

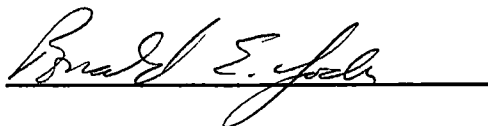
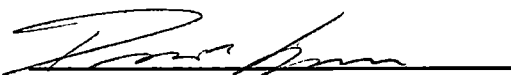
To the Graduate Council:

I am submitting herewith a thesis written by Craig Allen Easterly entitled "Evaluation of Manure as Cover on Tilled Soils." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering Technology.



C. Roland Mote, Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the Council:



Associate Vice Chancellor and Dean
of The Graduate School

Evaluation of Manure as Cover on Tilled Soils

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Craig Allen Easterly

May, 1996

To:

My parents

Kyle and Barbara Easterly

for their inspiring support and infinite encouragement

throughout my educational endeavors.

ACKNOWLEDGMENTS

The author expresses his sincere gratitude to his major professor Dr. C. Roland Mote for his patience and guidance.

Appreciation and thanks is also extended to Dr. Dan Yoder and Dr. Ron Yoder for their guidance and advice.

Special gratitude is expressed to Mr. John Buchanan and Mr. Richard Roy for their long hours in the field and lab. Also, thanks is expressed to both for their immense patience and support.

Thanks is also extended to fellow graduate students Michael Palmer, Matt Bowling, Scott Snyder, Andy Arthur, Deron Jagers, Mitch Hobby, and Alex Lowery. Their long hours are appreciated and work ethic commended.

Thanks is expressed to Dr. Saxton for the advice and assistance with statistical analysis for this project.

A special gratefulness is extended to Mr. Larry Click, undergraduate professor at Tennessee Technological University, for being not only a mentor but a friend.

ABSTRACT

A field experiment combining erosion control and waste disposal was conducted at the Plateau Experiment Station near Crossville, Tennessee. Beef cattle manure was surface applied to nine conventionally-tilled plots. The study was performed to determine the erosion-prevention potential of livestock waste when surface applied on disturbed soil. Also studied was the quality of runoff from these plots over a span of four weeks.

The plots were on a Typic Hapludult soil with a slope of 7-10%. An impermeable metal border surrounded the 11.18 m by 4.06 m plots. The border contained all water that fell in the plots, while preventing any water that fell outside the plots from entering.

Manure was hand applied one day after tillage was completed. Surface coverage percentages of 0 (control plot), 30, and 80% were replicated three times. Manure spread on the 30% and 80% plots averaged 6.35 and 14.21 t/ha (dry matter), respectively.

Three runoff events were produced by a solid set rain simulator. The rain simulator consisted of 41 irrigation sprinklers mounted on risers 3 m high. Due to limitations of the system, three plots (one bank) were irrigated at a time. Each of the three banks contained a 0%, 30%, and 80%-cover plot. Average intensity of the rainfall delivered by the simulator was 3.6 cm/h. The average coefficient of uniformity for simulated rainfall distribution on all plots was 0.76.

Rain 1 was applied immediately after manure application. Rains 2 and 3 were applied 1 week and 4 weeks after manure application, respectively. Runoff freely flowed to the lower end of the plots where a collection apparatus was in place. Runoff fell over a

metal lip inserted flush with the soil surface. The water then drained via gravity into a multislot divisor box. A portion (1/9) of the runoff exiting the divisor box was collected and weighed. Samples of the runoff were collected before it entered the divisor box and were transported to the lab for analysis.

Runoff samples were analyzed for total solids, total volatile solids, total Kjeldahl nitrogen, and total phosphorus. Total runoff was found by using the weight of water collected from the divisor box.

Analysis showed that, when normalized by the volume of rainfall applied, the mass of total solids and the volume of runoff exiting the plots decreased significantly with increases in applied percent cover. Based on the concentration of total solids in runoff leaving the plots erosion was reduced by the presence of cover, but the two levels of cover were not different in their impact on erosion. Elapsed time-since-application of manure had no effect on the mass of total solids in the runoff. The mass of volatile solids leaving the plots in the runoff was significantly less for the control plots (0% residue cover) than for the plots with manure cover. However, when normalized by volume of rainfall applied, significantly less volatile solids left the plots containing manure. Time had no effect on the mass of volatile solids leaving the plots. The concentration of total Kjeldahl nitrogen in the runoff from the control plots was significantly larger than that from the plots containing manure. Although, no difference existed in total Kjeldahl nitrogen leaving the plots when normalized by the amount of rainfall applied. Time had no effect on the mass of nitrogen leaving the plots. Off-site movement of phosphorus was not appreciably impacted by any of the observed treatments.

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CHAPTER 1

INTRODUCTION

Soil erosion and poor management of large concentrations of livestock waste have become two prominent problems for farmers around the world (Cooper and Lipe, 1992). Soil erosion costs both farmers and consumers large amounts of money each year through extensive cleanup bills for sediment-polluted surface water, and through decreased yields due to the loss of productive topsoil. The large concentrations of waste are a direct result of a shift to confined production of livestock. Improper management of livestock waste pollutes waterways and contaminates drinking water resources.

Sediment is the country's most widespread water pollutant. Estimated yearly discharge of sediment from agricultural land in the United States is 979 million metric tons. The Gulf of Mexico alone receives nearly 300 million metric tons of topsoil each year (Cooper and Lipe, 1992).

The soil erosion problem has subsided somewhat in recent years as a result of the significant implementation of no-till and the dramatic decrease in conventional till. No-till is a planting system in which the crop is planted into the stubble of the previous crop. No-till possesses many positive aspects when compared to conventional till procedures. Some of these advantages are increased soil moisture content, decreased soil erosion by maintaining a high crop residue cover, and a reduced number of equipment passes through a field during seedbed preparation and planting, which in effect reduces soil compaction

(Wendt and Burwell, 1985).

However, no-till does have drawbacks, with the most limiting factor being weed control. Some herbicides are less effective at controlling weeds due to the lack of mechanical incorporation into the soil (Buhler and Oplinger, 1990). This ineffectiveness causes the types and quantities of herbicides used to increase, which makes no-till a less than perfect alternative tillage system (Koskinen and McWhorter, 1986; Buhler and Oplinger, 1990).

Another possible drawback associated with no-till is the formation of a consolidated surface layer. It can become impervious to water, decreasing the infiltration rate and producing high runoff rates. However, this problem of a consolidated surface layer forming is debatable. Studies have proven that under certain conditions no-till increases runoff while in other conditions it reduces runoff (Lindstrom and Onstad, 1984).

In addition, no-till is not adapted perfectly for all soil, crop, and climate conditions. No-till is not well suited for some poorly drained, finely textured soils, as are sometimes found in the Corn Belt region of the U.S. (Laflen and Colvin, 1981; Griffith et al., 1973).

Capital cost is another concern when using no-till. Costs are initially increased due to most farmers only owning or having access to conventional tillage equipment. Farmers must now purchase and/or rent no-till equipment. This type of equipment is seemingly more expensive due to the comparative complexity and sturdiness of the machinery. Finally, a potential drawback of no till is the need for better management. The decisions and the timing with which the decisions are acted on also become vital to no-till being both successful and profitable (Griffith et al., 1973).

Another agricultural concern in addition to that of erosion control is what to do with large amounts of waste generated from massive confined livestock operations. Land application can be an effective and efficient method of waste disposal. However, runoff from surface-applied liquid or solid wastes may contain nutrients and organic material and may thus contribute to water pollution (Mitchell and Gunther, 1976; Westerman et al., 1983; Cooper and Lipe, 1992).

Although land application of manure can be problematic, there is a possibility that manure can be a very good erosion preventer if used as a mulch. Reports indicate that surface applied mulch is an effective method of preventing erosion and conserving soil and moisture on tilled land (Khan et al., 1986; Kramer and Meyer, 1969).

CHAPTER 2

REVIEW OF LITERATURE

1. Erosion Control -- Mulch

The benefit of soil cover in reducing erosion has been well studied and documented. Mannering and Meyer (1963) studied the effect of surface mulch on infiltration and erosion. Six rates of surface applied wheat straw mulch (0, 0.56, 1.12, 2.24, 4.48, and 8.96 t/ha) were used to compare the infiltration and erosion rate. Wheat straw was hand spread on the plots after the final tillage procedure.

Rainfall was applied using a rainulator. The intensity of the rain events was 6.35 cm/h. Rain was applied at varying intervals throughout a three day period. The total amount of rain applied to each plot was 15.88 cm/h.

Differences in infiltration rates were significant for most treatments at the 1% level, and all were significant at the 5% level. All soil loss differences for treatments were significant at the 1% level. Wheat straw applied at the rate of 2.24, 4.48, and 8.96 t essentially eliminated runoff and controlled erosion throughout all storms. The 0.56 t mulch treatment decreased soil loss by 15% to 38% when compared with the check plots receiving no mulch. The 1.12 t mulch treatment decreased soil losses by 1 to 16% when compared with the check plots.

Mannering and Meyer (1963) reported that mulch decreases soil loss in three ways. First, the mulch sustains an infiltration rate for a longer period by prohibiting crusting of the soil surface. Second, mulch protects the soil surface from raindrop energy impact, thereby decreasing soil detachment. Finally, it slows the runoff. Obstacles are created that force runoff to flow over or around the mulch. This decreases the load carrying capacity by decreasing the velocity of the runoff.

Sloneker and Moldenhauer (1977) reported that surface residue was very beneficial in reducing soil erosion. When compared with plots that received no residue, soil loss was decreased to 32% and 13% in plots that contained 50% and 80% residue cover, respectively. Plots with 100% residue coverage experienced practically no erosion.

Khan et al. (1986) completed a laboratory experiment studying the effect of simulated canopy cover and straw mulch cover on interrill erosion using Parr silt loam. Two, hour-long rainstorms were simulated with an intensity of 6.4 cm/h. The simulated rain first fell on dry soil. The second rainstorm was applied to the previously-wetted soil 24 h later. Straw mulch was placed on the soil pans at coverage percentages of 0, 33, 67, and 100. The weights of these coverage percentages were 0.54, 1.72, and 4.54 t/ha, respectively.

Data indicated that runoff and soil loss decreased as coverage increased. The maximum difference in soil loss between 100% cover and 0% cover for the first storm was 56%. For the second storm the maximum difference was 19%. Soil loss for the 33%, 67%, and 100% plots compared with 0% plots was 49%, 77%, and 96% less. The soil loss for the second storm was 45%, 69%, and 91% less for mulch covered plots compared

to bare plots. Benefits of using straw mulch to prevent soil loss due to erosion were apparent.

Laflen et al. (1981) reported residue on some soils in certain climates tends to decrease yields as the amount of covered soil surface increases. Therefore accurate prediction of erosion is required so the correct tillage procedures can be chosen to maximize yields while simultaneously reducing erosion. A primary objective of this study was to determine mulch-factor relationships for different crop canopies for continuous row crops grown using conservation tillage procedures. Also, a purpose of the project was to visually observe the function of crop residue in reducing soil erosion.

