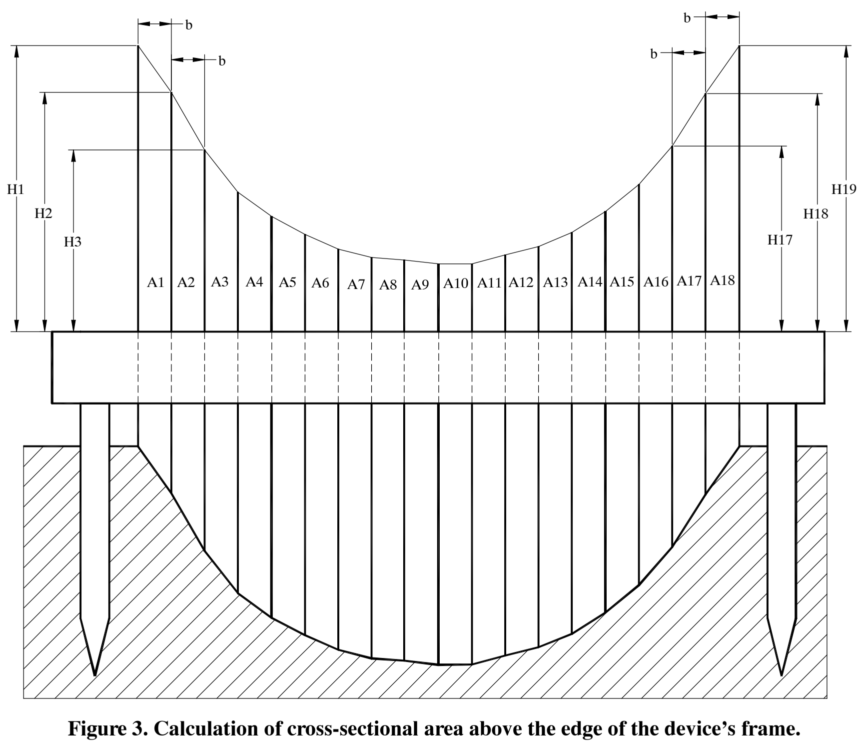

Figure 3. Calculation of cross-sectional area above the edge of the device's frame.

less intensive rainfall events. Rainfall depth during the experiment was only 21% of the average rainfall that normally occurs during that period. With a typical weather pattern in Southern Louisiana, soil erosion would be expected in quarter-drains rather than deposition because of higher flow volume and higher velocity of runoff water. Overall, there was a significant difference between main Residue treatments (p-value < 0.0001). No significant difference was found between PAM treatments (p-value ≤ 0.868). When averaged over four rainfall events residue cover reduced cumulative soil deposition in the quarter-drains by 28% relative to no-residue, i.e. from 13.8 kg/m for no-residue to 10.0 kg/m for Residue treatment, indicating that residue cover was mainly responsible for reducing soil deposition in quarter-drains. No difference in soil deposition was found between PAM (15.8 kg/m) and no-residue (13.8 kg/m) treatments. However, higher soil deposition in the quarter-drains for the PAM treatment might indicate that PAM provided some soil protection from erosion in the quarter-drains. Assuming that for both treatments the same amount of sediment was transported from furrows to quarter-drains; it appears that for PAM less soil from the quarter-drains was eroded so the net soil deposition in quarter-drains with PAM applied was higher. Although no difference was found between Residue + PAM (9.1 kg/m) and Residue (10.0 kg/m) treatments, Residue + PAM helped to further reduce soil deposition by 34% in comparison with the no-residue treatment (fig. 4).

Cumulative soil deposition in quarter-drains for residue and PAM treatments after each rainfall event are shown in table 1. After the first rainfall Residue + PAM treatment (4.0 kg/m) resulted in the highest reduction of soil deposition (58%) in comparison with the no-residue treatment (9.6 kg/m). Cumulative soil deposition in the quarter-drain did not differ between residue (5.6 kg/m) and residue + PAM treatment (4.0 kg/m). Likewise, no difference was found between PAM (10.4 kg/m) and no-residue (9.6 kg/m), suggesting that residue cover mostly reduced soil deposition in the quarter-drains.

