Runoff, erosion, and nutrient losses from compost and mulch blankets under simulated rainfall

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ABSTRACT: Control of soil erosion and associated nonpoint source pollution is essential to improving water quality. The use of compost or mulch blankets as a soil cover can help control soil erosion and provide sustainable alternatives to disposal for many biomass resources. The objective of this study was to investigate the amounts of runoff, erosion, and nutrient losses obtained under simulated rainfall using a variety of compost and mulch materials. Treatments included aged poultry litter, two different types of poultry litter compost, municipal solid waste compost, biosolids compost, food waste compost, yard waste compost, three different types of wood mulch, and bare soil. Results indicated that all of the treatments except for aged poultry litter were effective at reducing total solids loss in the runoff. Nutrient losses from most of the compost treatments, however, were higher than those from bare soil or mulch treatments. Treatments with lower respiration rates and nitrate-nitrogen concentrations tended to have less erosion and transport of solids. Nitrate-nitrogen content, respiration rates, soluble salt, sodium, and potassium contents were good indicators of ammonium and phosphorus losses.

Keywords: Compost, erosion control, mulch, nutrient loss, runoff, water quality

Sediment has been identified as one of the most important nonpoint source pollutants of streams, lakes, and estuaries. Sediment is recognized as a pollutant that has an impact on aquatic organisms, habitat, and is also a carrier of other nonpoint source pollutants (Ermine and Ligon, 1988). While sources of sediment and other nonpoint source pollutants include agriculture and forestry, other land uses such as construction, development, and roads are being recognized as the major contributors in urban and developing areas. In fact, soil loss rates from construction sites are typically 10 to 20 times those from agricultural land (USEPA, 1997). Amendments in 1987 to the Clean Water Act label construction activities as "point sources" under the National Pollution Discharge Elimination System, requiring improved erosion control practices and new permitting programs (USEPA, 2003). In addition, road construction and maintenance are commonly recognized as significant sources of sediment requiring substantial investment in erosion control and vegetation establishment.

Currently, common erosion control practices for construction projects and road development in Georgia consist of silt fences, hydroseeding, and establishing vegetation. Demonstration projects and experimental research have suggested that the use of compost and mulch applications could improve upon existing erosion control technologies (Demars et al., 2000, Glanville et al., 2001, Mitchell, 1997). The use of compost and mulches in erosion control has additional benefits of being a more sustainable method of dealing with "waste" materials. With agricultural byproducts such as animal manure, it represents a method of improving the nutrient balance on the farm through the development of off-farm uses. Utilization of other organic byproducts such as municipal biosolids, wood waste, food processing residuals, and municipal solid waste could also be improved through composting if value added markets were available. Using these organic materials to rebuild soils and control soil erosion offers significant advantages over landfilling provided it is done in an environmentally sound manner. Additionally, many of these organic by-products are generated near urban and developing areas where the need for erosion control technologies is often greatest.

Conventional methods to control sediment include silt fencing and riprap; while hydroseeding, wood fiber mats, coconut hull fiber mats and straw mats are conventional means to prevent soil erosion from occurring. Surface applied organic mulches to protect the soil surface can significantly reduce both runoff and soil erosion (Adams, 1966; Meyer et al., 1972; Laflen et al., 1978; Vleeschauwer et al., 1978; Foster et al, 1985; Agassi et al., 1998). The mechanisms behind these reductions include less soil crust formation in the underlying soil, dissipation of the energy associated with raindrop impact, and a reduction in the shear forces exerted on the soil surface. Surface layers of organic matter reduce the energy of raindrop impact and allow water to percolate into the soil, reducing surface runoff and erosion. The rougher surface created by mulches and some composts also allows for greater water storage and percolation and lower runoff velocities (Kramer and Meyer, 1969). Composted wood waste has also been shown to increase water infiltration and water holding capacity by improving soil structure (Demars et al., 2000). Applications of animal manure to soil surfaces can also reduce runoff and soil erosion. However, the mechanisms behind these reductions are not well defined (Gilley and Risse, 2001; Giddens and Barnett, 1980). In addition, a layer of organic litter on the soil surface insulates the soil and reduces evaporation creating a better environment for germination and root growth and therefore improved vegetative cover (Jordan, 1998). Establishment of vegetative cover can then provide for long-term protection of the soil surface.