Laflen et al. (1981) studied the interaction of cropping rotation practices, tillage systems, and canopy levels to evaluate soil losses as affected by crop residue at two locations in Iowa. Erosion rates were measured for combinations of various corn and soybean rotations and canopy cover percentages, used with conventional tillage, reduced tillage, and no-till planting systems. A rainfall simulator delivering 6.3 cm/h was used to supply water to 3 m by 10.7 m areas within a plot. All tillage procedures were performed up and down slope. Residue cover percentages were determined using a photographic grid method.

Results indicate that as residue cover increases soil erosion decreases. The reduction in erosion was attributed to residue trapping the sediment and preventing soil from leaving the plots. Also, small pools of water formed because of residue, preventing water from exiting the plots freely. These pools slowed the flow of water and allowed larger particles of sediment to settle out before leaving the plots. On plots with little or no

residue cover erosion rates at the end of a rainfall event were ten times higher than the rates at the beginning of the storm. However, on plots with large amounts of residue cover, the erosion rates at the end of the rainfall events were only three times the rate at the beginning of the storm.

Lattanzi et al. (1974) investigated the influences of mulch rate and slope steepness on erosion. Their experiment used plots of 61 cm by 61 cm with slopes of 2%, 6%, 12%, and 20%. Two replications were completed using 0, 0.5, 2, and 8 t/ha of mulch. These quantities of mulch produced 0%, 25%, 61%, and 95% surface coverage, respectively. Water was applied to the plots in three storms. The first storm occurred on day one and lasted for 1 h with an intensity of 6.4 cm/h. The second and third storms were executed on day two, with the same intensity as storm one, but only lasting for 30 min with a 15 min rest period between storms.

Analysis of the data showed that runoff began a short time after the start of the rainfall, and quickly stabilized for plots containing 0 and 0.5 t/ha of mulch. Plots with 2 t/ha of residue yielded a lower runoff rate for a longer time period than did plots with the lighter mulch rates. However, at the end of the 1 h storm the plots had constant runoff. The plot with 8 t/ha absorbed nearly all raindrop energy and allowed the infiltration rate to remain high throughout the storm.

The second hour of rain on day two produced results similar results to the first storm, except for greater runoff flow rates occurring at an even shorter interval for the 0, 0.5, and 2 t/ha cover. The heavy mulch cover performed similar to the first storm except for a slightly greater runoff rate.

Results of the experiment show that mulch significantly affected water loss. However, slope percentages failed to significantly affect water loss. Erosion was significantly affected by both mulch rate and slope steepness. Mulch rates from 0 to 2 t/ha decreased erosion, while 8 t/ha all but eradicated erosion. Also, as mulch rates increased, the effect it had on decreasing runoff and sediment diminished. Mulch application rate proved to exercise more control in decreasing erosion than runoff.

Kramer and Meyer (1969) constructed an experiment for testing the effect of several rates of surface mulch on erosion and runoff rates. The variables studied in the experiment were mulch rates, slope percentages, and lengths. Glass spheres were used to represent two particle sizes of soil. The larger sized spheres were equivalent to fine sand (121 microns), while the smaller size represented silt (33 microns). Fiberglass electrical sleeving was used instead of straw for mulch. The sleeving was spread at rates equivalent to 0, 0.28, 0.56, 1.12, and 2.24 t/ha. The slope percentages used were 4, 6, 8, and 10%, while the slope lengths were 12.19, 21.33, and 30.50 m. Simulated rainfall was applied at the rate of 3.81 cm/h for 30 min except in cases of very high erosion rates. Erosion rates and runoff velocities were measured in the latter half of the run after forces had stabilized.

Results show that mulch rate, slope steepness, and slope lengths significantly affect erosion and runoff rates at the 1% probability level. Erosion rates were affected by slope steepness the most, while the mulch rate had the greatest effect on runoff velocity. Mulch proved to be very effective for all slope lengths more than 12.19 m. Although, high mulch rates did suffer decreased effectiveness when compared to lighter mulch rates. A minimal

mulch rate of 0.56 t/ha proved to significantly reduce erosion for all slope lengths, slope percentages, and particle sizes.

2. Tillage Effects

Although no-till has been widely accepted as a best management system for farmers throughout this and other conservation-minded countries, it is not a holistic solution. There are reasons no-till is not appropriate for all farmland throughout the world. Buhler and Oplinger (1990) expressed concerns about weed control becoming a problem in no-till planting systems. In fact, it was listed as the main influence in limiting the acceptance of minimal tillage operations. Some types of herbicides are less effective when used with no-till due to the lack of mechanical incorporation of the herbicide. Also, the vegetative residue left on the soil surface absorbs the herbicide, resulting in less chemical reaching the soil. Field research was completed in Arlington and Janesville, Wisconsin, in 1986 and 1987 to determine the effect of various planting procedures on control and density of annual weeds in solid seeded soybeans (Buhler and Oplinger, 1990). The planting procedures examined were conventional tillage, chisel plow, and no-till systems. The experiment's purpose was to examine tillage effects on the population dynamics of annual weeds and on the control of weeds with pre-emergence herbicides in solid seeded soybeans grown in rotation with corn. It was noted that in their experiment that the weed population and type changed when tillage ceased. Giant foxtail and redroot pigweed became more difficult to control with less tillage, but velvetleaf was easier to

control. Soybean yield was unaffected by tillage procedure when grown in a weed free environment. Differences in yields that were apparent may be caused by various weed control procedures. Also, an increase in annual grasses was noticed as the amount of tillage performed decreased.

Koskinen and McWhorter (1986) suggested conservation tillage is fast becoming the preferred planting procedure. It is estimated that by the year 2010 nearly 95% of cropland in the United States will be farmed by conservation procedures. However, the main drawback prohibiting even quicker and more broad acceptance is the lack of availability of herbicides. Herbicide costs and weed control are two of the top three limiting factors for the adoption of conservation tillage procedures with the third factor being lack of proper equipment.

Koskinen and McWhorter (1986) reported that in minimal tillage farming operations an ecological shift in the soil and its properties occurs. Crop residue seems to diminish and/or alter herbicide performance after many years. The lack of tillage sometimes increases soil acidity due to ammonia fertilizer being nitrified closer to the soil surface. Change in soil and environmental factors has decreased the effectiveness of some triazine herbicides in small areas of the Corn Belt region in the United States. The result is an increase in grass population and perennial weeds. When tillage is decreased or halted fields in Tennessee, Georgia, Mississippi, and North Carolina, sometimes experience an increase in density of weeds such as milkweed, horse nettle, Bermuda grass, Johnson grass, trumpet creeper, and nutsedge. Also, some weeds that are now destroyed by herbicides may not be in the future. It is thought that by the year 2000 some weeds will

develop a resistance to certain herbicides. In fact, in the few years since the introduction of minimal tillage procedures some weeds have developed a slight tolerance to herbicides such as Atrazine, Trifluralin, 2,4-D, Bentazon, Diuron, Dicamba, and Paraquat.

In general, no-till practices tend to lower the effectiveness of herbicides. The increased amounts of residue and organic matter remaining on the soil surface prohibit herbicides from reaching the soil. It is estimated that as much as 50% of herbicide applied never reaches the soil. Surveys suggest herbicide usage increases in no-till corn and soybeans by 14% and 18% respectively, while the cost of the herbicides was 34% and 42% higher when compared with conventional tillage procedures (Koskinen and McWhorter, 1986).

Griffith et al. (1973) studied eight different tillage methods and how they affected soil temperature, percent stand, growth, and yield of corn on five Indiana soil types. The need for this research existed due to the rapid increase of non-conventional tillage operations occurring in the Corn Belt region of the United States. Most research completed at this time was extremely variable and conclusions were sometimes contradictory of other similar experiments.

This experiment was conducted on five soils found at Purdue University Regional Agricultural Centers in Indiana. The tillage and planting systems compared, ranged from conventional tillage to no-till and included various types of reduced tillage systems. The results show that germination rate decreases as the amount of residue cover increases. This problem seems to be magnified on poorly drained, fine textured soils. Eight weeks after planting, the no-till corn had the slowest growth and maturity rate while the

conventional tillage corn had the highest growth and maturity rate. Percent stand cover was good for all conventionally tilled test plots while the no-till fields had average percent stands, in general. Weed control also became more of a problem as the amount of tillage decreased.

Lindstrom and Onstad (1984) focused their research on runoff and infiltration of various tillage systems in the Corn Belt because of contradicting results that had been previously released. Some reports determine no-till infiltration rates are high due to vast macropore systems developing. Other reports show runoff from no-till systems being similar in quantity to runoff from conventional tillage systems. The reason for this large variance in runoff from no-till is thought to be because the macropore system develops slowly or not at all. Data from the Corn Belt indicates runoff rates from no-till and conventional tillage are similar. However, infiltration rates for no-till are smaller but soil losses are lower in conventional tillage. It is thought that in no-till a consolidated surface layer forms over time, which hampers infiltration of water.

Lindstrom and Onstad (1984) performed their experiment on a Barnes loam (Udic Haploboroll) on a 2% slope. The infiltration rate after planting of corn was studied using three different planting systems (conventional, reduced, no-till) and two residue amounts (harvested and not harvested). Rainfall was applied at the rate of 5.6 cm/h. Rainfall was applied to the plots at two different times. The first occurred at antecedent moisture conditions and lasted for 1 h. The second rain or wet run was performed 24 h after the dry run.

All treatments for the dry run with residue were statistically the same for runoff,

while higher runoff rates on the wet run were noticed on all plots. Higher runoff rates on tilled plots were attributed to surface sealing and saturation of the Ap layer (plow layer). In no-till the limiting factor was simply the infiltration of the water into the soil.

Jones et al. (1969) studied the effects of tillage and mulch on corn yields at Blacksburg, Virginia. The factors examined were conventional tillage versus no-till, and mulch versus no mulch. Mulch for no-till plots was killed grass, while mulch for tilled plots was straw. Data showed that surface cover had a greater effect on yields than did tillage. Mulch increased yields, whether applied to no-till or tilled plots. Mulch also increased the infiltration rate, thus decreasing runoff volumes. Runoff volumes amounted to 27% of total precipitation applied for bare plots, but only 4.5% on mulched plots.

3. Erosion Control -- Manure

Physical properties are similar between common mulch material and manure, and some manure application studies have indicated that manure may serve as a sufficient cover to prevent erosion. A lab study performed by Mitchell and Gunther (1976) examined applying three different amounts of pig manure (0, 9.5, 19.5 mm depth) onto two different slopes (3% and 9%) of packed Catlin silt loam. The test areas were 0.91 m by 0.91 m. Rainfall was applied at a rate of 76.2 mm/h for 0.5 h. Runoff was collected from these test areas during the rain and for 15 min after the rain had ceased.

Runoff from the test areas decreased by 50% for the 3% sloped test areas and by 10% for the 9% sloped test areas when compared to test areas containing no cover. The

largest application of manure did not reduce runoff more than the smaller application. The manure, in general, reduced the loss of total solids because the manure prevented the soil from being detached as readily. Also, manure prevented uninhibited flow of water, thereby decreasing the water's sediment-carrying capacity. Volatile solid concentration in the runoff from the 3% sloped test areas decreased as manure application rate increased. However, the opposite was true for the 9% sloped test areas, but total loss was unaffected. Results show manure application on soil caused a decrease in runoff for both slopes. Total solids concentration and Chemical Oxygen Demand (COD) in the runoff decreased as manure application rate increased.