Similar relationships were found after the second rainfall event. Cumulative quarter-drain soil deposition for the residue treatment was 10.3 kg/m and residue reduced soil deposition in quarter-drains by 28% compared with no residue (14.4 kg/m). No difference in soil deposition amount was found between residue (10.3 kg/m) and residue + PAM (9.6 kg/m) treatments. Residue + PAM provided the highest

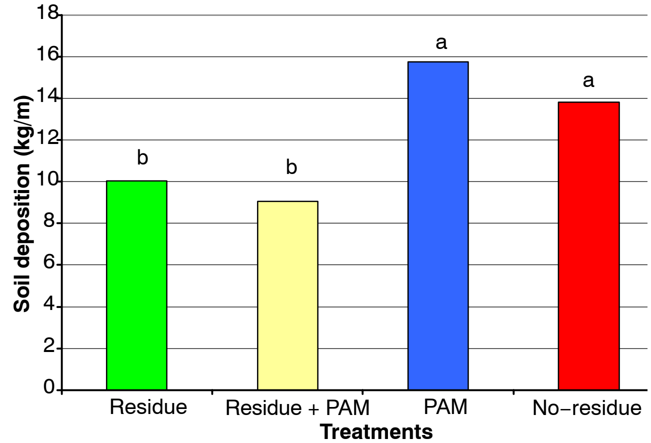

Figure 4. Cumulative soil deposition in quarter-drains averaged over four rainfall events.

reduction of soil deposition (33%) in comparison to no-residue (14.4 kg/m) and PAM (14.3 kg/m). The cumulative soil deposition in quarter-drains following the third rainfall was similar to that for the second rainfall for all treatments and most likely was associated with its short duration and smaller amount of rainfall produced (13 mm). No differences were observed between residue (10.8 kg/m), residue + PAM (9.6 kg/m), and no-residue (13.4 kg/m). However, despite a lack of significant differences, residue + PAM provided the highest soil deposition reduction (28%) when compared with no-residue.

After the fourth rainfall, no difference was observed between residue (13.4 kg/m), residue + PAM (13.1 kg/m), and no-residue (18.0 kg/m), although, residue and residue + PAM treatments reduced soil deposition by 26% and 27%, respectively, in comparison with no-residue treatment. PAM applied to quarter-drains helped to reduce soil deposition, but only when residue was present on the field. Higher soil deposition was observed for PAM (22.4 kg/m) in comparison with no-residue treatment and might indicate that with PAM less erosion occurred in quarter-drains, assuming that both treatments received the same amount of sediment from furrows.

It appears that soil deposited in the quarter-drains was most likely caused by unusually dry weather that resulted in low runoff amounts had enough energy to transport sediment from furrows to quarter-drains rather than carrying sediment

Table 1. Cumulative soil deposited for four rainfall events.[a]

Rainfall number	1	2	3	4	Overall Cumulative Average
Rainfall date	6 June 2003	11 June 2003	23 August 2003	13 September 2003	
Rainfall depth net/cumulative (mm)	16 / 16	43 / 59	13 / 72	32 / 104	
Rainfall intensity (mm/h)	3.3	4.0	6.4	3.6	
Treatment	Cumulative Soil Deposition (kg/m-drain)				
Residue	5.6b	10.3b	10.8b	13.4b	10.0b
No residue	9.6a	14.4a	13.4ab	18.0ab	13.8a
Residue + PAM	4.0b	9.6b	9.6b	13.1b	9.1b
PAM	10.4a	14.3a	15.6a	22.4a	15.8a
LSD 0.1	3.3	3.0	4.6	6.7	2.9

[a] Values followed by the same letter are not significantly different for Residue and PAM treatments. Comparisons are valid only within columns for each rainfall event.