Studies conducted on 10.6 m by 3.1 m (35 ft by 10.2 ft) plots at a 2:1 slope by the Connecticut Department of Environmental Protection and Transportation showed that

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Table 1. Treatment names and descriptions.

Treatment name	Description/Primary feedstocks	Replicates
PLC1	Poultry Gold Compost/Composted poultry litter	2
PLC2	Sargents Nutrients Compost/Composted poultry litter	2
PL	Aged Poultry Litter/Layer manure from underhouse storage	2
MSC	Cobb County Compost/Municipal solid waste compost, biosolids	2
BSC	Erthfood Compost/Biosolids, peanut hulls	3
FWC	Creative Earth Compost/Food residuals, ground wood waste	2
YWC	UGA Compost/Yard waste, ground wood waste, some manure	3
WMf	Woodtech Superfine Mulch/Finely ground wood mulch	2
WMm	Woodtech Medium Hardwood Mulch/Medium ground wood mulch	3
WM2	Rockdale County Mulch/Coarse ground yard waste and waste wood	2
Soil	Bare soil control	3

Table 2. Physical characteristics of composts and mulches.

Treatment	Moisture content (%)	Volatile solids (%)	Bulk density (kg/m^3)	Respir. rate (g O_2/g VS/h)*
PLC1	24	14	799	0.06
PLC2	27	25	751	0.10
PLC3	36	13	724	0.07
PL	26	26	877	0.34
MSC	41	36	461	0.04
BSC	21	46	562	0.04
FWC	51	18	751	0.05
YWC	42	27	615	0.05
WMf	26	33	446	0.06
WMm	32	67	213	0.02
WM2	48	47	363	0.03
Soil	18	5	1453	0.14

*** VS = gram 02 per gram volatile solids per hour.**

blankets of both yard waste mulch and yard waste compost reduced erosion by an order of magnitude and that the compost treatments performed as well or better than the conventional treatment of hay and seed (Demars et al., 2000). In Texas, Storey et al. (1996) compared compost amended plots and plots mulched with shredded wood to commonly used synthetic chemical tackifiers. They found that the compost amended plots reduced erosion as well or better than the other treatments with the greatest reductions occurring on sandy soils. Glanville et al. (2001) compared three types of compost to bare soil and traditionally treated soils on new highway embankments in Iowa. They found that runoff from all three compost plots was significantly lower than the control and runoff from bio-industrial and yard waste compost was significantly lower than from plots amended with topsoil; however, plots amended with composted biosolids were not significantly different. All of the composts produced significantly less interrill erosion than topsoil-amended plots. While differences in the growth of the planted cover crop were statistically indistinguishable, weed growth was significantly lower on some of the compost treatments.

Although erodibility is defined as a soil property and is quantified in terms of sediment loss, composts and mulches should display a similar property relative to the total solids lost from a surface cover. Very few people have investigated the measurement of erodibility on composts or mulches. Westerman et al. (1983) studied the erodibility of layer manure and broiler litter on sand and clay soils. They found that the addition of manure or litter resulted in increased transport of total solids and nutrients in the runoff, yet the erodibility of the manure was between that of the sand and clay. Many of the previously mentioned studies have attempted to quantify the total solids lost from compost or mulch blankets but few have related these data to the characteristics of the cover material. The erodibility of composts and mulches should be an important factor in their ability to control erosion.

The overall goal of this project is to develop a better understanding of the characteristics of composts and mulches as related to their use in erosion control technologies. Specifically, the objectives of this work were to test the runoff quantity, sediment loss and nutrient loss of various compost and mulch materials used as blankets under simulated rainfall and to correlate the physical and chemical properties of the materials to the measured losses.

