IMPACTS OF ORGANIC SOIL AMENDMENTS ON RUNOFF AND SOIL EROSION UNDER THE NATURAL RAINFALL CONDITINOS, PRELIMINARY RESULTS

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Abstract. Organic amendments such as composts and mulches have been shown to improve soil quality and reduce the impacts of stormwater runoff and soil erosion Previous studies using rainfall simulators have documented that runoff volumes and soil erosion can be significantly reduced when organic materials are added to the soil profile. The objectives of this study are to measure the changes in runoff and soil erosion under natural rainfall conditions in Georgia over a five year period and to determine the changes in soil carbon levels over time. Results from such measurements could be used to improve prediction technologies such as the curve number method and RUSLE type erosion models that engineers and designers use to account for soil erosion during construction as well as long term stormwater management.

INTRODUCTION

Every year thousands of acres of land are disturbed in a manner that promotes runoff, erosion of topsoil and loss of soil organic carbon. While these construction and development projects are required by law to control stormwater during the develop process, the long term changes in soil properties impact the surrounding environment for decades. Many studies have investigated the use of compost and other organic soil amendments to control runoff and soil erosion (Claassen, 2000; Faucette et al., 2004; Faucette et al., 2005; Hernando et al., 1989; Shiralipour and Aziz 1992). Almost all of these studies have been conducted using rainfall simulators and have only measured the changes for short periods of time (some have lasted up to one year). Since the primarily mechanism of soil improvement using organic matter is improved soil structure and higher infiltration rates (Mukhtar et al., 2004; Risse and Faucette, 2001), these studies, which often use very high rainfall rates, may be underestimating the effects of organic amendments by only considering the extreme events. Since the majority of rainfall events are small events (often less than 1 inch) of shorter duration, amended plots often produce little or no runoff compared to plots with little or no organic cover. Furthermore, organic amendments promote biological activity that improves soil structure and may allow for greater differences in infiltration rates over time. One primary goal of this project is to measure the changes in runoff and soil erosion under natural rainfall conditions in Georgia over a five year period. Results from such measurements could be used to improve prediction technologies such as the curve number method and RUSLE type erosion models that engineers and designers use to account for soil erosion during construction as well as long term stormwater management.

Adding organic materials to the soil also sequesters carbon and could potentially be a method of combatting global warming. While there is considerable data on the fate of organic carbon under agricultural and forested conditions, very little data exists concerning the fate of carbon when added to disturbed soils under urban/suburban land uses such as grassed lawns. A secondary objective of this study is to observe long term changes in soil carbon levels under these conditions. This paper reports on the establishment of these plots and the preliminary results during the period from June 1 to December 2, 2010.

EXPERIMENTAL SETUP

Twenty four natural runoff plots (1.52 m × 4.57m ft at 10% slope) were established at the University of Georgia's Horticultural Farm located near Watkinsville, Georgia. The farm was equipped with a weather station and consists of primarily sandy clay and clay loam soils. Plots were installed on a hillslope that has historically been in grass meadow for at least the last twenty years. These plots were disturbed by digging a 1.2 m wide collection ditch at the toe of the slope, placing all the excavated material on the plots, and grading the plots to produce uniform 10% slopes. Since a soil morphologist identified some differences in depth to the Bt horizon and drainage across the site, three treatment blocks were established for experimental design (Figure 1).

The plots were installed using a plastic landscape border buried 8 cm on three sides with 2.5 cm exposed along the edges of the plots. On the lowest side of each plot, a runoff receiver was installed using a quarter-cut 1.52 m long, 10.2 cm PVC pipe. The opening quarter of the pipe was installed facing up the slope so that runoff from the plot could be collected while little rainfall outside the plot would be caught. The plot borders were connected to either end of the runoff receiver. The runoff receivers directed all of the runoff into a 19 liter bucket housed in a 208 liter drum using a 8 cm diameter PVC pipe. The bucket was sufficient to collect most smaller storms and was easier to maintain. For larger events, the bucket would overflow in the drum and the entire volume could be collected. The drum was sized to insure that it would handle at least of 5 yr, 24 hr design storm without overtopping.