Land application of manure is a common disposal method. It is estimated that the first three days after application represent the highest pollution potential period. Since most farmers do spread manure on land and do not incorporate manure immediately after application, if at all, Westerman et al. (1983) wished to study the short term effects of manure on soil.

Westerman et al. (1983) performed a lab study using 1 m by 0.64 m soil bins packed with Cecil clay or Norfolk sandy loam on a 9% slope. The manure used was undercage layer manure or broiler house litter applied at rates of 2.72 and 5.44 t/ha (dry matter). Rainfall intensity applied to these plots was 5 and 10 cm/h which represented 1 and 7 y return period storms for Raleigh, North Carolina. Drying time between manure application and rainfall ranged from 1 to 3 d.

Results show that the amount of manure or litter applied did not affect the volume of runoff or total solids, but it did alter the transport of volatile solids, manure solids, and

nutrients. Drying time influenced manure and soil transport. Also, the physical characteristics of the manure changed with time, affecting soil particle detachment, infiltration rate, and runoff. Overall, erodibility of the soil decreased as time after manure application increased.

Mathers and Stewart (1984) conducted research on applying beef feedlot manure and inorganic fertilizer on plots for 14 y in Bushland, Texas. The manure and fertilizer were spread on Pullman clay loam at varied amounts and intervals. They found that large amounts of manure (67 M/ha) tended to reduce yields, when compared to lower application rates of manure. The yields were affected by high concentrations of ammonia or salt damaging young seedlings. However, applications of manure dramatically increased the hydraulic conductivity of the soil, while the bulk density was decreased. The proper amount of manure applied to soil of this type for irrigated corn, wheat, corn sorghum would be 22 M/ha of manure.

Mueller et al. (1984) performed an experiment analyzing the effect of tillage system and manure application on runoff and soil loss. The experiment was conducted in West Bend, Wisconsin on four 15 m by 15 m plots randomly located within a 0.81 ha area. Two of the plots contained manure, surface applied, while the remaining two contained no manure. Three tillage systems were also studied (no-till, conventional, and chisel plow). The plots were located on a Dresden silt loam soil (Mollic Hapludoll) with a slope ranging from 4% to 6%.

Runoff from the plots immediately after May planting was significantly greater for the no-till planting system as compared with conventional and chisel plow systems. In

July, runoff was significantly greater for the conventional till and chisel plow systems when compared with May runoff rates. No-till runoff rates for June were very similar to May runoff rates. Manure applied to the plots for all tillage systems only decreased runoff significantly for one season of a two-growing-season study. However, lower runoff volumes were received both seasons from all plots, despite tillage systems, where manure had been applied.

Abu-Zrieg et al. (1994) concluded the stabilization effect of organic waste is dependent on time. The soil's chemical and physical properties improve as time advances. Microbial activity decomposes organic waste and produces polysaccharides that bind soil particles. These polysaccharides help to create more stable soil aggregates. Given enough time, the organic waste will become incorporated with the soil. Eventually the soil will increase in organic matter and in aggregate stability.

Abu-Zrieg et al. (1994) reported that the short term effects of surface applying wastes may be negative. The organic waste increases soil detachability and soil loss due to the low particle density and low settling velocity of the applied manure. This makes the waste laden soil more apt to erode. However, long term effects of organic waste are positive. Organic waste will increase organic matter, water retention, and hydraulic conductivity while reducing bulk density, runoff, and soil loss.

4. Water Quality

A drawback of applying manure as a mulch for erosion control is the nutrients that

are present in manure. In mulch, nutrients are not a concern because of usually low concentrations, whereas manure predominately contains high levels of nitrogen, phosphorus, and other nutrients. These nutrients may become a problem as rain water comes into contact with manure spread as cover, and moves off site. High concentrations of these nutrients may be present in the runoff water.

Westerman and Overcash (1980) designed an experiment to study the impact of time between manure application and rainfall events on the pollution potential of manure application. They also studied the time required for runoff after manure application to return to near normal water quality.

The plots used were 1 m by 1 m in an established fescue sod. They were on an 11% to 16% slope and contained Cecil series soil. Nine tests were completed using common flush schedules but different intervals between tests. Initial flushes ranged from 1 h to 3 d after manure application. A flush was used instead of simulated rainfall in order to normalize crop canopy interactions and because the flushes were easily repeatable.

The results show that concentrations of pollutants decreased as the interval between application and flush increased. Chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) concentrations were 10 times greater for runoff from flushes 1 h after application than for runoff from flushes after 3 d. The 1 h flushes had 20 times greater concentrations of COD, TKN, and TP than the runoff from check plots. The concentrations from the flush after 3 d were nearly two times larger than the check plot runoff. The greatest drop in pollutant concentration occurred within the first 24 h after manure application. Only slight drops were noticed for the 2 and 3 d

intervals, but the totals were still twice the check plots. Runoff concentrations from manured plots became equal to concentrations of check plot runoff within 10 d. In general, the concentration of pollutants in the runoff decreased by 90% within 3 d, and an increase in the interval between manure application and initial flushes decreased concentrations in the runoff.

Diezman et al. (1989) found that application of sewage sludge decreased sediment and runoff totals on conventionally tilled soil. Phosphorus concentration in the runoff increased in plots receiving sludge when compared to plots receiving no sludge. However, with sewage sludge applications of less than 115.4 kg/ha, decreased sediment mass leaving the plots in runoff resulted in an overall decrease in mass of phosphorus that actually left the plots. However, as sludge amounts greater than this were applied, the decrease in sediment did not overcome the increase in phosphorus concentration in runoff, and a net increase in phosphorus was noted.

Ross et al (1979) examined the effect of runoff from sod and bare plots. The plots received manure either by surface spreading or injection. Test results demonstrate that pollution potential decreases as time-since-application increases. In general, the pollution concentration from the plots 1 d after application was 80-97% less than the concentration of runoff within 2 h of application. This trend was similar for 7 d after application but was not as pronounced.

Pollution concentration percentages were quite similar for sod and bare plots for runoff collected after 1 d. Chemical Oxygen Demand (COD) for sod was 8 times higher for 2 h delays, than for 1 d delays in runoff. However, the COD percentage in bare soil

was 60 times larger for 2 h delays compared with 1 d delays. Numbers for 7 d delays followed the same trend. Time also decreased the rate at which pollutants were washed off the plots. With a 1 d delay it took 75% of runoff to carry 80% of total pollutant off site, while with a 2 h delay it took only 30% of the runoff to wash away 80% of total pollutants.

Due to the reduction in pollution potential in manure as time increases, questions arise. If the pollution potential does decrease as time increases, is it possible to spread manure on soil if it is known that for a short period of time little movement of water off site will occur? Also, as research certifies, conventionally tilled soil does possess high infiltration rates for a short period of time following soil disturbance. The infiltration rate decreases as time passes when a crust forms due to raindrop energy impacting the bare soil surface. Surface applied manure may maintain the infiltration rate at a relatively high level for a sufficient period of time to allow the pollution potential of manure to drop to acceptable levels, then is it possible to apply manure to the surface of a conventionally tilled soil? Will water that moves off site, whether immediately after manure application, or a month after application be contaminated? Theoretically, the infiltration rate of the tilled soil will result in less runoff which in turn will decrease the likelihood of contaminated water leaving the site. When the crust forms on the surface the pollution potential will have dropped to acceptable levels and there should be no fear of contamination.

CHAPTER 3

OBJECTIVE

The hypothesis of this project was that surface application of manure to conventionally tilled soil would reduce soil erosion and not produce significant negative impacts on water quality. This would allow farmers to till soil as needed, but still retain residue cover on seeded land needed to control erosion and to remain eligible for all agriculturally related government subsidies and benefits.

The realm of this study included surface applying beef cattle waste in solid form to conventionally tilled seedbeds. The study dealt with the quantifying the runoff water volume, the quality of runoff water, the amount of sediment in the runoff, and the amount of manure in the runoff. It was conceded that freshly tilled soil has a higher infiltration rate and lower runoff potential due to the disturbance of the soil. It was believed that by applying waste to the disturbed soil immediately after planting, the cover would serve three purposes in preventing erosion. First, the waste on the soil surface would dissipate a majority of the raindrop's energy and decrease the amount of bare soil exposed to rainfall. This would prevent detachment of soil particles and prevent sealing of the soil surface. Because the surface was not sealed as quickly, a higher infiltration rate would be maintained for a longer period of time than if the surface were bare. Second, decreased detachment of soil particles would result in less soil loss (Kramer and Meyer, 1969; Lattanzi et al. 1974; Mitchell and Gunther 1976; Mathers and Stewart, 1984). Last, it was

surmised that decreased erosion would also occur due to the residue hampering and blocking continuous water flow; in effect decreasing the velocity which would in turn decrease its carrying capacity (Mannering and Meyer, 1963; Meyer et al., 1971, Lattanzi et al., 1974; Khan et al., 1986).

This project would be deemed a success if, in fact, manure used as a soil cover did decrease the amount of sediment and water leaving the plots. Also, the cover must maintain a high infiltration rate for a period of time sufficient for the pollution potential of the manure to be minimal. This would result in the quality of the water leaving the plots being relatively unaffected by tillage and manure application.

CHAPTER 4

LAYOUT AND DESIGN

The experiment utilized nine field plots, which are 11.18 m by 4.06 m. The plots are located at the Tillage Tract on The University of Tennessee's Plateau Experiment Station near Crossville, Tennessee. The nine plots were divided into three banks, containing three plots each. Each bank contained a 0%, 30%, and 80% residue cover plot. The field plots are located on a Lonewood silt loam soil (Typic Hapludult) and have a slope of 7-10%. Each field plot is surrounded by an impermeable metal border that is partially inserted into the ground. This prohibits water that falls outside the plot from entering the plot. Also, the borders will not allow any water that falls in the plot to leave other than through the desired outlet. Water that leaves the plots as runoff flows to the lower end of the plots. There it flows over a metal lip and falls into a horizontal 15.24 cm diameter PVC collection tube. The collection tube stretches the entire width of the plot to catch all runoff. The collection tube is manufactured so that water flows to the middle via gravity. A 90° elbow placed under a hole in the middle of the collection tube allows the water to exit the tube. Water then drains into a 2.44-3.04 m long, 15.24 cm diameter PVC drain pipe. Runoff exits the drain pipe and falls into a flow divider box.

The divider box divides the flow into nine equal volumes. The flow divider apparatus is simply a box without a top, the sides and bottom of which are made of galvanized steel. Ends of the box are made of PVC. One end has nine evenly spaced and

precisely cut slots perpendicular to the bottom of the box. The slots equally divide the water flowing through the end wall. The slots do not extend to the bottom of the end wall (Brakensiek et al. 1979). Because of this, water is allowed to settle and pool in the bottom of the box before rising to the slots. This pooling effect causes water to flow through the slots in a uniform manner the entire length of the wall. However, to accomplish this, the box must be completely level. Since this is usually not possible, an equalizer bar is located in front of the slots. This bar can be leveled by loosening the screws and placing a bubble level on the bar. The bar can be moved up and down until level, and the screws can then be tightened.

