

USE OF COMPOSTED WASTE MATERIALS IN EROSION CONTROL

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Abstract. The objective of this series of studies was to investigate the use of compost and mulch materials in erosion control and stabilization projects. The first phase of the study looked primarily at the impacts of surface blankets of twelve different compost and mulch materials on solids loss and water quality and found that mulch blankets produced runoff with the lowest solids and nutrient contents. Compost blankets were significantly less erodible than bare soil, and compost maturity seemed to be an important factor as respiration rate was significantly correlated to solids loss. Raw poultry litter produced more runoff and erosion than bare soil and three different poultry litter composts. Effective erosion control strategies must both protect the soil surface and establish and sustain vegetation. The second part of this project looked at the impacts of these same materials on grass establishment and growth. The findings indicated that the compost treatments produced more vegetative biomass and cover than the mulch treatments. The final phase of this study compared four combinations of compost blankets and berms to both bare soil and conventional treatments such as hydroseeding and silt fences. Preliminary results indicate that the use of compost blankets and berms offer significant improvements in water quality through improved erosion control, reduction in nutrient loads and improved the establishment of vegetation. Further analysis is ongoing to document the long term changes in soil quality and vegetation using these treatments. This paper will only report on the first phase of the study due to space limitations.

INTRODUCTION

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 impacts 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 10-20 times those from agricultural land (USEPA, 1997). As of August 1, 2000 Georgia enacted the nation's toughest regulations on erosion and runoff from construction sites in an effort to improve water quality in the state's surface waters. The new regulations label development as "point sources" requiring improved erosion control practices and new permitting programs. 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 consists of silt fences, hydroseeding, and establishing vegetation. Several demonstration projects 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; Michaud, 1995; and 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. Many of these organic byproducts are generated near urban and developing areas where the need for erosion control technologies is often greatest.

OBJECTIVES

The overall goal of this study is to develop a better understanding of the characteristics of composts and mulches related to their use in erosion control technologies and to demonstrate the effectiveness of these materials. A secondary objective was to determine the physical and chemical properties of compost and mulch materials that are correlated to their effectiveness in controlling solids loss.

LITERATURE REVIEW

Conventional methods to control moving 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. 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 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. Establishment of vegetative cover can then provide for long term protection of the soil surface.

Current literature suggests that many states have experimented with using compost to control soil erosion informally, but there is little scientific literature on the impacts of compost blankets on erosion or water quality. A survey by Mitchell (1997) indicated that 19 state's Department of Transportation had developed specifications for compost use and at least six had conducted experiments on using compost to control soil erosion. Michaud (1995) suggests that blanket applications of up to 10 cm of compost will effectively control erosion on slopes up to 45% for up to 3 years.

Demars et al. (2000) showed that 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. Storey et al. (1996) compared compost amended plots and plots mulched with shredded wood to synthetic chemical tackifiers and found that compost amended plots reduced erosion as well or better than the other treatments with the greatest reductions 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 and found that runoff from all three compost plots were significantly lower than the control, and runoff from bio-industrial and yard waste compost were significantly lower than plots amended with topsoil.

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 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 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 solids lost from compost or mulch blankets but few have related this data to the characteristics of the cover material. The erodibility of composts or mulches should be an important factor in its ability to control erosion yet little is known about the erodibility of these materials.

INTERILL PAN STUDIES

Materials and Methods

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). These treatments were selected based on their availability commercially and previous studies of feedstock quantities produced in Georgia. Each of the materials was supplied by a commercial vendor and was tested as supplied. The bare soil control (eroded Cecil sandy clay loam) was obtained from a construction site that had undergone extensive grading and soil relocation. Initial plans called for

three replicates of each treatment; however, due to limited supplies fewer replicates were used on many of the plots (Table 1).

The physical and chemical properties of each treatment and methods of measurement are reported in Risse et al. (2002). Bulk density, moisture content, total and volatile solids, major nutrients, aggregate and particle size, pH, C:N ratio, soluble salts, and respiration rate were measured for each material. The USEPA 503 metals were analyzed and all of the treatments were below the pollutant levels specified in USEPA Part 503, Table 3.