METHODS

Five treatments, control grass (CG), mulch (M), surface compost (SC), incorporated compost (IC), incorporated biochar (BC), and a control bare soil (BS), were assigned and installed among the plots with three replications for each treatment using completely randomized block design. The grass seed mix selected was a blend of Bermuda grass, brown-top millet, and fescue as specified in the Georgia manual from erosion and sediment control for summer conditions. The mulch was a mixture of ground hard and soft woods obtained from the UGA physical plant. The compost was also obtained from the UGA physical plant and was primarily yard waste and organic debris mixed with ground wood mulch. The char was primarily pine chips that were pyrolyzed at low temperatures. Seeding was conducted at establishment for plots of BC, IC, SC, and CG. All treatments were installed following guidelines of the Manual for Erosion and Sediment Control in Georgia. For the mulch and compost surface cover, approximately 1.5 inches of material was added to the surface. On the IC plot and the char plot, a similar volume of material was incorporated in the upper six inches of the soil.

Measurements of total runoff and solids loss were made immediately after each rainfall event that produced runoff on any of the plots from June 1 to December 2, 2010. The amount of runoff from each plot was recorded by measuring depth and converting to volume on site, while solids loss was obtained by taking agitated runoff subsamples and analyzing the solids content in the water quality lab in Department of Biological and Agricultural Engineering at UGA. Analysis of variance (ANOVA) was conducted to test the significance of soil blocks to runoff generated from each type of plot and compare the amounts of runoff and solids loss from each plot.

RESULTS AND DISCUSSION

During the period of June 1 to December 2, 2010, twenty rainfall events were recorded (Figure 2). Based on comparison of runoff volume generated from BS plots, the twenty rainfall events were grouped as large events (7.29 – 10.97 cm) medium events

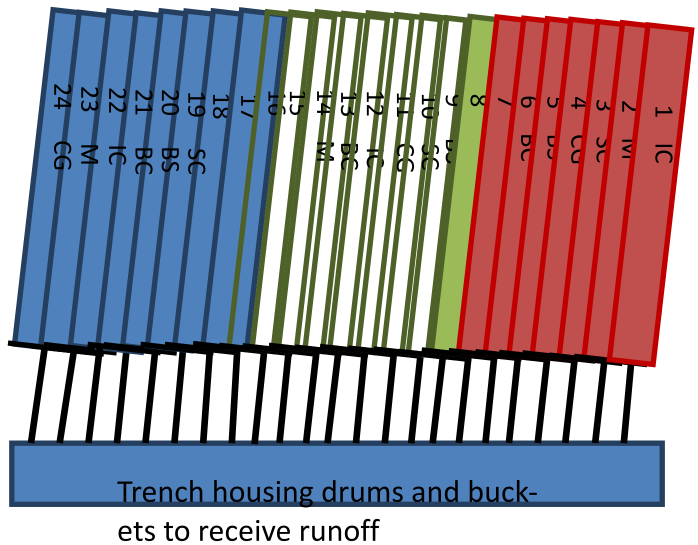

Figure 1. Plots and treatment layout, different colors indicate blocking based on soil differences.

(2.49 – 4.67 cm), and small events (0.51 – 2.18 cm). Runoff volume and solids loss generated from various plots were then analyzed based on the grouped rainfall events as well as monthly events. For the initial results, an analysis of variance indicated that the soil blocks were not significantly different in the amount of runoff or solids loss generated for each type of plot (Table 1). Table 2 shows the comparison and significance of runoff generated from BS plots under various rainfall events.

Table 1. Analysis of variance (ANOVA) for significance of soil blocking to runoff from each type of treatment.

treat-ment	**BS**	**BC**	**CG**	**IC**	**M**	**SC**
P-value	0.12	0.24	0.11	0.26	0.18	0.13

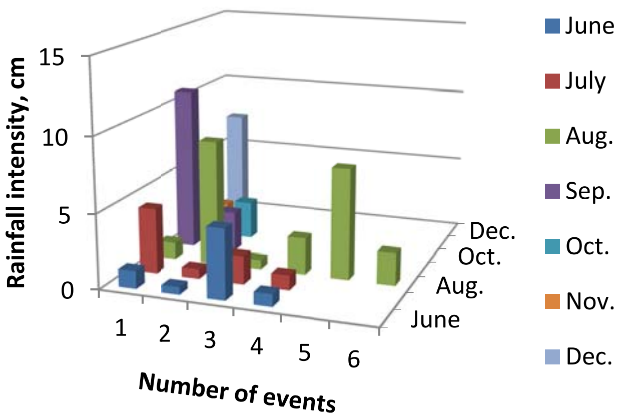

Figure 2. Rainfall events from June 1st to Dec. 2nd, 2010 around the experimental plots.