Methods and Materials

Eleven treatments including three poultry litter composts, a municipal solid waste compost, a food waste compost, a yard waste compost, a biosolids/peanut hull compost, three grades of wood mulches and a bare soil control were selected for use in this study (Table 1). Compost is defined as organic material that has undergone a controlled, microbiological heat process and has decomposed to a biologically stable, humus rich material (Alexander, 1996). Mulch is simply a ground woody material generally derived from wood waste or yard debris. It has a relatively wide carbon to nitrogen ratio, a low nutrient content and has not gone through a controlled biological heat process. These treatments were selected based on their commercial availability in Georgia. Each of the materials was supplied by a commercial vendor and was tested as supplied. The bare soil control was obtained from a construction site that had undergone extensive grading and soil relocation. The site was originally mapped as an eroded Cecil sandy clay loam soil. Approximately, 1.81 metric tonnes (2 tons) of fill material was removed from the

Table 3. Particle size distribution of composts and mulches.

Treatment	Aggregate size (%<25mm)	Aggregate size (%<16 mm)	Aggregate size (%<6.3 mm)	Aggregate size (%<3.35 mm)	Aggregate size (%<2.26 mm)	Aggregate size (%<1.4 mm)	Aggregate size (%<1 mm)	Aggregate size (%<.710 mm)	Aggregate size (%<.500 mm)	Aggregate size (%<.125 mm)
PLC1	100	100.0	97.1	87.7	80.2	64.5	50.5	31.8	16.0	0.1
PLC2	100	99.7	93.0	83.4	75.1	58.5	47.4	37.6	28.1	5.3
PL	100	99.35	95.2	84.8	76.1	57.8	44.0	32.1	21.0	1.5
MSC	100	99.85	97.5	90.3	80.1	56.1	37.9	23.7	14.4	0.5
BSC	100	100	91.1	67.4	54.8	42.6	35.9	29.3	21.8	2.2
FWC	100	100	94.8	77.4	65.4	46.7	34.1	23.5	15.3	0.6
YWC	100	100.0	90.7	77.4	67.1	46.8	31.9	18.5	10.9	0.1
WMf	100	98.9	94.9	82.7	73.2	55.9	45.7	36.1	27.4	3.6
WMm	96.2	90.4	43.0	21.5	13.7	6.0	3.7	2.4	2.0	0.6
WM2	98	89.94	63.4	43.9	34.3	21.5	13.5	8.5	5.9	0.1
Soil	100	100.0	99.2	90.7	84.3	71.5	61.5	49.2	38.3	1.9

site, and passed through a 1.27 cm (0.5 in) screen to remove rocks and large aggregates. Initial plans called for three replicates of each treatment; however, due to limited supplies fewer replicates were used with several of the materials (Table 1).

Tables 2, 3 and 4 present the physical and chemical properties of each treatment. Bulk density, aggregate size, soluble salts, and respiration rate were measured at the University of Georgia Bioconversion laboratory using procedures outlined in Test Methods for the Examination of Compost (USCC, 1997). The remaining parameters were measured at the University of Georgia Agricultural and Environmental Services Laboratory using EPA or AOAC approved procedures (University of Georgia, 2004). Metals were analyzed and all of the treatments were below the pollutant concentration levels as specified in USEPA part 503 Table 4 (USEPA, 1993).

Each replicate was placed in a 92 cm by 107 cm (36.2 in by 42.1 in) stainless-steel frame that was 15 cm (5.9 in) deep. These frames were attached to a plywood base that was placed at a 10% slope and equipped with a flume on the downslope end. The bottom of this flume was 5 cm (2 in) below the lip of the frame giving each collector an effective depth of 10 cm (4 in) with a 5 cm (2 in) border above the soil surface. Three 2.5 cm (1 in) holes were drilled in the plywood base to allow for seepage; however, little seepage occurred during the testing period. Five centimeters of soil was placed in the bottom of each collector and covered with cheesecloth and an additional 5 cm (2 in) of compost or mulch material was added for each run (except for the bare soil treatment). Between each run, the compost or mulch material was removed; the collector and soil surface rinsed, and the next treatment would be loaded into the collector. While the surface of the material was smoothed to ensure that it was flush with the flume edge and at a constant slope, no attempts were made to pack the compost, mulch, or soil treatments to an equal density. Prior to the initial run and to loading the treatments, the subsoil was pre-wet to saturation to insure that soil conditions would not influence the amount of runoff generated. Figure 1 shows the experimental set up.