The multislot divisor boxes were tested in the lab at The University of Tennessee at Knoxville for accuracy and reliability of sediment and water division. Under static flow conditions, the boxes more accurately divided the flow for large flow rates than for small flow rates. The error was 50% at flow rates below 1 gpm, but at flow rates between 1 and 10 gpm the error was only 8%. These boxes performed extremely well at storm cycle flows lasting 15 min with a maximum flow rate of 5 and 10 gpm. The error for 5 gpm, 15 min storms was 5.4%. However, the error for 10 gpm, 15 min storms was only 2% (See Appendix G).

Results of the sediment division tests indicate that the boxes performed satisfactorily. Two different weights of sediment were deposited into a stream of water flowing into the divider boxes. Collection from the output of the flow dividers averaged 1.35% and 3.32% below the correct weights for the 8000 g and 2500 g tests, respectively (See Appendix G).

The divider boxes performed extremely well in the ranges of sediment mass and flow rates that the boxes would be subjected to in this project. Therefore, the boxes were deemed to be accurate and reliable enough to confidently implement into this project

For this project, water from one slot, or one ninth of flow through the box, was gravity drained by flexible hose into a bucket. The bucket was periodically emptied manually into a 68-L container. Water accumulated in the 68-L container was a representative fraction ($1/9$) of the total runoff.

Runoff events were created by simulated rainfall. Rainfall was simulated by 41, Toro 423, irrigation nozzles located on top of 3-m risers positioned upslope and downslope from the plots. Three plots or one bank was irrigated at a time due to limited pump output. A 5 hp centrifugal pump was used to transfer water from a pond to the rainfall simulator sprinklers. The average amount of water applied was 3.6 cm/h. The average coefficient of uniformity for water application on all plots was 0.76.

CHAPTER 5

PROCEDURES

1. Data Collection

The plots were tilled a few days prior to manure application. This helped to control and destroy all plant growth. It also buried large amounts of plant residue and organic matter. After tilling the plots, experiment station employees applied a preemergence herbicide to the plots. The herbicide was used to control further plant and weed growth. The plots were tilled again immediately before manure application and the beginning of the data collection. A rear-tine, self-propelled tiller was used to till the plots. This was done to simulate tillage performed by a farmer for seedbed preparation. Samples of the soil were collected 15-20 cm deep using a soil probe. These samples were placed in a plastic bag for transport back to the lab for determination of moisture content.

Residue cover on the plots was checked prior to manure application. A residue grid was used to determine percent residue cover on the plots. The grid is a 1 m by 1 m aluminum square with 100 evenly spaced beads. The beads are spaced on 10 cm centers. The square was randomly placed on the plots. Beads that covered a piece of residue were counted. The number of beads was then totaled to find percent cover. This process was replicated 3-5 times per plot.

Manure was spread on the plots by hand. The mass of the manure applied was

determined using a wheelbarrow attached to a 227-kg load cell. The wheelbarrow and load cell was suspended from a front end loader attached to a small tractor. After the predetermined weight of manure was applied to the plots, the percent cover was checked 3-5 times using the residue grid. If the percent cover was not as desired, more manure was applied until the desired degree of cover was reached. Samples of manure were collected and placed in plastic bags at random intervals during application. Manure samples were brought back to the lab for moisture, volatile solids, and nutrient content analysis.

Runoff

Water was applied to the plots by the overhead irrigation system. The water was applied until the flow of runoff had stabilized and a sufficient volume of runoff from the least-producing plot was collected so as to provide a sample of adequate volume for analysis. The lengths of application and amount of water applied varied due to weather, antecedent moisture of the soil, percent residue cover, and slope of the plots. Runoff from each plot was caught and placed in a 68-L container. The runoff was then transferred to smaller containers for weighing. After weighing the water was returned to the 68-L containers. The water was swirled vigorously and three grab samples were obtained. These samples were returned to the lab and placed in the freezer for analysis at a later time. Water and sediment remaining in the divider box were placed in a 38-L container and brought back to lab for analysis.

The amount and uniformity of simulated rain applied to the plots were measured

by placing eight collection cups in a grid pattern inside each plot border. The volume of water caught in these cups to determine the amount and the uniformity of water applied.

Total Solids

The mass of total solids (TS) leaving the plots was determined by adding total dissolved solids (TDS) and total suspended solids (TSS). TSS was established by filtering the samples of the runoff with a fiber filter disk without an organic binder (Gelman type A-E). The filter was weighed, dried at 105° C for at least 8 h, and reweighed (APHA, 1992 Section 2540D). A concentration was found and multiplied by the measured total runoff leaving the plot to determine the total suspended solids in runoff. This number is designated as TSS.

Total dissolved solids (TDS) was found by placing filtered water into a container and evaporating the water. The container was weighed, dried at 105° C for at least 8 h, reweighed, and a concentration was established (APHA, 1992. Section 2540C). The concentration was multiplied by the total amount of runoff and a TDS amount was found. TDS and TSS amounts were added to find TS.

Volatile Solids

Volatile solids were found by drying an unfiltered, well-mixed sample for at least 8 h at 105° C. The samples were weighed and placed in an oven at 500° C for at least 1 h (APHA, 1992. Section 2540E). The samples were weighed and a percent volatile number was calculated.

Total Kjeldahl Nitrogen

Soil

Total Kjeldahl nitrogen (TKN) tests were run to determine the levels of organic nitrogen in the sediment transported off the plot. Total Kjeldahl nitrogen in the sediment was found using Lachat Instrument Method 13-107-06-2-D developed from the Methods Manual for Forest Soil and Plant Analysis, Information Report NOR-X-39 (Kaltra and Maynard, 1991). The data were received in percentage form. The percent was multiplied by total sediment collected and a mass was calculated. The minimum detectable level for the test was 0.01%.

Runoff

Nitrogen levels in the runoff were determined by using Lachat Instrument Method 10-107-06-2-D developed from total Kjeldahl nitrogen (TKN) tests using Environmental Protection Agency Method 351.2 (USEPA, 1983) and American Society for Testing and Materials Method D3590-89 (ASTM, 1991). Results were reported in concentration form. Concentrations were multiplied by total volume of runoff to calculate total mass. The minimum detectable level was 0.2 mg nitrogen per L. The masses for both total Kjeldahl nitrogen tests (TKN soil and TKN water) were added to find total mass of nitrogen leaving the plot.

Total Phosphorus

Soil

Phosphorus amounts in sediment leaving the plots were determined by using a method developed by R.A. Bowman (1988). The resulting mass was determined using a method detailed by Watanabe and Olsen (1965). Minimum detectable level was 0.01%.

Runoff

The total phosphorus mass leaving the plots was determined by using the Lachat Instrument Method 10-115-01-1-C developed from the block digester method suggested by the Environmental Protection Agency, Method 365.4 (USEPA, 1983). Results were issued in g of phosphorus per L of sample. The concentrations were multiplied by the volume of runoff leaving the plots to find total phosphorus mass. The minimum detectable level was 0.01 mg phosphorus per L.

2. Event 1

Manure was spread on Banks A and B early on the morning on August 11, 1994. The 30% plots received an average of 30.2 kg (dry matter) of manure while the 80% plots received 78 kg (dry matter) of manure. The mass of manure needed for each cover percent was found by applying small amounts of manure to the plots. As each amount was spread the weights were recorded and the percentage of cover was checked using the residue grid. When the desired cover percent was reached the mass of manure was totaled

and the weight of moisture was subtracted.

Manure used for this project was produced by beef cattle confined on concrete at the experiment station. The confinement area was bedded using sawdust. A separate pile of manure was used for each year. The makeup of the manure was somewhat similar for both years. However, the texture of the manure used for both years was different. This caused the weight needed to reach each coverage level to be different. The manure used in the fall of 1994 was clumpy and the desired percent was more difficult to reach. A heavy amount was applied to reach the cover percentages. However, the manure used in the study for the spring of 1995 was fine and covered the plots in a more uniform manner. Less weight was required to reach the desired cover percentages. The differences in the texture of the manure resulted from different storage lengths and handling procedures. The manure used in 1994 was allowed to remain undisturbed for a few months and some moisture may have leaked through the plastic that covered the pile. The manure used in 1995 was relatively fresh manure and was covered immediately after removal from the confinement area.

Simulated rain was applied directly after the spreading of manure on the plots. Bank A received rain for 1.5 h with an intensity of 4.1 cm/h. Bank B received rain for 2.5 h with an intensity of 2.8 cm/h. Manure was spread on Bank C on August 12, 1994. The rain lasted for 1.75 h with an intensity of 3.3 cm/h. Banks A, B, and C, received 61, 70, and 57 mm of rainfall, respectively. Average antecedent soil moisture content for all plots was 13% by weight.

The second rain was applied, a week later, on August 18, 1994. The rain for

Banks A, B, C, lasted for 1.75, 2, and 1.58 h, respectively. The banks received 65, 71, and 62 mm of water at an intensity of 3.7, 3.6, and 3.9 cm/h, respectively. Average antecedent soil moisture content for all plots was 15% by weight. Procedures were the same as for the first rain, with the exception of no manure being spread.

Rain three was completed on September 8, 1994. This was three weeks after rain two and four weeks after rain one. The rain for all three banks lasted for 1.58 h. The total amount of rainfall water received by the banks was 55, 61, and 65 mm with an intensity of 3.5, 3.8, and 4.1 cm/h, respectively. Average antecedent soil moisture content for all plots was 16% by weight.

3. Event 2

Event two occurred in the same manner and order as event one with the exception of determining total solids. Total solids in the runoff was analyzed in its entirety instead of being subsampled. The procedure for determining total solids mass was changed in hopes of obtaining a more accurate account of sediment leaving the plots. Some variation in sediment concentrations was thought to be present in the grab samples taken in Event 1. To receive more complete sediment totals, the runoff was weighed and set beside a building near the plots. The containers were allowed to remain undisturbed for at least one week. This allowed the sediment particles to settle out. After one week the water was decanted or siphoned off using small diameter flexible tubing. All sediment remaining in the bottom of the container was brought back to the lab and dried.

TS was determined by drying and weighing all sediment remaining in the containers. Since no subsamples were taken from the water after it was weighed, samples were taken as the water actually exited the plot. Three samples were collected from the PVC connector tube before the water entered the divider box. These samples were gathered throughout the rainfall event. They were gathered as close to the beginning, middle, and end of the event as possible. These samples were used in the analysis of the runoff water. TSS and TDS was determined in the same manner previously described in procedures section.

Manure was spread on the morning of May 31, 1995. The 30% plots received 27.5 kg (dry matter) and the 80% plots received 51.1 kg (dry matter). Immediately after manure application water was applied to the plots. The length of the rains for all banks was 2 h. The total amount of rainfall applied to the banks was 46, 66, and 67 mm with an intensity of 2.3, 3.3, and 3.3 cm/h, respectively. Average antecedent soil moisture content for all plots was 14% by weight.