from furrows further downslope. Data indicate that the higher soil deposition in the quarter-drains of no-residue plots resulted from increased erosion on the bare soil from the field and in the furrows, which were exposed to rainfall energy and increased soil particle detachment. In addition, the heat from burning cane residue might decrease infiltration, contributing to increased runoff amounts from furrows that carry sediment. Robichaud (2000), who studied the effects of forest fires on soil infiltration, stated that the heat from burning caused formation of hydrophobic substances on soil surfaces which decreased soil hydraulic conductivity by 10% to 40%. Sugarcane residue reduced sediment buildup in quarter-drains during the entire experiment presumably by intercepting rainfall energy, minimizing splashing, and lowering velocity of surface runoff in furrows (Schwab et al., 1993). Savabi and Scott (1994) studied effects of residue covers on interception of rainfall energy and concluded that winter wheat residue significantly increased interception of rainfall energy when compared with the same amounts of less dense residues from corn and soybean. According to McGregor et al. (1990), a 79% cover of wheat residue reduced soil erosion by 88% under simulated rainfall.

In addition to effective soil protection from erosion, residue plays an important role in carbon sequestration. According to Brady and Weil (1999) all plant dry tissue material contains ~42% carbon. During decomposition of sugarcane residue, approximately two-thirds of the carbon is used by microbes as a source of energy. However, about one-third of carbon is converted by microbes to soil organic carbon. Based on the amount of sugarcane residue discharged after harvest (8600 kg/ha dry mass) the total amount of carbon from residue is over 3600 kg/ha, thus 1200 kg of carbon per ha could be sequestered in the topsoil. This is especially important from the standpoint of building up the organic carbon level of low organic content alluvial soils (less than 1%) in southern Louisiana. When sugarcane residue is removed by burning, over 3600 kg/ha of carbon is released to the atmosphere as carbon dioxide. During burning other toxic gases are also released. There is a growing concern with smoke inhalation problems on newly developed residential communities and schools located close to sugarcane fields as human population around sugarcane fields increases. Smoke from burning sugarcane residue accounts for up to 21% of total air pollution in Louisiana which is known to cause public health problems such as asthma and emphysema (Boopathy, 2004).

Based on visual observations and measurements of quarter-drains cross-sections, there was evidence of soil erosion from the sides of the quarter-drain in several measuring locations especially after the first rainfall. The highest erosion depth occurred for PAM and no-residue treatments at both side walls of the quarter-drains with an 8-mm erosion depth at the edges that progressed approximately 150 mm toward the quarter-drain's center with an erosion depth of 4 mm. However, it appears that the sediment found in the quarter-drains was transported with runoff from field and furrows and was much greater than the quarter-drain erosion, with deposition as the net result. The main reason for deposition was that very low runoff had insufficient energy to cause appreciable erosion to the quarter-drains. Low runoff was related to the dry periods with very low rainfall (105 mm) during the experiment. In a typical year during the similar period of this experiment, over 500 mm of rainfall is usually occurring in Southern Louisiana causing erosion to quarter-drains rather than deposition. A study of soil erosion in quarter-drains conducted by Kornecki et al. (2005) showed that with 368 mm of rainfall in a similar period in 2002, quarter-drains were eroded since runoff amount was much higher.

Second, abnormally dry and hot weather conditions in the spring of 2003 might have caused degradation of PAM because no precipitation occurred between the PAM application date (23 April) and 11 June when the first rainfall occurred. During that 49-day period, the direct sun exposure of treated quarter-drain soil to UV radiation caused the breakdown of PAM's long chain. Seybold (1994) stated that changes in PAM chemical composition were related to environmental factors such as sunlight, chemical hydrolysis, and mechanical degradation. Research has shown that the majority of PAM photodegradation caused changes in both the physical and chemical properties of polymer due to the absorption of energy via photons of sunlight having a sufficient energy to disrupt chemical bonds and to reduce the molecular weight of the degraded PAM (Caulfield et al., 2002; Kishore and Bhanu, 1988; Rabek, 1996). According to Sohma (1989), when a sufficient mechanical energy is transferred to the polymer chain, bond separation occurs causing the formation of free unstable radical species that further degrades PAM. Likewise, a study conducted by Bjorneberg (1998) indicated that PAM efficacy can be significantly lowered during the mixing and spraying process due to a reduction in PAM's chain length. Wallace (1986) also noted that PAM degrades during soil disruption such as cultivation causing soil surface separation and destroying the polymer's chain. During the first 49 dry and hot days of the experiment, we observed a formation of cracks throughout the soil surface in quarter-drains. It appears that the crack formation (break in cohesive forces at the surface due to shrinking soil) could also have caused irreversible mechanical degradation of PAM, thus further diminishing PAM effectiveness.