An eight-nozzle (V-jet nozzle operating at 4.2 kg/cm^2) Norton rainfall simulator obtained from the USDA National Soil Erosion Research Laboratory was used for this study. The simulator covered approximately a 6 m by 2 m (19.8 ft by 6.6 ft) area uniformly with rainfall. Therefore, four collectors fit under the simulator for each rainfall event and a total of seven runs were used in the study. Two runs used only three treatments. The treatments were randomly distributed throughout these runs. Actual rainfall rates were measured using 10 gages for each run. Average measured rainfall rates were 16 ± 0.7 cm/h (6.3 ± 0.3 in/h). The high rate of rainfall exceeds the 1-hour, 100-year storm event for Athens, Georgia (US Department of Commerce, 1961); how-

Table 4. Chemical characteristics of composts and mulches.

Treatment	pH	Soluble salts (dS/m)	C:N ratio	Total N (%)	(NO_3-N) (mg/kg^{-1})	(NH_4-N) (mg/kg^{-1})	Total P (mg/kg^{-1})	K (mg/kg^{-1})	Al (mg/kg^{-1})	Ca (mg/kg^{-1})	Mg (mg/kg^{-1})	Na (mg/kg^{-1})	Zn (mg/kg^{-1})
PLC1	7.2	5.87	15	0.56	732	56	9,009	7,835	13,300	51,540	3,454	1,330	192
PLC2	8.3	7.13	27	0.62	200	357	9,015	8,450	19,170	38,750	2,800	2,217	213
PL	7.1	20.60	9	1.74	4,876	35	13,830	14,990	2,347	29,810	3,494	4,660	261
MSC	8.3	5.03	23	1.18	210	1	3,186	2,571	9,357	18,270	1,718	2,700	372
BSC	4.9	7.65	13	1.09	1,460	116	8,086	4,872	11,670	6,028	1,705	283	202
FWC	7.7	0.80	29	0.46	1	63	622	2,622	11,760	3,715	1,093	151	41
YWC	5.0	0.11	36	0.39	74	245	351	1,868	19,240	483	1,043	44	39
WMf	6.0	0.25	113	0.16	21	21	192	1,076	11,280	1,954	651	50	21
WMm	5.6	0.20	637	0.09	1	42	74	578	756	1,065	204	28	8
WM2	7.0	0.24	139	0.18	4	28	141	773	2,383	1,761	275	42	27
Soil	5.0	0.11	9	0.08	88	172	351	1,868	19,240	483	1,043	44	39

Figure 1
Rainfall simulator and experimental setup.

ever, it was our intention to evaluate these treatments under a "worst case" scenario because most erosion occurs during these large events. Since there was similar variability in rainfall rates within the runs as between them, no attempt was made to correct for rainfall rate. As soon as runoff began, which ranged from three minutes (soil) to 23 minutes (mulch) after rainfall was started, an initial sample of approximately 500 ml (16.9 oz) of runoff was collected. Additional samples were then collected at five minute intervals until a total time of 60 minutes had elapsed. An analysis of the data revealed that almost all the plots appeared to reach steady-state conditions during this period as the runoff rates were fairly constant near the end of the sampling period.