Rain two occurred on June 7, 1995, one week after rain one. The 80% cover plot in Bank A received rain for 1.38 h. Total amount of rainfall applied to the 80% cover plot was 55 mm with an intensity of 4 cm/h. The two remaining plots in Bank A received rain for 0.75 h. The total amount of rainfall applied to the two remaining plots in Bank A was 34 mm with an intensity of 4.5 cm/h. The 80% cover plot received more rain due to no runoff occurring. Banks B and C received rain for 1 h. The total amount of rainfall to Banks B and C was 30 and 40 mm with an intensity of 3 and 4 cm/h, respectively. Average antecedent soil moisture content for all plots was 19% by weight.

Rain three took place on June 28, 1995, which was three weeks after rain two and four weeks after rain one. Bank A received rain for 1 h. The total amount of rainfall applied on Bank A was 35 mm with an intensity of 3.8 cm/h. The 0% cover plot in Bank B received rain for 0.5 h, but the remaining plots in Bank B received rain for 1 h. The 0% cover plot received 19 mm of rainfall at an intensity of 3.8 cm/h. However, the remaining plots in Bank B received 32 mm of rainfall with an intensity of 3.2 cm/h. In Bank C, the 30% and 80% cover plots received rain for 1 h, but the 0% cover plot received rain for only 0.5 h. The rainfall amount applied to the covered plots was 30 mm with an intensity of 3 cm/h. The 0% cover plot received 59 mm of water at an intensity of 5.9 cm/h. The rains were shortened due to sufficient runoff occurring early. Average antecedent soil moisture content for all plots was 17% by weight .

4. Data Analysis

The study was designed as a split plot randomized block, with cover as the whole plot and rain as the subplot. General Linear Modeling (SAS Institute, 1989) procedures and Least Significant Difference tests ($\alpha = .05$) were performed on the data. Log transformations were used where necessary to normalize the data.

Statistical analyses were conducted on data reduced in two separate ways. For one set of analyses, the mass of contaminants leaving the plots was normalized by the volume of rainfall applied. This information provides a comparison of the effects surface-applied manure will have on the amount of runoff and erosion resulting from a quantity of

rainfall. Also, the effect manure will have over time can be analyzed.

For the second set of statistical analyses, the concentration of contaminants in the runoff was used. This comparison allowed the quality of the runoff water leaving the plots to be compared for each rainfall. Concentration in runoff may relate more directly to quality of a given stream than does quantity of contaminants moved off-site by a given quantity of rainfall

CHAPTER 6

RESULTS

As stated previously, this project was undertaken to determine if surface applying manure on a conventionally tilled soil would reduce soil erosion and not produce significant negative impacts on water quality. For this project, manure was surface applied to freshly tilled plots once in each of two consecutive years. Runoff from three rainfall events distributed over a four-week period after each manure application was measured and evaluated for quality.

1. Runoff

Increased percent cover decreased the volume of runoff water leaving the plots (Table 1). Mean runoff from the plots with 80%, 30%, and 0% cover was 0.05, 0.13, and 0.27 L runoff per L water applied, respectively. The resulting volume of runoff per volume of water applied for each cover was significantly different.

A significant interaction occurred between degree of manure cover and the time-since-application of manure when rainfall occurred (Figure 1). Runoff from the plot with no cover increased appreciably with time, whereas there was little change in runoff from the 30% and 80% covered plots as time-since-application of manure increased from 0 to 4 weeks.

Table 1. Mean runoff data obtained from plots with three levels of manure cover.

Cover %	Normalized Runoff (L Runoff/ L Rainfall Applied)	Normalized Runoff (L Runoff/ L Rainfall Applied)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.27 ^{A*}	0.0879
30	0.13 ^B	0.0692
80	0.05 ^C	0.0211

*Means with like letters are not significantly different at $P > .05$.

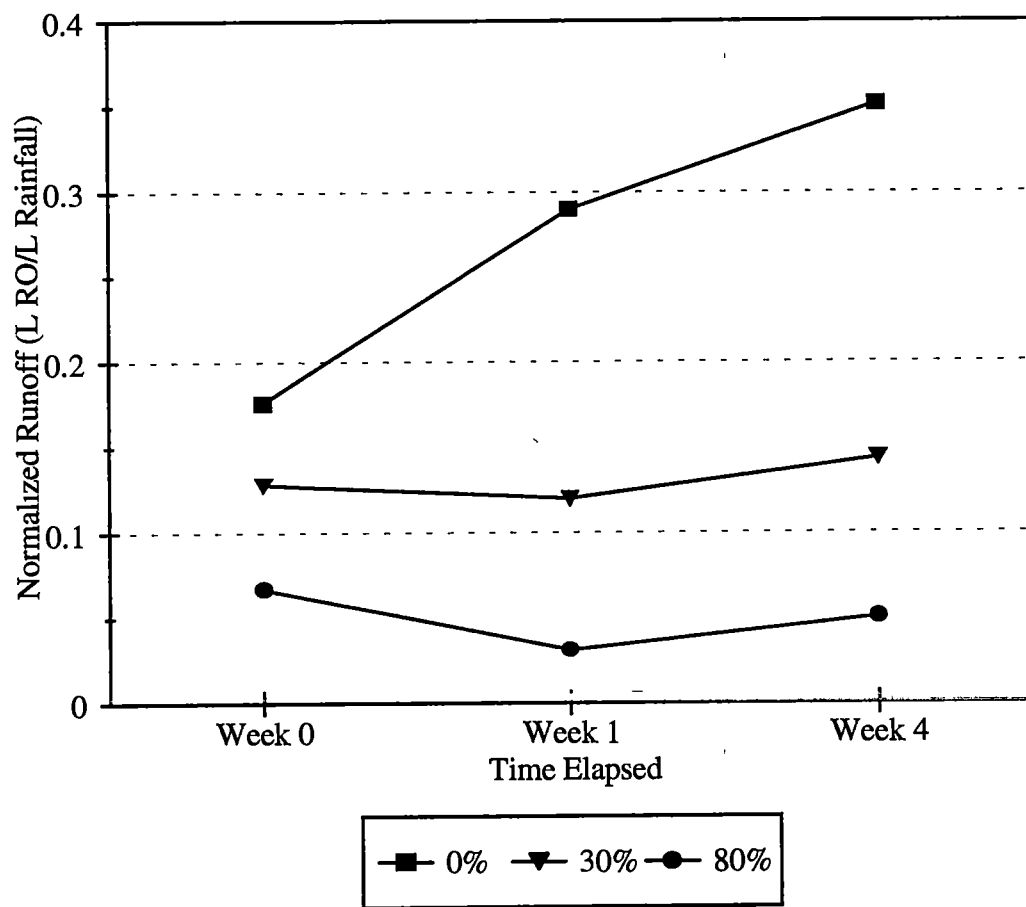


Figure 1. Relationship between elapsed time and runoff from soil plots with three levels of manure cover.

2. Total Solids

Analysis of the data showed cover decreased the mass of total solids leaving the plots when normalized by the volume of rainfall applied (Table 2). The mean loss from 80%, 30%, and 0% covered plots was 0.15, 0.41, and 1.58 g sediment leaving the plots per L water applied to the plots. The resulting sediment mass leaving the plots per volume of water applied for each cover was significantly different.

A significant interaction was also noticed between degree of cover and time-since-application of manure when rainfall occurred (Figure 2). The interaction followed the same trend as did runoff. Total solids leaving the plots with no cover increased with advancing time, although there was a reduction in total solid mass exiting the 30% and 80% covered plots as time increased from 0 to 4 weeks.

Statistical analysis comparing the concentrations of total solids in the runoff determined that cover effectively decreased the mass of sediment in the runoff (Table 3). Zero percent cover contained 1.54 g sediment per L runoff. This was significantly more than the 30% and 80% concentrations which were 1.00 and 0.90 g sediment per L runoff, respectively. However, no significant difference in sediment concentrations in the runoff were noticed as time-since-application of manure increased (Table 4).

Table 2. Mean total solids data obtained from plots with three levels of manure cover

Cover %	Normalized Total Solids (g TS/ L Rainfall Applied)	Normalized Total Solids (g TS/ L Rainfall Applied)
	<u>Mean</u>	<u>Standard Deviation</u>
0	1.58 ^{A*}	0.9908
30	0.41 ^B	0.2496
80	0.15 ^C	0.0562

*Means with like letters are not significantly different at $P > .05$.

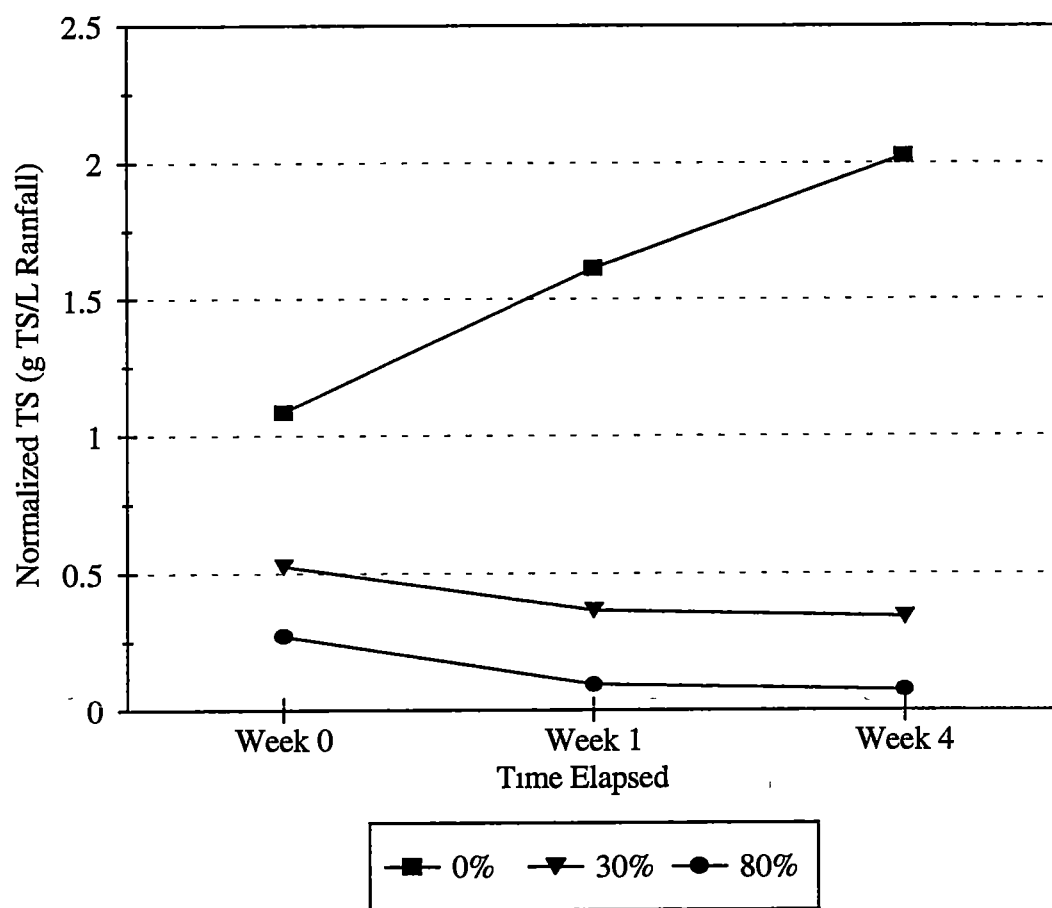


Figure 2 Relationship between elapsed time and sediment from soil plots with three levels of manure cover.