Rainfall Effects

To determine which rainfall event caused the highest soil deposition in the quarter-drains, net soil depositions for each of four rainfalls were averaged over all treatments (fig. 5). There was a significant difference in net soil deposition between rainfall events (p-value < 0.0001). Data showed that the highest net deposition in quarter-drains was generated by the first rainfall (7.4 kg/m). There were no differences in soil deposition produced by rainfall 2 and 4 (4.7 and 4.3 kg/m). Rainfall 3 produced the least amount of sediment (0.3 kg/m), LSD = 1.35 (fig. 5).

To determine if the rainfall amount and rainfall intensity had an influence on soil deposition a simple regression analysis was performed. The regression results are shown in table 2. There was a poor correlation between rainfall amount and soil deposition in quarter-drains produced by each rainfall (R-square = 0.59 for residue + PAM treatment, with P-significance ≤ 0.231); however, no correlation was found between rainfall amounts and other treatments. Better correlation was found between rainfall intensity and soil deposition produced by each rainfall for all treatments with R-squares between 0.695 and 0.802, indicating that soil deposition was associated with rainfall intensity rather than rainfall amount (table 2). Examining the contribution of each

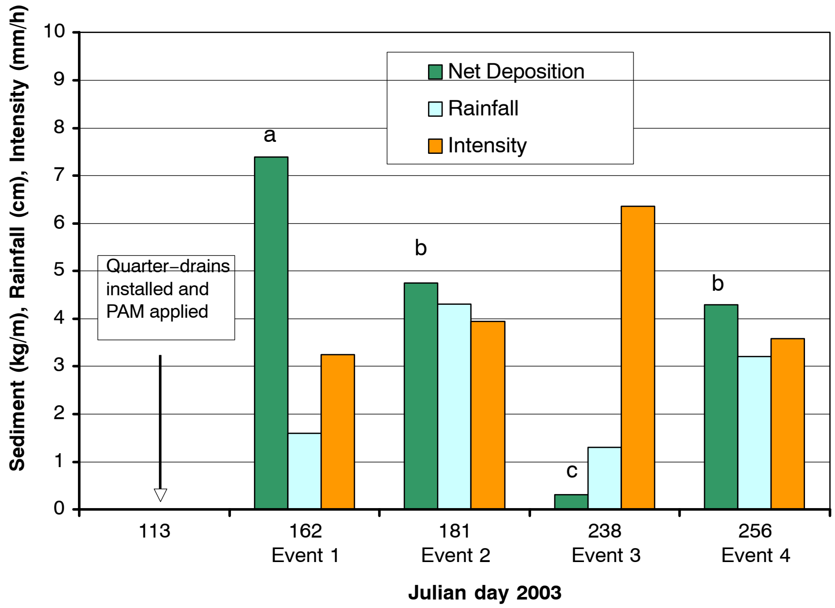

Figure 5. Rainfall effects in net soil deposition in quarter-drains averaged over treatments for each rainfall event. Values followed by the same letter are not significantly different.

rainfall event to net soil deposition for all treatments, the data in table 2 indicate that each rainfall caused sedimentation in quarter-drains except after the third rainfall event. After the third rainfall erosion in quarter-drains was observed only for the No-residue treatment. It appears that exposing bare and unprotected soil to the highest rainfall intensity (6.4 mm/h), the third rainfall had enough energy to cause erosion to the quarter-drain, but most likely did not have enough energy to produce sediment and runoff contributions from furrows.