The runoff rate at five minute intervals during the simulation was plotted and the total runoff amount was calculated by summing the area under the runoff curve. In addition, each bottle was oven dried at 105°C (221° F) until constant weight was achieved to determine the total solids content and total amount of solids lost from the plot. Volatile solids (VS), total solids (TS), total phosphorus (TP), ortho-phosphorus (PO_4), total nitrogen (TN), nitrate-nitrogen (NO_3-N), and ammonium-nitrogen (NH_4-N) were analyzed for the first flush sample and at the end of the run (steady-state sample). The TS and VS were measured using methods 2540 B Total Solids Dried at 103-105° C (217-221° F) and method 2540 Fixed and Volatile Solids Ignited at 550° C (1022° F) (USEPA, 1983). Nitrate-nitrogen and total nitrogen were measured using EPA standard method 353.2 (colorimetric, automated, cadmium reduction), ammonium-nitrogen using EPA standard method 350.1 (colorimetric, automated phenate), and phosphorus using EPA standard method 365.1 (colorimetric, automated, ascorbic acid) (USEPA, 1983). A persulfate digest for water (Qualls, 1989) was used as a pretreatment for determination of total nitrogen and phosphorus. Total nutrient loads were estimated by averaging the concentrations of the first flush and steady state and multiplying by the runoff volume.

SAS version 8.2 (SAS, 2001) was used for the statistical analyses. Analysis of variance (PROC ANOVA) using Duncan's Multiple Range test for significant differences with unequal cell sizes was used to determine any significant differences between the treatments ($p \leq 0.05$). Correlation analysis (PROC CORR) was used to determine which of the physical and chemical treatment parameters were correlated to the measured runoff, total solids, and nutrient concentrations and loads.

Results and Discussion

There was significant variability in the runoff volume and total solids loss between the treatments (Table 5). The poultry litter treatment had a runoff volume that was significantly higher than three of the composts (MSC, FWC, PLC2) and one of the mulches

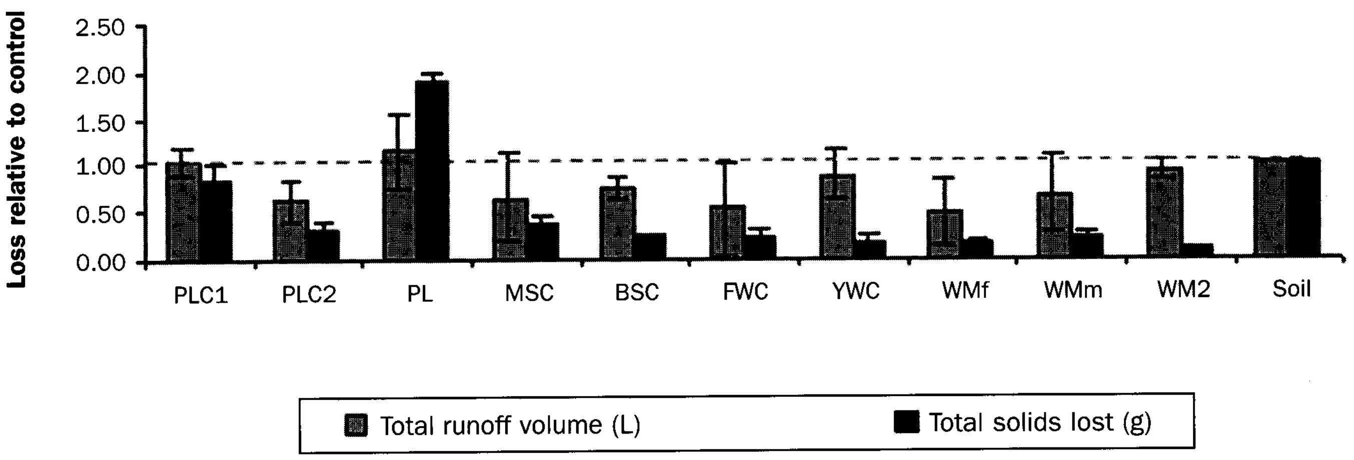
Table 5. Mean runoff, solids and nutrient loss data.