Each replicate was placed in a 92 cm by 107 cm stainless steel frame that was 15 cm 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 the flume was 5 cm below the lip of the frame giving each collector an effective depth of 10 cm with a 5 cm border above the soil surface. Three 25 cm 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 cheese cloth and an additional 5 cm of compost or mulch material for each run (except for the bare soil treatment). Between each run, the compost or mulch material would be removed, the collector and soil surface would be rinsed and repacked if necessary, and the next treatment would be loaded into the collector. While the surface would be smoothed to insure 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 insure uniform initial conditions.

An eight nozzle (V-jet nozzle operating at 60 psi) Norton rainfall simulator obtained from the National Soil Erosion Research Laboratory was used for this study. The simulator uniformly covered approximately a 6 m by 2 m area with rainfall. Therefore, four collectors fit under the simulator for each rainfall event. Actual rainfall rates were measured using 10 gages for each run. Average measured rainfall rates were 16 ± 0.7 cm/hr and each run lasted for one hour. As soon as runoff began, which ranged from 3 (soil) to 23 (mulch) minutes after rainfall was started, an initial sample of approximately 500 ml of runoff was collected. Additional samples were then collected at five minute intervals until a total elapsed time of 60 minutes had been reached. The weight of runoff and time over which it was collected was recorded at five minute intervals. From this data, 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 sample bottle was oven dried at 105 °C 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 (PO₄), total nitrogen (TN), nitrate nitrogen (NO₃-N), and ammonia nitrogen (NH₄-N) were analyzed for the first flush sample and at the end of the run (steady state sample). Total nutrient loads were estimated by averaging the concentrations of the first flush and steady state and multiplying by the runoff volume. SAS version 8.0 (SAS, 1999) was used for the statistical analysis which include an analysis of variance (PROC ANOVA) using Duncan's Multiple Range test for significant differences with unequal cell sizes and correlation analysis (PROC CORR) to determine which of the physical and chemical treatment

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
PLC3	Gro-mor Compost/Composted poultry litter, vegetable waste, yard waste	1
PL	Aged Poultry Litter/ Layer manure from underhouse storage	2
MSC	Cobb Co. Compost/ Municipal Solid Waste Compost, biosolids	2
BSC	Erthfood compost/Biosolids, peanuts hulls	3
FWC	Creative Earth Compost/Food residuals, ground wood waste	2
YWC	UGACompost/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 Co. Mulch/Course ground yard waste and waste wood	2
Soil	Bare Soil Control	3

parameters were correlated to the measured runoff and solids loss.

Results

There was significant variability in the runoff volume and the total solids loss between the treatments (Table 2). The poultry litter treatment had highest runoff volume and steady state rate (not shown) and was significantly higher than the plots with mulch cover. This was probably due to the fact that the 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. 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 rates and volumes. The mulches had the most storage volume (pore space) and took the longest to generate runoff due to the higher infiltration rate. There were very few differences in runoff among the compost treatments. 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 and there were no significant differences. The runoff rates only varied from 17 to 26 ml/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 solids loss data exhibited more differences between treatments (Table 2 and Figure 1). 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 other treatment. 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 where the flow concentrates and forms small rills indicating erosion by flow stresses rather than just raindrop impact and sheetflow. By protecting the soil surface, all of the treatments, except the poultry litter, seemed to reduce or eliminate the impacts of concentrated flow and rill erosion. Some floating solids were visible in the runoff samples especially from the fine mulch and poultry litter treatments; however, this was not a large portion of the solids loss. Initially, there was some concern that the mulch treatments might float resulting in higher solids loss, but this did not occur.

The biosolids compost had significantly higher total nitrogen and nitrate losses than any other treatments, even though the poultry litter had higher total nitrogen and nitrate contents in the initial analysis of the composts. The poultry litter had significantly higher ammonia losses than any other treatment even though many other treatments had higher ammonia contents in the initial analysis. This indicates that the nutrients in