Table 3. Mean total solids data obtained for runoff from plots with three levels of manure cover.

Cover %	Normalized Total Solids Concentrations (g TS / L Runoff)	Normalized Total Solids Concentrations (g TS / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
0	1.54 ^{A*}	2.2291
30	1.00 ^B	1.0140
80	0.90 ^B	1.9138

*Means with like letters are not significantly different at $P > .05$.

Table 4. Mean total solids data obtained for runoff from plots for three rain events

Time Elapsed	Normalized Total Solids Concentrations (g TS / L Runoff)	Normalized Total Solids Concentrations (g TS / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	1.36 ^{A*}	2.1130
Week 1	1.13 ^A	1.3958
Week 4	0.94 ^A	1.6481

*Means with like letters are not significantly different at $P > .05$.

3. Volatile Solids

The mass of volatile solids leaving the plots compared with mass of total solids leaving the plots was significantly effected by percent cover on the plots (Table 5). Means from the 80% and 30% cover plots, which were 0.15 and 0.13 g volatile solids per g sediment leaving the plots, respectively, were not statistically different. However, both were significantly greater than the mean of 0.05 g volatile solids per g sediment from the 0% cover plots. Rain occurring from 0 to 4 weeks after manure application had no significant effect on volatile solids leaving the plots. Although a trend was present showing a reduction in mass of volatile solids per liter of water applied leaving the plots as time-since-application of manure increased (Table 6).

Statistical analysis of the concentrations of volatile solids in the runoff showed no difference existed for either percent cover of the plot or an increase in time-since-application of manure (Tables 7 and 8). However, statistics performed comparing the mass of volatile solids leaving the plots with the volume of rainfall applied showed a significant reduction in volatile solids leaving the 80% cover plots (0.0222 g volatile solids per L water applied). The 0% and 30% cover plots which had 0.0527 and 0.0449 g volatile solids per L of water applied, respectively, showed no difference from each other (Table 9). Also, no difference was present when comparing the mass of volatile solids leaving the plots as time-since-application of manure increased (Table 10).

Table 5. Mean volatile solids data obtained for total solids from plots with three levels of manure cover.

Cover %	Normalized Volatile Solids Concentrations (g VS / g TS)	Normalized Volatile Solids Concentrations (g VS / g TS)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.05 ^{A*}	0.0349
30	0.13 ^B	0.1160
80	0.15 ^B	0.1557

*Means with like letters are not significantly different at $P > .05$.

Table 6. Mean volatile solids data obtained for total solids from plots for three rain events.

Time Elapsed	Normalized Volatile Solids Concentrations (g VS / g TS)	Normalized Volatile Solids Concentrations (g VS / g TS)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.13 ^{A*}	0.1366
Week 1	0.11 ^A	0.0970
Week 4	0.09 ^A	0.0730

*Means with like letters are not significantly different at $P > .05$.

Table 7. Mean volatile solids data obtained for runoff from plots with three levels of manure cover.

Cover %	Normalized Volatile Solids Concentrations (g VS / L Runoff)	Normalized Volatile Solids Concentrations (g VS / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.21 ^{A*}	0.1264
30	0.39 ^A	0.3871
80	0.39 ^A	0.4170

*Means with like letters are not significantly different at $P>.05$.

Table 8. Mean volatile solids data obtained for runoff from plots for three rain events.

Time Elapsed	Normalized Volatile Solids Concentrations (g VS / L Runoff)	Normalized Volatile Solids Concentrations (g VS / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.47 ^{A*}	0.5662
Week 1	0.33 ^A	0.2660
Week 4	0.20 ^A	0.0982

*Means with like letters are not significantly different at $P>.05$.

Table 9. Mean volatile solids data obtained from plots with three levels of manure cover.

Cover %	Normalized Volatile Solids (g VS / L Rainfall)	Normalized Volatile Solids (g VS / L Rainfall)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.0527 ^{A*}	0.0290
30	0.0449 ^A	0.0432
80	0.0222 ^B	0.0228

*Means with like letters are not significantly different at $P > .05$.

Table 10. Mean volatile solids data obtained from plots for three rain events.

Time Elapsed	Normalized Volatile Solids (g VS / L Rainfall)	Normalized Volatile Solids (g VS / L Rainfall)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.0460 ^{A*}	0.0565
Week 1	0.0366 ^A	0.0162
Week 4	0.0372 ^A	0.0224

*Means with like letters are not significantly different at $P > .05$.

4. Total Kjeldahl Nitrogen

Cover had an effect on total Kjeldahl nitrogen leaving the plots (Table 11). The 0% cover plots had a mean of 0.0030 g nitrogen leaving the plot per L water applied. This was more than the mean in runoff from 30% or 80% cover plots which was 0.0012 and 0.0005 g nitrogen per L water applied, respectively. However, the mean values from 30% and 80%-cover plots did not differ significantly. Rains occurring from 0 to 4 weeks after manure application did not result in statistical differences in mass of total Kjeldahl nitrogen leaving the plots. However a trend was present illustrating a decrease in mass of total Kjeldahl nitrogen per liter of water applied leaving the plots as time-since-application of manure increased (Table 12).

Statistical comparison of mass of total Kjeldahl nitrogen leaving the plots in the runoff showed no difference in cover (Table 13). However, a significant interaction occurred between degree of cover and the time since-manure-application when rainfall occurred (Figure 3). Mass of total Kjeldahl nitrogen in runoff from plot with 80% cover decreased substantially with time. However, there was a less drastic reduction in mass of total Kjeldahl nitrogen leaving plots with 0% and 30% cover as time-since-application increased from 0 to 4 weeks.

There was a significant reduction in total Kjeldahl nitrogen leaving the plots as time-since-application of manure increased (Table 14). Runoff from Week 0 contained 0.0148 g total Kjeldahl nitrogen per L runoff. This was significantly greater than the

Table 11. Mean total Kjeldahl nitrogen data obtained from plots with three levels of manure cover.

Cover %	Normalized Total Kjeldahl Nitrogen (g TKN / L Rainfall Applied)	Normalized Total Kjeldahl Nitrogen (g TKN / L Rainfall Applied)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.0030 ^{A*}	0.0023
30	0.0012 ^B	0.0008
80	0.0005 ^B	0.0002

*Means with like letters are not significantly different at $P > .05$.

Table 12. Mean total Kjeldahl nitrogen data obtained from plots for three rain events

Time Elapsed	Normalized Total Kjeldahl Nitrogen (g TKN / L Rainfall Applied)	Normalized Total Kjeldahl Nitrogen (g TKN / L Rainfall Applied)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.0020 ^{A*}	0.0016
Week 1	0.0016 ^A	0.0009
Week 4	0.0011 ^A	0.0007

*Means with like letters are not significantly different at $P > .05$.

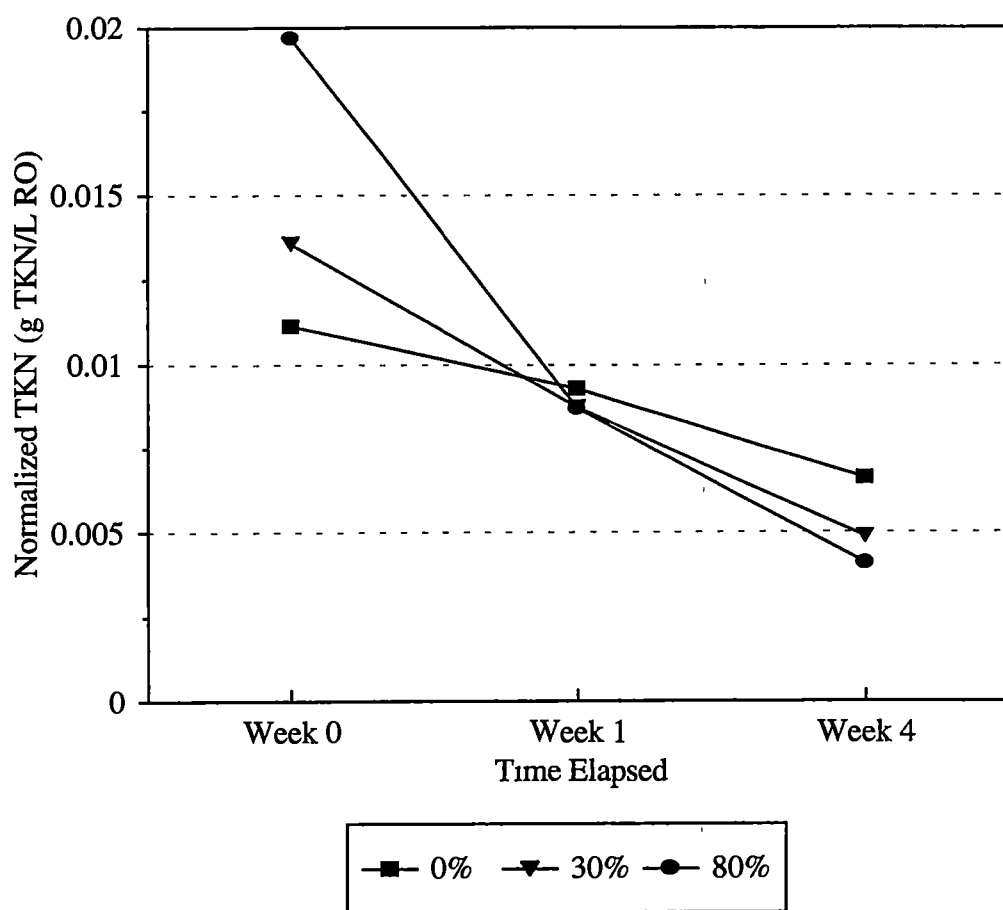


Figure 3. Relationship between elapsed time and mass of total Kjeldahl nitrogen in runoff from soil plots with three levels of manure cover.

Table 13. Mean total Kjeldahl nitrogen data determined for runoff from plots with three levels of manure cover.

Cover %	Normalized Total Kjeldahl Nitrogen Concentrations (g TKN / L Runoff)	Normalized Total Kjeldahl Nitrogen Concentrations (g TKN / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.0090 ^{A*}	0.0054
30	0.0091 ^A	0.0029
80	0.0108 ^A	0.0043

*Means with like letters are not significantly different at $P > .05$.

Table 14. Mean total Kjeldahl nitrogen data obtained for runoff from plots for three rain events.

Time Elapsed	Normalized Total Kjeldahl Nitrogen Concentrations (g TKN / L Runoff)	Normalized Total Kjeldahl Nitrogen Concentrations (g TKN / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.0148 ^{A*}	0.0069
Week 1	0.0089 ^B	0.0050
Week 4	0.0052 ^C	0.0026

*Means with like letters are not significantly different at $P > .05$.

0.0089 g total Kjeldahl nitrogen per L runoff which was the concentration in runoff from Week 1. Also, the concentration of total Kjeldahl nitrogen in runoff for Week 4 which was 0.0052 g total Kjeldahl nitrogen per L runoff was significantly less than Week 1.

5. Total Phosphorus

The mean mass of total phosphorus leaving the plots normalized by the amount of rainfall applied to the plots did not significantly differ for either coverage or rains occurring 0 to 4 weeks after manure application. Although a trend was present depicting an increase in phosphorus mass leaving the plots per liter of water applied as time-since-application of manure increased (Tables 15 and 16).