Treatment	Runoff volume (L)	Total solids loss (g)	TN load (mg)	NO_3-N load (mg)	NH_4-N load (mg)	TP load (mg)	PO_4 load (mg)
PLC1	74 ab	552 bc	4128 bc	2343 bc	138 b	10046 b	7588 b
PLC2	44 bcd	208 cd	1272 cd	751 c	45 b	1589 b	1253 c
PL	83 a	1221 a	1327 cd	14 c	6573 a	30266 a	23755 a
MSC	47 bcd	236 cd	645 d	410 c	194 b	294 b	242 c
BSC	53 abcd	154 d	8113 a	6301 a	241 b	2693 b	2217 c
FWC	37 cd	139 d	628 d	840 c	33 b	219 b	213 c
YWC	63 abcd	111 d	744 d	321 c	57 b	199 b	170 c
WMf	35 d	102 d	64 d	6 c	15 b	28 b	23 c
WMm	48 abcd	144 d	97 d	20 c	7 b	32 b	16 c
WM2	66 abcd	74 d	434 d	32 c	94 b	357 b	304 c
Soil	71 abc	646 b	150 d	42 c	20 b	52 b	57 c

* **Treatments with the same letter are not significantly different at $p \leq 0.05$.**

Figure 2

Total runoff volume and total solids loss relative to that from the bare soil control.



(WMf). This was probably due to the fact that the poultry litter appeared to be somewhat hydrophobic. At the end of the rainfall simulation, it was noted that the wetting front had not advanced through the layer of poultry litter. The poultry litter at the upper end of these plots was still dry after one hour of intense rainfall. None of the other treatments exhibited this and most appeared totally saturated. Although not significantly different, the composted poultry litters had less runoff and behaved more like the other treatments. The composting process appeared to reduce the hydrophobic properties of the poultry litter. The fine and medium mulches had the lowest runoff volumes. Although not significantly correlated to particle size distribution, mulches had the most storage volume (pore space) and took the longest to generate runoff due to the higher infiltration rate. The second wood mulch treatment (WM2) did not display these lower runoff rates. This may be due to the fact that this mulch contained post consumer wood waste, more hardwood that appeared to absorb less water and had a higher initial moisture content.

Compared to the bare soil, most of the compost and mulch treatments had less runoff and total solids loss (Figure 2). This indicates that almost all of the treatments were effective in reducing erosion.

There were very few differences in runoff among the compost treatments. In fact, these treatments only varied from 55 to 102 percent of the runoff observed on the bare soil treatment and overall there was only an average of 20 percent less runoff on the treated plots than the bare soil control. The point at which runoff began and the time to reach a semi steady-state condition appeared to vary from treatment to treatment but the steady-state rates were similar. Under these test conditions, the rainfall rate was much greater than the infiltration rate of the soil layer beneath the treatment. Therefore, excess water would pond on the soil surface in the cover treatment until it reached the lip of the flume and began to run off.

Near the end of the simulation, when most of the cover treatment was saturated, all of the treatments with the exception of the poultry litter and mulches had similar runoff rates, but the differences were not significant. The runoff rates only varied from 17 to 26 ml/s (0.6 oz to 0.9 oz/s) and this could probably be attributed to differences in the rainfall rates and plot preparation. Under field conditions where the treatments are given time to influence vegetation and soil properties or with lower rainfall rates, greater differences in runoff rates and volumes would be expected.

The sediment loss data exhibited more differences between treatments. The total solids concentration over time was highly variable. In general, the first flush of runoff, when runoff rates were lower, had higher total solids concentrations, which generally decreased over time in an erratic manner. Due to the high variability between measurements, total solids lost, which aggregates the data, is probably a better indicator of performance than the first flush or steady-state concentration. Total solids loss for the poultry litter treatment was significantly higher than any other treatment. Total solids loss on the bare soil was significantly higher than all but one of the compost treatments (PLC1). Generally, the mulch treatments had the lowest total solids loss although these were not statistically different than many of the compost treatments. During the simulation, the poultry litter treatment and the bare soil control were the only treatments that displayed rill formation indicating erosion by flow stresses rather than just raindrop impact and sheet flow. By protecting the soil surface, all of the treatments, except the aged poultry litter, visually appeared to reduce or eliminate the impacts of concentrated flow and rill erosion.