Table 2. Grouped* rainfall events from June 1st to Dec. 2nd.

	Rainfall, cm	Mean runoff from BS plot, Liter
Small events	0.51	0.04 a
	0.64	0.85 a
	0.66	2.84 a
	0.84	0.07 a
	0.99	8.02 a
	1.14	0.48 a
	1.19	0.32 a
	1.22	0.08 a
	1.24	0.09 a
	1.91	3.78 a
	2.18	4.39 a
Medium events	2.49	100.27 ab
	2.54	76.75 ab
	2.69	52.62 ab
	4.39	127.41 ab
	4.67	115.01 ab
Large events	7.29	205.17 b
	7.44	196.16 b
	8.43	207.21 b
	10.97	178.43 b

*Rainfall events are grouped into three categories based on runoff generated from bare soil (BS) plots. In the column of " Mean runoff from BS plot", values with same letters indicate no significant difference at alpha =0.05.

Runoff. For the smaller rainfall events, amount of runoff generated from all treated plots was not significantly different from the amount of runoff generated from BS plots, even though runoff reductions from 18% on the IC plots to 84% on the SC plots were observed. Under medium and large rainfall conditions, runoff was significantly reduced for all treated plots. Amongst the treated plots, CG, M, and SC plots (runoff reductions were 83% - 97%) showed significantly higher efficiency of runoff reduction compared to BC and IC plots (runoff reductions were 43% - 79%) (Table 3).

Table 3. Runoff volume generated from various plots under small, medium, and large rainfall events. Mean values with various letters in the same row indicate significant difference at alpha =0.05.

Events	Stats	BS	BC	CG	IC	M	SC
		Kg					
Small events	**Mean**	1.91a	1.45a	0.81a	1.56a	0.30a	0.40a
	Stdev	3.03	3.72	1.76	2.81	0.30	0.47
	Percent reduc-tion,%	0.00	24.10	57.33	18.36	84.47	79.01
Medium events	**Mean**	94.41a	47.34 b	15.67 bc	53.09 b	4.73c	2.77c
	Stdev	40.29	50.20	27.41	61.29	7.31	3.85
	Percent reduc-tion,%	0.00	49.86	83.40	43.77	94.99	97.06
Large events	**Mean**	196.74a	49.97 b	27.51 bc	41.34 b	12.29 c	4.80c
	Stdev	22.88	67.74	59.13	56.99	15.18	2.28
	Percent reduc-tion,%	0.00	74.60	86.01	78.99	93.75	97.56

Table 4. Analysis of monthly runoff volume generated from various plots from June to December*, 2010. Mean values with various letters in a same row indicate significant difference at alpha =0.05,.

Month	Stats	BS	BC	CG	IC	M	SC
		Liter					
June	Mean	115.45 a	41.98b	17.15 b	126.0 1a	9.75b	8.28b
	Stdev.	51.11	16.26	19.14	24.63	12.21	7.93
	Percent reduc-tion, %	0.00	63.27	84.64	-9.10	91.02	92.28
July	Mean	142.06 a	139.29 a	33.17 ab	103.4 8ab	7.37b	3.07b
	Stdev.	18.05	34.06	48.89	74.10	11.46	0.62
	Percent reduc-	0.00	1.94	76.65	27.15	94.81	97.84

	tion, %						
August	Mean	509.36 a	252.62 ab	128.44b	198.63b	48.28 b	12.72 b
	Stdev.	62.15	176.35	166.22	109.76	36.94	5.56
	Percent reduction, %	0.00	50.41	74.79	61.00	90.52	97.50
September	Mean	231.06 a	9.12b	12.82 b	7.63b	6.42b	7.65b
	Stdev.	5.83	6.51	11.70	7.00	0.65	3.72
	Percent reduction, %	0.00	96.05	94.45	96.70	97.22	96.69
October	Mean	76.83a	2.58b	0.68b	2.44b	1.17b	2.01b
	Stdev.	40.92	3.12	0.55	2.58	0.96	1.09
	Percent reduction, %	0.00	96.64	99.12	96.83	98.48	97.39
November	Mean	9.56a	2.14a	0.44a	1.67a	1.55a	1.75a
	Stdev.	8.05	3.15	0.12	0.99	0.89	0.88
	Percent reduction, %	0.00	77.59	95.35	82.51	83.80	81.72

*: Only one event in December then it was lumped into November's events.