Quarter-drains are an annual expense and these structures have to be refurbished each spring for sufficient transfer of runoff waters from furrows through the quarter-drains to main ditches. Typically, Southern Louisiana receives up to 1500 mm of rainfall per year causing soil losses over 9900 kg/ha (Bengston et al., 1995). Our results showed that residue + PAM applied to quarter-drains reduced sediment deposition in quarter-drains by 42% compared to PAM. Assuming a 42% reduction of soil erosion from quarter-drains and furrows during a typical year, about 4200 kg/ha of sediment buildup in main ditches might be reduced by leaving sugarcane residue in furrows after harvest. Cleaning ditches is costly and a very time-consuming process. On the actual cost of cleaning ditches from our experiment site in St. Gabriel, a backhoe must be rented for two weeks (every other year) which amounts to $1400 ($700/week) and $2400 to pay a skilled operator. The operator cost was based on 40 hours per week (80 hours) and an operator wage of $30/hour. In addition, fuel and maintenance cost was $480. The recent increase in higher fuel prices most likely will increase this amount. Adding these costs, the total cleaning cost every other year is $4680 per 8 ha of sugarcane land ($585/ha). Therefore, an average the yearly cost for sediment removal from main ditches is $292/ha. With a 42% reduction of soil erosion, residue left on site would provide savings of $123/ha on a yearly basis. Adjusting for the actual cost for sweeping of sugarcane residue to furrows using mechanical sweeper that was $17/ha in 2004 in Houma Sugarcane Research Station, Louisiana (Viator, 2004), the total yearly savings to sugarcane producers would be $106/ha.

Summary and Conclusions

Results of this study show that soil deposition in quarter-drains was the main process observed in this experiment, which occurred due to unusually dry weather

Table 2. Net soil deposition (kg/m) vs. rainfall amount and intensity with their regression parameters for residue and PAM treatments.

Rainfall No.	Rainfall Depth (mm)	Rainfall Intensity (mm/h)	Fisher's LSD	Residue	No Residue	Residue + PAM	No Residue + PAM	Averaged Across Treatments
1	16	3.3	3.29	5.64b[a]	10.39a	3.98b	9.56a	7.4a[b]
2	43	4.0	1.51	4.62ab	4.82ab	5.63a	3.89b	4.7b
3	13	6.4	2.19	0.57ab	−1.0b	0.01ab	1.68a	0.3c
4	32	3.6	4.48	2.56a	4.64a	3.47a	6.48a	4.3b
Average			1.5	3.34b	4.7ab	3.3b	5.4a	LSD = 1.4
Regression parameters	Rainfall amount vs. net soil deposition		R-square	0.100	0.009	0.59	0.007	
			F-significance	0.683	0.903	0.231	0.913	
	Rainfall intensity vs. net soil deposition		R-square	0.695	0.802	0.704	0.727	
			F-significance	0.166	0.104	0.160	0.147	

[a] Values followed by the same letter are not significantly different. Comparisons are valid only within rows for each rainfall event.
[b] Comparisons of net soil deposition averaged across Residue and PAM treatments are valid within last column.

conditions. Measurements obtained during the investigation represent the combined effect of treatments on the field and sediment transported through the quarter-drains.

Based on four rainfall events with a cumulative rainfall amount of 105 mm, sugarcane residue left in furrows and residue left in furrows with PAM applied to quarter-drains reduced soil deposition in quarter-drains by 28% and 34%, respectively, in comparison with residue removed from site by burning.

The maximum treatment induced reduction in soil deposition to quarter-drains was observed after the first rainfall: The highest (62%) overall soil deposition reduction was observed with residue + PAM in comparison to PAM treatment. Residue reduced soil deposition in quarter-drains by 42% in comparison with no-residue (burned).

The lack of observed difference in soil deposition between residue and residue + PAM treatments indicates that residue cover left on the field was mainly responsible for reducing soil deposition in quarter-drains.

Adding PAM as a water solution provided only marginal protection from soil erosion in quarter-drains. This low PAM effectiveness is likely related to PAM's photo degradation caused by exposure to the sun's UV radiation or to mechanical shearing during mixing/spraying PAM solution.

Direct PAM application to quarter-drains might provide improved stabilization of these structures during a typical spring; however, sugarcane residue should be left in furrows since the residue efficiently reduces sediment transport from furrows.

Leaving sugarcane residue cover in furrows might provide multiple benefits in terms of reducing soil erosion, improving soil quality by increasing organic matter, minimizing negative environmental effects due to burning, and reducing the cost of sediment cleanup from surface drainage system on sugarcane land.