Table 5 shows the nutrient loss data for each treatment. The biosolids compost had significantly higher total nitrogen and nitrate losses than any other treatment, even though the poultry litter had higher total nitrogen and nitrate contents in the initial analysis of materials. The poultry litter had significantly higher ammonium losses than any other treatment even though many other treatments had higher ammonium contents in the initial analysis. This indicates that the nutrients in some of the compost treatments were more available to runoff than equivalent concentrations in other treatments. The mulch and bare soil treatments generally had lower total nitrogen, nitrate, and ammonium losses; however, these were often not statistically significant. The phosphorus losses were significantly higher for the poultry litter treatment. Even though this was the only statistically significant difference, many of the compost treatments had phosphorus losses one or two orders of magnitude greater than the bare soil or mulch treatments. The high nutrient levels may be due to the fact that this simulation was conducted under worst case conditions including first flush following application with little opportunity for available nutrients

Table 6. Results from Correlation Analysis. All variables were tested against the complete list of parameters in Tables 2, 3 and 4. This table lists all the variables with significant correlation (r>0.70) or the most highly correlated variable.

Independent variable	Variable with significant correlation (Correlation coefficient)*
Total runoff volume	Res. (0.59)
Total solids loss	Res. (0.92), NO_3-N (0.83), SS (0.78), K (0.78), Na (0.72)
Total N loss	P (0.45)
Nitrate-N loss	P (0.33)
Ammonium N loss	NO_3-N (0.96), Res. (0.92), SS (0.88), K (0.88), Na (0.72), Total N (0.72)
Total P loss	NO_3-N (0.96), SS (0.91), K (0.89), Res. (0.88), Na (0.79), P (0.79), Total N (0.72), Mg (0.72)
PO_4 loss	NO_3-N (0.96), SS (0.91), K (0.89), Res. (0.88), Na (0.80), P (0.79), Total N (0.72), Mg (0.71)

*** SS = Soluble salts, Res. = Respiration rate, BD = Bulk density**

to move into the soil, no vegetation, and very intense prolonged rainfall. Nevertheless, this does indicate that the environmental impacts of nutrient losses from these treatments must be weighed against the environmental benefits of reduced runoff and soil erosion. Future work should investigate the changes in nutrient losses over time from each of these treatments.

All of the physical and chemical characteristics in Tables 2, 3, and 4 were correlated against all measured outputs in Table 5, but only those that were highly correlated ($r>0.70$, $p\leq0.05$) are reported (Table 6). None of the independent variables measured were well correlated with total runoff volumes. Total solids loss was correlated with the respiration rate, nitrate-nitrogen, soluble salt, potassium and sodium contents of the treatment. Treatments with lower respiration rates and nitrate concentrations tended to show a reduction in the loss of total solids. The bare soil and poultry litter had the highest respiration rates (respiration rate is measured per gram of volatile solids and the bare soil had a very low amount of volatile solids and higher respiration rate) and the highest loss of total solids. Likewise, nitrate-nitrogen content, respiration rates, soluble salt, sodium, potassium, and total nitrogen contents were good indicators of ammonium and phosphorus losses. The fact that respiration rate was correlated to the total solids loss may be an indication that the biological processes involved in the composting process do influence the ability of the materials to resist detachment and movement. This was especially evident in the poultry litter composts, where those that had lower respiration rates showed reduced solids loss. This relationship warrants further research, as it could be an important component for standards involving compost use in storm water management applications. Soil erosion studies have indicated that particle size has a significant impact on erodibility (Foster et al, 1985, Wischmeier and Smith, 1978); however, the aggregate size analysis in this study was not well correlated to the erosion observed.