The highest runoff reduction occurred on the SC plots (>97%) which was probably due to the high water holding capacity of compost as described in the findings of Zhu and Risse (2009) and Zhu *et al.* (2010) that surface applied compost demonstrated considerable reduction of runoff. Incorporated compost plots on which the same type and rate of compost had been applied showed more runoff than the SC plots. The process of incorporation reduced the amount of compost on plot surface which resulted in reduced capacity to hold water. Table 4 shows monthly runoff reduction from various plots, which also shows the runoff reduction was greatest on the plots treated by SC and M.

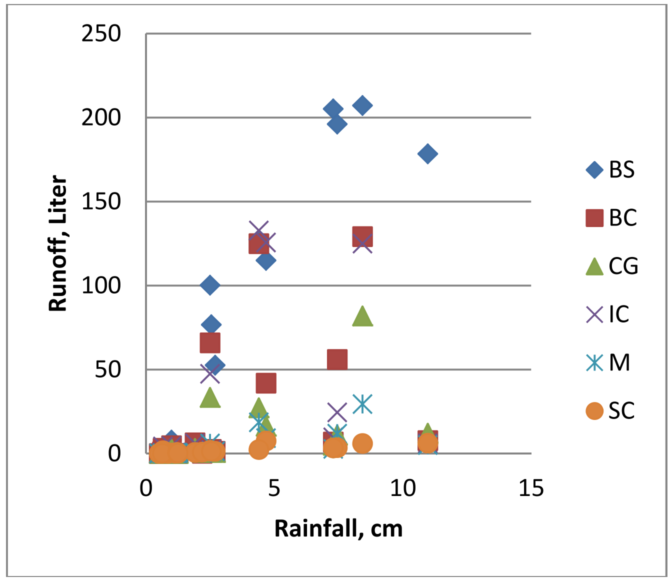

Figure 3. Mean runoff amount generated from different plots under various rainfall events (n=3). BS: Bare soil, BC: BirChar, CG: Control Grass, IC: Incorporated compost, M: Mulch, SC: Surface compost.

Solids loss. Solids loss from each plot for each rainfall event was calculated by multiplying the total amount of runoff generated from each plot by solids content of runoff from the plot. Tables 5 and 6 show the reduction in solids loss from treated plots compared to the BS plots under various rainfall amounts and by month. For small events, reduction of solids loss from treated plots were not significant compared to BS plots, while under medium and large rainfall conditions, solids loss from treated plots exhibited significant reduction compared to BS plots, with exception of BC and IC plots under medium events and IC plots under large events which showed no significant difference in spite of 15.4% – 89.01% solids loss reduction. Even though it was not significant, the percent reduction of solids loss under small events ranged from 10% on the IC plots to 74% on the M plots, while for both medium and large events, reduction of solids loss ranged from 88%-95% on the CG plots, 95%–98% on the M plots, and 91%–93% on the SC plots. Monthly reduction of solids loss (table 6) exhibited similar trends of significant solids loss from CG, M, and SC plots. The reduced solids loss from SC plots compared to IC plots was primarily due to the great reductions of runoff amounts on SC plots. While the surface applied compost promotes aggregation of soil materials, the process of incorporation in IC plots breaks the soil aggregates and lead to greater amount of soil particles being washed away, as shown in table 6 where solids loss from IC plots in June was actually greater than the solids loss from BS plot.

Table 7 summarized the mean total amount of runoff and solids loss from each treatment, indicating the mulch and surface applied compost plots were most efficient in both runoff and solids loss reduction amongst the tested treatments in this study.

Table 5. **Analysis of solids loss from various plots under small, medium, and large rainfall events. Mean values with different letters in the same row indicate significant difference at alpha =0.05.**

Events	Stats	BS	BC	CG	IC	M	SC
		Kg					
Small events	Mean	1.90a	9.20a	6.28a	1.71a	4.87a	8.84a
	Stdev	0.45	0.51	0.20	0.80	0.36	0.58
	Percent reduction,%	0.00	51.68	67.04	10.03	74.39	53.55
Medium events	Mean	6.58a	2.4ab	0.81b	5.57ab	0.30b	0.58b
	Stdev	1.52	0.66	0.22	1.19	0.12	0.12
	Percent reduction,%	0.00	63.06	87.75	15.47	95.48	91.17
Large events	Mean	11.05a	0.80b	0.57b	1.21ab	0.25b	0.76b
	Stdev	5.60	0.48	0.27	0.47	0.05	0.73
	Percent reduction,%	0.00	92.79	94.88	89.01	97.74	93.14