Table 2. Runoff, Solids and Nutrient Loss Data

Treatment	Runoff Volume (L)	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 b	2343 bc	138 b	10046 b	7588 b
PLC2	44 bc	208 cd	1272 c	751 cd	45 b	1589 b	1253 b
PLC3	52 abc	168 cd	4679 b	3125 b	101 b	1085 b	903 b
PL	83 a	1221 a	1327 c	14 d	6573 a	30266 a	23755 a
MSC	47 bc	236 cd	645 c	410 d	194 b	294 b	242 b
BSC	53 abc	154 cd	8113 a	6301 a	241 b	2693 b	2217 b
FWC	37 bc	139 cd	628 c	840 cd	33 b	219 b	213 b
YWC	63 abc	111 cd	744 c	321 d	57 b	199 b	170 b
WMf	35 c	102 d	64 c	6 d	15 b	28 b	23 b
WMm	48 bc	144 cd	97 c	20 d	7 b	32 b	16 b
WM2	66 abc	74 d	434 c	32 d	94 b	357 b	304 b
Soil	71 ab	646 b	150 c	42 d	20 b	52 b	57 b

* Treatments with the same letter are not significantly different at Alpha=0.05.

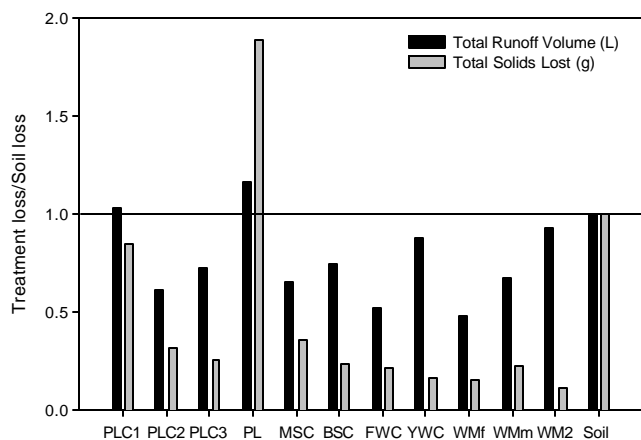


Figure 1. Runoff and soil loss relative to soil.

some of the compost treatments were more available to runoff than equivalent concentrations in other treatments. The mulch and soil treatments generally had lower total nitrogen, nitrate, and ammonia 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 P losses one or two orders of magnitude greater than the soil or mulch treatments. All of the nutrient loss concentrations were surprisingly high compared to values reported in field studies and to EPA standards for human or aquatic health. The high nutrient levels may be due to the fact that this simulation was conducted under worse case conditions including first flush following application with little opportunity for available nutrients to move into the soil, no vegetation, and very intense prolonged rainfall.

The results from correlation analysis were used to investigate which of the physical and chemical parameters of the treatment material were correlated with each of the output parameters measured in the runoff. All of the measured physical and chemical characteristics were tested against all measured runoff, solids loss, and nutrient loads. None of the independent variables measured were well correlated with total runoff volumes or rates. Total solids loss was correlated to the respiration rate and the nitrate-nitrogen content of the treatment. Treatments with lower respiration rates and nitrate concentrations tended to lose less solids. The soil and poultry litter had the highest respiration rates (respiration rate is measured per gram of volatile solids which elevates the soil rate) and the highest amounts of solid loss. Likewise, nitrate-nitrogen content, respiration rates, soluble salt,

sodium, and potassium contents were good indicators of ammonium and phosphorus losses. Soil erosion studies have indicated that particle size has a significant impact on erodibility; however, the aggregate size analysis in this study was not well correlated to the erosion observed. This may be due to the fact that only the large classifications were measured in this study. Further analysis should investigate smaller particle size classifications and include them in the correlation analysis.

CONCLUSIONS

This study looked primarily at the impacts of surface blankets of twelve different compost and mulch materials on solids loss and water quality and found that mulches generally produced runoff with the lowest solids and nutrient contents. Compost blankets were much less erodible than bare soil, and compost maturity seemed to be an important factor as respiration rate was significantly correlated to solids loss, and raw poultry litter produced more runoff and erosion than bare soil and three different poultry litter composts. Effective erosion control strategies must both protect the soil surface and establish and sustain vegetation. Other work associated with this project looked at the impacts of these same materials on grass establishment and growth. The findings indicated that the compost treatments were much more effective than the mulch treatments at establishing and maintaining grass under these conditions. These results are being used in an ongoing field study comparing four combinations of compost blankets and berms to both bare soil and conventional treatments such as hydroseeding and silt fences. Preliminary results indicate that the use of compost blankets and berms offer significant improvements in water quality through improved erosion control and reduction in nutrient loads as well as improving the establishment of vegetation.

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