Summary and Conclusion

All of the treatments tested, except for the poultry litter treatment, were effective at reducing total solids lost compared to a bare soil under these simulated conditions. The poultry litter treatment had significantly more runoff than did the mulch treatments. The poultry litter treatment also lost significantly more total solids than any other treatments. The bare soil lost significantly less total solids than the poultry litter treatment, but significantly more than all of the other treatments except for one of the poultry litter composts. In all cases, composted poultry litter treatments had less runoff, erosion, and nutrient loss than did aged poultry litter. The mulch treatments had lower total solids loss and less runoff than most of the composts; however, these differences were often not statistically significant. Losses of nutrients tended to be higher for the poultry litter and biosolids compost treatments. Total nitrogen loads were significantly higher for the biosolids compost treatment and two of the poultry litter composts were significantly higher than the other treatments. Total phosphorus losses were significantly higher for the poultry litter. Treatments with lower respiration rates, nitrate-nitrogen, soluble salt, potassium, and sodium concentrations tended to have less erosion and transport of solids. Nitrate-nitrogen content, respiration rates, soluble salt, sodium, potassium, and total nitrogen contents were good indicators of ammonium and phosphorus losses. Further work is needed to better quantify the relationships between the physical and chemical properties of the treatments and the runoff, erosion, and nutrient losses. The goal of a soil cover should be to provide short-term protection with little environmental impact while vegetation is being established. Ultimately, the vegetation establishment is an equally important goal and the nutrients in the compost treatments should aid in this process. Further work is ongoing to investigate similar compost and mulch materials to determine which are effective at establishing and maintaining long-term vegetative cover and soil quality. Ultimately, the results from both studies should be combined to develop decision aids in the selection of compost and mulch materials for erosion control.

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Soil erosion following forest operations in the Southern Piedmont of central Alabama

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ABSTRACT: In recent years, nonpoint source pollution (NPS) has been recognized as one of the major threats to the nation's water quality. Clearly, forest operations such as harvesting and site preparation have the potential to have degrading impacts on forest water quality. However, there exists a gap in the understanding of the nature and extent of NPS pollution problems related to forest operations. The study presented here was performed in Lee County, Alabama to investigate the impact of clear-cut harvesting and mechanical site preparation on a 20-year-old loblolly pine (*Pinus taeda* L.) plantation on sediment and runoff yield. Sediment and runoff yield responses on treated areas were compared to that of undisturbed areas. Impacts were evaluated by monitoring isolated small plots, 2 m (6.6 ft) by 5.5 m (18 ft), over a two-year period following the harvest prescription. Sediment yield from the control treatment was 0.11 t/ha (0.30 ton/acre) over the study period. Sediment yield increases of 0.11 t/ha (0.30 t/ac) and 1.3 t/ha (3.5 t/ac) were observed from clear cut harvest/site prep/plant (H-SP-P) treatment and clear cut harvest /plant (H-P) treatment, respectively. However, erosion losses from the most erosive treatment, clear cut harvest /plant, was still very low at less than 1 t/ha/yr. Runoff yield results were similar to those observed with sediment yields from treatments in the investigation. Differences in the two treatments were likely due to the differences in surface roughness, which affects infiltration and surface flow velocity.

Keywords: Forest operations, harvesting, site preparation, soil erosion, surface runoff

NPS pollution accounts for the majority of the total pollutant load to nation's inland surface waters (USEPA, 1993). In the southern United States, where NPS pollution is a major environmental concern, agriculture is the major contributor of NPS pollution (USEPA, 1984; Myers et al., 1985). In the region, NPS problems related to forestry activities are localized but can affect waters used for human consumption and fisheries habitat. Forest operations having the potential to impact NPS pollution include road construction, road maintenance, pesticide and fertilizer application, harvesting, and burning (Neary et al., 1989). Types of NPS pollution that can be generated by forestry activities include sediment, nutrients, pesticides, and organic chemicals. Sediment is perhaps of the greatest concern because many other pollutants are bound and transported with eroded sediment. Sediment alone can carry more than 1 million metric tons of nitrogen to surface waters in the Southern region (Larsen et al., 1983). Research has shown adverse impacts on the nation's water quality from soil erosion and stream sedimentation (Authur et al., 1998; Binkley and Brown, 1993; Megahan et al., 1991).

Undisturbed forest conditions afford a high level of protection against soil erosion and NPS pollution. Vegetative cover intercepts raindrops and therefore reduces the energy for soil detachment (Grace, 2000). Forest floor cover provides surface roughness

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