Table 6. **Analysis of solids loss from various plots from June to November. Mean values with different letters in a same row indicate significant difference at alpha =0.05.**

Month	Stats	BS	BC	CG	IC	M	SC
		Kg					
June	Mean	1.05a	0.30a	0.05a	3.02b	0.02a	0.02a
	Stdev.	0.55	0.11	0.061	1.14	0.02	0.02
	Percent reduction, %	0.00	71.72	94.95	188.22	98.48	98.39
July	Mean	2.41a	1.4ab	0.15b	1.24a	0.01b	0.00b
	Stdev.	1.11	1.33	0.25	0.93	0.015	0.002
	Percent reduction, %	0.00	40.11	93.75	48.52	99.58	99.87
August	Mean	2.75a	1.40b	0.57b	1.76b	0.09b	0.03b
	Stdev.	1.54	1.54	0.85	1.76	0.07	0.017
	Percent reduction, %	0.00	94.89	97.94	93.59	99.67	99.89
September	Mean	1.21a	0.01b	0.01b	0.010b	0.00b	0.01b
	Stdev.	838.50	0.006	0.001	0.010	0.001	0.016
	Percent reduction, %	0.00	99.44	99.59	99.21	99.85	98.88
October	Mean	0.45a	0.00b	0.00b	0.003b	0.00b	0.01b
	Stdev.	0.09	0.004	0.004	0.003	0.000	0.003
	Percent reduction, %	0.00	99.12	99.40	99.34	99.82	98.11
November	Mean	12.0a	0.00b	0.00b	0.00b	0.00b	0.00b
	Stdev.	0.004	0.004	0.00	0.00	0.00	0.002
	Percent reduction, %	0.00	75.16	95.41	85.09	88.59	79.72

Table 7. Summary of total rainfall, runoff, and solids loss from various plots.*

Summary	BS	BC	CG	IC	M	SC
Mean total Runoff, gal	337.73	119.39	52.07	118.19	20.07	9.88
Percent reduction,%	0.00	64.65	84.58	65.01	94.06	97.07
Mean total solids loss, kg	95.35	24.55	12.71	47.74	7.49	15.42
Percent reduction,%	0.00	74.26	86.67	49.94	92.15	83.83

* 20 rainfall events from 6/1/2010 to 12/2/ 2010 with a total amount of 63 cm. For mean total values of each type of treated plot, n=3

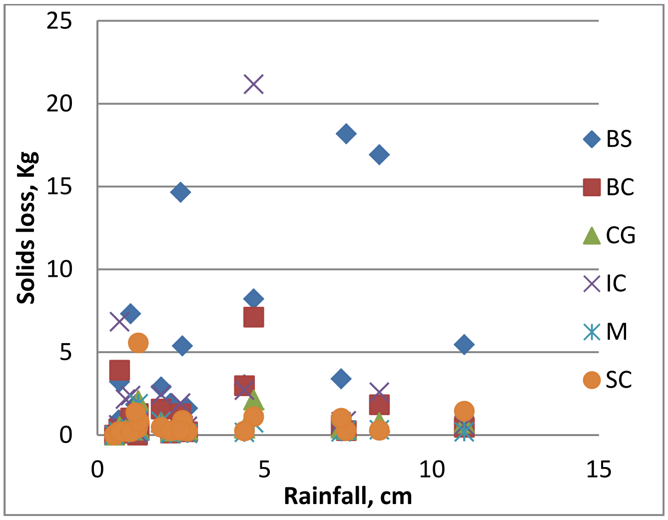

Figure 4. Mean solids loss from different plots under various rainfall events (n=3). BS: Bare soil, BC: BirChar, CG: Control Grass, IC: Incorporated compost, M: Mulch, SC: Surface compost.

CONCLUSIONS

The experimental plots were designed to study the amounts of runoff and solids loss from various organic matter treatments. Based on the natural rainfall occurring from June 1 to December 2, 2010, runoff was significantly reduced from all treated plots under medium and large events, with significantly greater reduction from plots of control grass, mulch, and surface applied compost compared to plots of biochar and incorporated compost. The treated plots exhibited similar trends in solids loss except there were no significant differences among the plots of biochar, control grass, mulch, and surface compost plots, furthermore, no significant reduction was observed from plots of incorporated compost under both medium and large events. This is an ongoing study and a major goal will be to determine how long these impacts last and wheter or not changes in soil organic carbon levels will be detectable over time.

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