The concentration of total phosphorus in the runoff did not differ significantly as the percent cover on the plots increased (Table 17). However, the concentration of phosphorus in the runoff differed significantly as time-since-application of manure increased. Rains 1 and 2 resulted in 0.0378 and 0.0481 g of phosphorus per L of runoff leaving the plots, respectively. These totals, while not different from each other, were significantly different from 0.0393 g of phosphorus per L of runoff which was the phosphorus concentration from Rain 3 (Table 18).

Table 15. Mean total phosphorus data obtained from plots with three levels of manure cover.

Cover %	Normalized Total Phosphorus (g TP / L Rainfall Applied)	Normalized Total Phosphorus (g TP / L Rainfall Applied)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.123 ^{A*}	0.0193
30	0.007 ^A	0.0079
80	0.002 ^A	0.0016

*Means with like letters are not significantly different at $P > .05$.

Table 16. Mean total phosphorus data obtained from plots for three rain events.

Time Elapsed	Normalized Total Phosphorus (g TP / L Rainfall Applied)	Normalized Total Phosphorus (g TP / L Rainfall Applied)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.004 ^{A*}	0.0041
Week 1	0.007 ^A	0.0088
Week 4	0.010 ^A	0.0160

*Means with like letters are not significantly different at $P > .05$.

Table 17. Mean total phosphorus data obtained for runoff from plots with three levels of manure cover.

Cover %	Normalized Total Phosphorus Concentrations (g TP / L Runoff)	Normalized Total Phosphorus Concentrations (g TP / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
0	0.0459 ^{A*}	0.0629
30	0.0490 ^A	0.0525
80	0.0302 ^A	0.0330

*Means with like letters are not significantly different at $P > .05$.

Table 18. Mean total phosphorus data obtained for runoff from plots for three rain events

Time Elapsed	Normalized Total Phosphorus Concentrations (g TP / L Runoff)	Normalized Total Phosphorus Concentrations (g TP / L Runoff)
	<u>Mean</u>	<u>Standard Deviation</u>
Week 0	0.0378 ^{A*}	0.0393
Week 1	0.0481 ^A	0.0511
Week 4	0.0393 ^B	0.0579

*Means with like letters are not significantly different at $P > .05$.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The purpose of this project was to discover alternative ways to dispose of livestock waste in a manner that would not cause degradation of water quality. An added benefit of surface application of manure onto conventionally tilled soil would, theoretically, be a decrease in erosion rates.

Research conducted showed that surface application of manure on conventionally tilled soil may provide a simple solution to both erosion control and waste disposal problems. The data show that increased percent cover of tilled soil decreased the amount of runoff, which in turn decreased the mass of total solids that left the plots. Also important is that as time passed no crusting was noticed. This is supported by observations of a decrease in runoff from plots containing manure as time advanced. This reduction in runoff coupled with manure protection of the soil surface managed to retain sediment in the plot. The decrease in sediment could be associated with the manure decreasing the carrying capacity of the water by forming obstacles and pools that allow heavy particles to settle out and prohibit free flow of water. Also, manure acted as a cover that absorbed a portion of the water droplets' energy, resulting in fewer soil particles being disturbed.

Although significantly less total solids left plots that had manure applied, there was a significant increase in volatile solids that left these plots when compared to plots

containing bare soil. However, there was no significant difference between the total mass of volatile solids for 30% and 80% manure cover plots.

The mass of total volatile solids leaving the plots significantly increased with degree of manure cover, but did not significantly change with each succeeding rain. This indicates all the manure was not washed off during the first rain. This allowed the manure to have an effect over the entire length of the experiment. The remaining manure kept runoff volumes and sediment losses low throughout the entire period of testing.

When nitrogen mass washed off-site was normalized by rainfall applied to the plots, a significant decrease was noticed for plots containing manure cover. This was reasoned to have occurred because less sediment mass was transported off-site due to the erosion prevention characteristics of manure. Manure applied on the surface of the plots did not cause nitrogen concentrations in runoff to increase. No differences in mass of nitrogen per liter of water applied leaving the plots were noticed for any rains. Although, nitrogen concentrations in the runoff decreased significantly as time-since-application of manure increased.

In general, the mass of total phosphorus per liter of water applied leaving the plots did not significantly vary as cover or time increased. Based on results of this study, it appears that phosphorus pollution of surface water is not a concern for this type of waste disposal / erosion control method.

CHAPTER 8

RECOMMENDATIONS

Although the project produced some encouraging results, certain aspects of the study need to be improved and repeated for verification of results. A more uniform rainfall with a higher intensity should be used for future work. Similar studies use 1 or 7-year return storms, which have a higher intensity than the output capacity of the rain simulator used in this study. Also, a sizable amount of variation among plots was noted, with some of the variation evidently resulting from wind affecting the manner in which the droplets fell. Better weed control methods should also be investigated. The author found that performing this study in the spring resulted in rampant growth of weeds, forcing curtailment of planned data collection events. However, performing the study in the fall escaped the severe weed growth pressure and all data collection events proceeded as planned.

This study could be further extended to determine which crops grow well in this type waste disposal and tillage system. A final suggestion would be to use natural rainfall to see if the same trends occur when control over the rainfall can not be exercised

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APPENDICES

Appendix A.

Runoff Data

Volume of runoff from plots compared to volume of water applied.

				R-O/App'd (L/L) 0%	R-O/App'd (L/L) 30%	R-O/App'd (L/L) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.1220	0.1413	0.0648
			2	0.0273	0.1209	0.0783
			3	0.1129	0.0802	0.1165
		Rain 2	1	0.2278	0.1440	0.0209
			2	0.1781	0.1145	0.0202
			3	0.3126	0.0844	0.0480
		Rain 3	1	0.3720	0.2489	0.0162
			2	0.2583	0.1892	0.0299
			3	0.3382	0.1602	0.0741
1995	Event 2	Rain 1	1	0.1805	0.2367	0.0619
			2	0.2514	0.1318	0.0506
			3	0.3673	0.0574	0.0303
		Rain 3	1	0.3873	0.1089	0.0336
			2	0.3340	0.0870	0.0398
			3	0.2994	0.1787	0.0230
		Rain 4	1	0.4372	0.1603	0.0592
			2	0.4110	0.0738	0.0552
			3	0.2919	0.0266	0.0692

Appendix B.
Total Solids Data

Mass of total solids leaving the plots compared to volume of water applied.

				TS (g/L APP) 0%	TS (g/L APP) 30%	TS (g/L APP) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.5626	0.4223	0.2681
			2	0.1153	0.5800	0.2229
			3	0.4215	0.2032	0.3472
		Rain 2	1	0.8684	0.4510	0.0754
			2	1.0801	0.5024	0.1031
			3	2.3474	0.2833	0.0795
		Rain 3	1	0.6980	0.6922	0.0462
			2	1.4781	0.5110	0.0664
			3	3.8855	0.4497	0.0832
1995	Event 2	Rain 1	1	1.5762	1.1373	0.3070
			2	0.8884	0.6423	0.4053
			3	2.9534	0.1645	0.0751
		Rain 2	1	2.2570	0.1517	0.1087
			2	1.9909	0.2838	0.1325
			3	1.1445	0.5166	0.0562
		Rain 3	1	2.8224	0.1477	0.1211
			2	2.5419	0.1644	0.0584
			3	0.7223	0.0800	0.0636

Mass of total solids leaving the plots compared to volume of runoff.

				TS/RO (g/L Runoff) 0%	TS/RO (g/L Runoff) 30%	TS/RO (g/L Runoff) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	3.3113	2.9284	4.0494
			2	3.9508	4.5620	2.7791
			3	3.6423	1.2020	2.9407
		Rain 2	1	3.7588	3.0794	3.4921
			2	6.0147	4.3384	4.8865
			3	7.5089	3.2752	1.5783
		Rain 3	1	1.8585	2.7667	2.7485
			2	5.6949	2.6746	2.0903
			3	11.4563	2.7688	1.0858
	Event 2	Rain 1	1	5.1119	4.8143	8.5514
			2	3.5638	3.7554	10.5517
			3	7.5086	2.8825	2.7069
		Rain 2	1	5.8363	1.4175	0.3599
			2	3.3390	3.3022	3.3822
			3	3.8347	2.9027	2.5455
		Rain 3	1	6.4597	0.9294	2.0642
			2	6.1924	2.2483	1.0807
			3	2.4821	3.0674	0.9472

Appendix C.
Volatile Solids Data

Mass of volatile solids leaving the plots compared to volume of water applied.

				VS (g/L APP) 0%	VS (g/L APP) 30%	VS (g/L APP) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.0511	0.0798	0.1092
			2	0.0120	0.2740	0.0558
			3	0.0435	0.0657	0.0801
		Rain 2	1	0.0625	0.0419	0.0020
			2	0.0415	0.0152	0.0000
			3	0.0694	0.0273	0.0099
		Rain 3	1	0.0309	0.0242	0.0013
			2	0.0226	0.0260	0.0037
			3	0.0571	0.0215	0.0066
1995	Event 2	Rain 1	1	0.0095	0.0096	0.0041
			2	0.0090	0.0047	0.0078
			3	0.0056	0.0043	0.0020
		Rain 2	1	0.0692	0.0313	0.0045
			2	0.0634	0.0623	0.0413
			3	0.0360	0.0513	0.0292
		Rain 3	1	0.1524	0.0362	0.0113
			2	0.1271	0.0239	0.0137
			3	0.0849	0.0088	0.0173

Mass of volatile solids leaving the plots compared to mass of total solids.

				VS/TS (g/g) 0%	VS/TS (g/g) 30%	VS/TS (g/g) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.0909	0.1889	0.4071
			2	0.1042	0.4724	0.2503
			3	0.1031	0.3232	0.2307
		Rain 2	1	0.0720	0.0930	0.0272
			2	0.0384	0.0302	0.0260
			3	0.0296	0.0963	0.1250
		Rain 3	1	0.0442	0.0349	0.0290
			2	0.0153	0.0509	0.0552
			3	0.0147	0.0478	0.0790
1995	Event 2	Rain 1	1	0.0103	0.0085	0.0078
			2	0.0101	0.0095	0.0148
			3	0.0020	0.0259	0.0249
		Rain 2	1	0.0306	0.2063	0.0412
			2	0.0318	0.2196	0.3120
			3	0.0314	0.0993	0.5194
		Rain 3	1	0.0540	0.2453	0.0936
			2	0.0500	0.1452	0.2348
			3	0.1175	0.1097	0.2725

Mass of volatile solids leaving the plots compared to volume of runoff.