References

Appelboom, T. W., G. M. Chescheir, R. W. Skaggs, and D. L. Hesterberg. 2002. Management practices for sediment reduction from forest roads in the Costal Plains. *Transactions of the ASAE* 45(2): 337-344.

Azzam, R., O. A. El-Hady, A. A. Lofty, and M. Hegela. 1983. Sand-RAPG combination simulating fertile clayey soils, parts I to IV. *Int. Atomic Energy Agency* SM-267(15): 321-349.

Bengston, R. L., C. E. Carter, J. L. Fouss, L. M. Southwick, and G. H. Willis. 1995. Agricultural drainage and water quality in Mississippi Delta. *J. Irrigation Drainage Eng.* 121(4): 292-295.

Bjorneberg, D. L. 1998. Temperature, concentration, and pumping effects on PAM viscosity. *Transactions of the ASAE* 41(6): 1651-1655.

Bjorneberg, D. L., J. K. Aase, and D. T. Westermann. 2000. Controlling sprinkler irrigation runoff, erosion, and phosphorus loss with straw and polyacrylamide. *Transactions of the ASAE* 43(6): 1545-1551.

Blough, R. F., A. R. Jarret, J. M. Hamlett, and M. D. Shaw. 1990. Runoff and erosion rates from slit, conventional, and chisel tillage under simulated rainfall. *Transactions of the ASAE* 33(5): 1557-1562.

Boopathy, R. R. 2004. Fuel alcohol production from post-harvest sugarcane residue. 104th General Meeting of the American Society for Microbiology, Paper No: O-076, New Orleans, Louisiana.

Brady, N. C., and R. R. Weil. 1999. *The Nature and Properties of Soils*, 12 ed. Upper Saddle River, N.J.: Prentice-Hall, Inc.

Brown, L. C., and L. D. Norton. 1994. Surface residue effects on soil erosion from ridges of different soils formation. *Transactions of the ASAE* 37(5): 1515-1524.

Caulfield, M. J., G. G. Qiao, and D. H. Solomon. 2002. Some aspects of the properties and degradation of polyacrylamides. *Chem. Rev* 102(9): 3067-3084

Dickey, E. C., D. P. Shelton, and P. J. Jasa. 1986. Residue management for soil erosion control. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.G81-544-A.

Erman D. C., and F. K. Ligon. 1988. Effects of discharge fluctuation and the addition of fine sediment on streams fish and macroinvertebrates below a water filtration facility. *Environmental Management* 12(1): 85-97.

Gilley, E. J., S. C. Finkner, and G. E. Varvel. 1986. Runoff and erosion as affected by sorghum and soybean residue. *Transactions of the ASAE* 29(6): 1605-1610.

Haan, C. T., B. J. Barfield, and J. C. Hayes. 1994. *Design Hydrology and Sedimentology for Small Catchments*. San Diego, Calif.: Academic Press, Inc.

Kishore, K., and V. A. Bhanu. 1988. Effect of oxygen on the polymerization of acrylamide. *J. Poly Sci. Part A, Polym Chem.* 26(10): 2831-2833.

Kornecki, T. S., B. C. Grigg, J. L. Fouss, and L. M. Southwick. 2005. Polyacrylamide (PAM) application effectiveness in reducing soil erosion from sugarcane fields in southern Louisiana. *Applied Engineering in Agriculture* 21(2): 189-196.

Lentz, R. D., I. Shainberg, R. E. Sojka, and D. L. Carter. 1992. Preventing irrigation furrow erosion with small applications of polymers. *Soil Sci. Soc. Am. J.* 56(6): 1962-1932.

Letey, J. 1994 Adsorption and desorption of polymers on soil. *J. Soil Sci.* 158(4): 244-248.

Lichatowich, J., L. Mobrand, and L. Lestelle. 1999. Depletion and extinction of Pacific salmon (Oncorhynchus spp.) A different perspective. *ICES J. Marine Sci.* 56(4): 467-472.

Lilleboe, D. 1997. PAM is looking good! *The Sugarbeet Grower* 35: 22-24.

Long, C. 1991. National policy perspectives and issues regarding the prevention and control of nonpiont pollution. USEPA-ORD Workshop on Nonpoint Pollution Control. Washington, D.C.: U.S. EPA.

McGregor, K .C., C. K. Mutchler, and M. J. M. Romkens. 1990. Effects of tillage with different crop residue on runoff and soil loss. *Transactions of the ASAE* 35(5): 1551-1556.

Peterson, J. R., D. C. Flanagan, and K. M. Robinson. 2003. Channel evolution and erosion in PAM- treated and untreated experimental waterways. *Transactions of the ASAE* 46(4): 1023-1031.

Rabek, J. F. 1996. In *Photodegradation of Polymers: Physical Characteristics and Applications*. Berlin: Springer-Verlag.

Robichaud, P. R. 2000. Fire effects on infiltration rates after prescribed fire in Northern Rocky Mountain forests, USA. *J. Hydrology,* 231-232: 220-229.

SAS. 2001. SAS Institute Inc. Proprietary Software Release 8.2. Cary, N.C.

Savabi, M. R., and D. E. Scott. 1994. Plant residue impact on rainfall interception. *Transactions of the ASAE* 37(4): 1093-1098.

Schwab, G. O., D. D. Fangmeier, W. J. Elliot, and R. K. Frevert. 1993. *Soil and Water Conservation Engineering*, 4th ed. New York: John Wiley & Sons, Inc.

Seybold, C. A. 1994. Polyacrylamide review: soil conditioning and environmental fate. *Commun. Soil. Sci. Plant Anal.* 25(11&12): 2171-2185.

Shainberg, I., and G. L. Levy. 1994. Organic polymers and soil sealing in cultivated soils. *J. Soil Sci.* 158(4): 267-273.

Shainberg, I., D. N. Warrington, and P. Rengasamy. 1990. Water quality and PAM interactions in reducing surface sealing. *Soil Sci.* 149(5): 301-307.

Sohma, J. 1989. In *Comprehensive Polymer Science: The Synthesis Characterization, Reactions & Applications of Polymers*, ed. G. Allen. Oxford, UK: Pergamon Press.

Sojka, R. E., and R. D. Lentz. 1994. Time for yet another look at soil conditioners. *J. Soil Sci.* 158(4): 233-234.

Sojka, R. E., R. D. Lentz, and D. T. Westermann. 1998. Water and erosion management with multiple applications of polyacrylamide in furrow irrigation. *Soil Sci. Soc. Am. J.* 62(6): 1672-1680.

Steel, R. G. D., and J. H. Torrie. 1980. *Principles and Procedures of Statistics A Biometrical Approach*, 2nd ed. New York: McGraw-Hill Publishing Co.

Stephens, S. H. 1991. Final report on the safety assessment of polyacrylamide. *J. Am. Coll. Toxicol.* 10: 193-202.

Tolstikh, L. I., N. I. Akimov, I. A. Golubeva, and I. A. Shvetsov. 1992. Degradation and stabilization of polyacrylamide in polymer flooding conditions. *Int. J. Polymetric Material.* 17(3-4): 177-193.

Trout. T. J., R. E. Sojka, and R. D. Lentz. 1995. Polyacrylamide effect on furrow erosion and infiltration. *Transactions of the ASAE* 38(3): 761-765.

USDA – NASS. 1998. Farm & Ranch Irrigation Census of Agriculture. Special Study. National Agricultural Statistical Service. Volume 3, Special study. Census of Agriculture 1997.

Viator, R. 2004. Personal correspondence. Ryan P. Viator: Research Plant Physiologist, USDA-ARS, Southern Regional Research Center, Sugarcane Research Unit, Houma, La.

Wallace, A. 1986. Effect of polymers in solution culture on growth and mineral composition of tomatoes. *Soil Sci.* 141(5): 395-396.

Wallace, A., G. A. Wallace, and A. M. Abouzamzam. 1986. Effects of excess levels of a polymer as a soil conditioner on yields and mineral nutrition of plants. *Soil Sci.* 141(5): 377-379.