				VS/RO (g/L Runoff) 0%	VS/RO (g/L Runoff) 30%	VS/RO (g/L Runoff) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.4190	0.5644	1.6857
			2	0.4398	2.2669	0.7124
			3	0.3851	0.8194	0.6876
		Rain 2	1	0.2744	0.2912	0.0980
			2	0.2331	0.1325	0.0006
			3	0.2221	0.3232	0.2071
		Rain 3	1	0.0830	0.0972	0.0827
			2	0.0876	0.1376	0.1225
			3	0.1689	0.1341	0.0887
	Event 2	Rain 1	1	0.0524	0.0407	0.0664
			2	0.0357	0.0356	0.1548
			3	0.0152	0.0742	0.0664
		Rain 2	1	0.1786	0.2873	0.1335
			2	0.1898	0.7166	1.0378
			3	0.1202	0.2872	1.2717
		Rain 3	1	0.3486	0.2260	0.1915
			2	0.3093	0.3236	0.2484
			3	0.2908	0.3299	0.2504

Appendix D.
Total Kjeldahl Nitrogen Data

Mass of TKN leaving the plots compared to volume of water applied.

				TKN (g/L APP) 0%	TKN (g/L APP) 30%	TKN (g/L APP) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.0007	0.0011	0.0016
			2	0.0001	0.0019	0.0010
			3	0.0006	0.0012	0.0011
		Rain 2	1	0.0012	0.0008	0.0001
			2	0.0013	0.0007	0.0002
			3	0.0059	0.0010	0.0003
		Rain 3	1	0.0008	0.0011	0.0001
			2	0.0007	0.0008	0.0000
			3	0.0044	0.0009	0.0001
1995	Event 2	Rain 1	1	0.0090	0.0038	0.0009
			2	0.0022	0.0019	0.0011
			3	0.0054	0.0010	0.0005
		Rain 2	1	0.0047	0.0007	0.0004
			2	0.0040	0.0006	0.0003
			3	0.0033	0.0028	0.0002
		Rain 3	1	0.0034	0.0008	0.0003
			2	0.0034	0.0005	0.0003
			3	0.0018	0.0001	0.0003

Mass of TKN leaving the plots compared to volume of runoff.

				TKN/RO (g/L Runoff) 0%	TKN/RO (g/L Runoff) 30%	TKN/RO (g/L Runoff) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.0060	0.0077	0.0254
			2	0.0042	0.0156	0.0124
			3	0.0053	0.0144	0.0096
		Rain 2	1	0.0053	0.0056	0.0068
			2	0.0071	0.0057	0.0114
			3	0.0080	0.0117	0.0056
		Rain 3	1	0.0020	0.0046	0.0080
			2	0.0028	0.0041	0.0007
			3	0.0129	0.0056	0.0013
	Event 2	Rain 1	1	0.0291	0.0161	0.0248
			2	0.0086	0.0110	0.0291
			3	0.0136	0.0167	0.0169
		Rain 2	1	0.0123	0.0063	0.0109
			2	0.0121	0.0073	0.0074
			3	0.0109	0.0157	0.0101
		Rain 3	1	0.0077	0.0050	0.0059
			2	0.0083	0.0064	0.0046
			3	0.0060	0.0035	0.0040

Appendix E.
Total Phosphorus Data

Mass of phosphorus leaving the plots compared to volume of water applied.

				TP (g/L APP) 0%	TP (g/L APP) 30%	TP (g/L APP) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.0075	0.0102	0.0033
			2	0.0008	0.0130	0.0075
			3	0.0058	0.0089	0.0076
		Rain 2	1	0.0147	0.0108	0.0012
			2	0.0123	0.0155	0.0022
			3	0.0494	0.0092	0.0014
		Rain 3	1	0.0168	0.0289	0.0008
			2	0.0132	0.0102	0.0009
			3	0.0930	0.0104	0.0009
1995	Event 2	Rain 1	1	0.0017	0.0010	0.0002
			2	0.0005	0.0005	0.0003
			3	0.0014	0.0002	0.0001
		Rain 2	1	0.0012	0.0002	0.0001
			2	0.0009	0.0002	0.0001
			3	0.0007	0.0007	0.0001
		Rain 3	1	0.0007	0.0001	0.0001
			2	0.0003	0.0001	0.0000
			3	0.0003	0.0000	0.0001

Mass of phosphorus leaving the plots compared to volume of runoff.

				TP/RO (g/L Runoff) 0%	TP/RO (g/L Runoff) 30%	TP/RO (g/L Runoff) 80%
				=====	=====	=====
1994	Event 1	Rain 1	1	0.0616	0.0723	0.0517
			2	0.0301	0.1074	0.0958
			3	0.0515	0.1104	0.0649
		Rain 2	1	0.0646	0.0754	0.0581
			2	0.0688	0.1355	0.1090
			3	0.1459	0.1095	0.0283
		Rain 3	1	0.0453	0.1162	0.0496
			2	0.0512	0.0539	0.0293
			3	0.2749	0.0647	0.0115
	Event 2	Rain 1	1	0.0054	0.0036	0.0058
			2	0.0019	0.0023	0.0067
			3	0.0034	0.0027	0.0037
		Rain 2	1	0.0060	0.0049	0.0029
			2	0.0094	0.0116	0.0158
			3	0.0031	0.0087	0.0074
		Rain 3	1	0.0017	0.0008	0.0016
			2	0.0008	0.0015	0.0008
			3	0.0010	0.0009	0.0008

Appendix F.
Rainfall Data

Data received from plots for each manure application and rain event.

Event #1	Rain #1	8/11/94										
Sample #	Cover %	Rainfall Intensity (cm/h)	Coefficient of Uniformity	Total Rainfall Applied (L)	Total Runoff Collected (L)	Total Solids Collected (g)	Volatile Solids Collected (g)	TKN Collected (g)	Phosphorus Collected (g)			
A1	0	3.87	0.71	2632.66	321.28	1481.08	134.60	1.94	19.79			
A3	30	4.06	0.76	2763.36	390.47	1166.87	220.39	3.01	28.24			
A5	80	4.39	0.73	2987.42	193.44	801.06	326.08	4.92	10.00			
B1	0	2.67	0.66	3029.74	82.69	349.20	36.37	0.35	2.49			
B3	30	2.96	0.83	3230.14	390.38	1873.33	884.94	6.09	41.94			
B5	80	3.01	0.88	3286.16	257.30	732.45	183.31	3.20	24.65			
C2	0	3.08	0.74	2445.95	276.11	1030.97	106.33	1.46	14.22			
C3	30	3.24	0.63	2576.65	206.54	523.55	169.23	2.98	22.81			
C5	80	3.35	0.60	2726.02	317.50	946.46	218.32	3.05	20.60			

Data received from plots for each manure application and rain event.

Event #1	Rain #2	8/18/94										
Sample #	Cover %	Rainfall Intensity (cm/h)	Coefficient of Uniformity	Applied (L)	Total Runoff Collected (L)	Total Solids Collected (g)	Volatile Solids Collected (g)	TKN Collected (g)	Phosphorus Collected (g)			
A1	0	2.99	0.74	2371.26	540.28	2059.16	148.23	2.88	34.88			
A3	30	3.95	0.88	3136.79	451.62	1414.84	131.52	2.52	34.03			
A5	80	4.15	0.87	3410.63	71.30	257.16	6.98	0.48	4.15			
B1	0	2.98	0.84	2825.60	503.27	3052.01	117.32	3.56	34.62			
B3	30	3.67	0.73	3286.16	376.30	1651.05	49.86	2.14	50.98			
B5	80	3.95	0.93	3584.90	72.35	369.56	0.04	0.82	7.89			
C2	0	3.74	0.85	2613.99	817.17	6136.06	181.47	6.57	119.19			
C3	30	4.18	0.77	3006.09	253.59	851.50	81.97	2.97	27.76			
C5	80	3.84	0.73	2757.14	132.30	219.23	27.40	0.74	3.74			

Data received from plots for each manure application and rain event.

Event #1	Rain #3	9/8/94										
Sample #	Cover %	Rainfall Intensity (cm/h)	Coefficient of Uniformity	Applied (L)	Total Runoff Collected (L)	Total Solids Collected (g)	Volatile Solids Collected (g)	TKN Collected (g)	Phosphorus Collected (g)			
A1	0	2.29	0.69	1643.08	611.18	1146.81	50.74	1.25	27.68			
A3	30	3.96	0.77	2844.27	708.02	1968.74	68.80	3.23	82.26			
A5	80	4.21	0.78	3024.76	49.10	139.89	4.06	0.39	2.44			
B1	0	2.71	0.86	1948.04	503.09	2879.39	44.07	1.39	25.74			
B3	30	4.38	0.88	3149.24	595.84	1609.21	81.97	2.44	32.11			
B5	80	4.45	0.87	3199.03	95.70	212.50	11.72	0.06	2.80			
C2	0	3.59	0.91	2632.66	890.48	10229.17	150.40	11.46	244.81			
C3	30	4.10	0.79	2943.85	471.57	1323.93	63.24	2.64	30.49			
C5	80	4.56	0.84	3273.71	242.57	272.22	21.52	0.31	2.79			

Data received from plots for each manure application and rain event

Event #2	Rain #1	5/31/95										
Sample #	Cover %	Rainfall Intensity (cm/h)	Coefficient of Uniformity	Total Rainfall Applied (L)	Total Runoff Collected (L)	Total Solids Collected (g)	Volatile Solids Collected (g)	TKN Collected (g)	Phosphorus Collected (g)			
A1	0	2.54	0.55	2302.80	415.76	2119.00	21.80	12.10	2.30			
A3	30	2.88	0.55	2613.99	618.66	2973.00	25.20	9.93	2.50			
A5	80	1.48	0.37	1344.34	83.17	707.00	5.52	2.06	0.53			
B1	0	3.19	0.68	2894.06	727.59	2571.00	26.01	6.23	1.45			
B3	30	3.79	0.90	3441.75	453.61	1699.00	16.14	5.00	1.33			
B5	80	2.91	0.62	2645.11	133.74	1395.00	20.70	3.89	0.94			
C2	0	3.37	0.69	3062.10	1124.84	8437.00	17.10	15.32	3.91			
C3	30	3.46	0.72	3136.79	180.12	516.00	13.36	3.01	0.72			
C5	80	3.15	0.65	2856.72	86.42	230.00	5.74	1.46	0.33			

Data received from plots for each manure application and rain event

Event #2	Rain #2	6/7/95										
Sample #	Cover %	Rainfall Intensity (cm/h)	Coefficient of Uniformity	Total Rainfall Applied (L)	Total Runoff Collected (L)	Total Solids Collected (g)	Volatile Solids Collected (g)	TKN Collected (g)	Phosphorus Collected (g)			
A1	0	5.47	0.77	1860.91	720.65	4200.00	128.72	8.83	2.21			
A3	30	3.58	0.77	1219.86	132.88	185.00	38.17	0.84	0.24			
A5	80	3.53	0.72	2483.29	83.36	270.00	11.13	0.91	0.24			
B1	0	3.02	0.65	1369.23	457.39	2726.00	86.80	5.53	1.30			
B3	30	2.52	0.82	1145.18	99.59	325.00	71.37	0.73	0.21			
B5	80	3.36	0.75	1524.83	60.73	202.00	63.03	0.45	0.12			
C2	0	4.11	0.73	1867.14	559.03	2137.00	67.19	6.08	1.22			
C3	30	4.33	0.68	1966.72	351.42	1016.00	100.93	5.51	1.30			
C5	80	3.61	0.73	1636.86	37.58	92.00	47.78	0.38	0.08			

Data received from plots for each manure application and rain event.

Event #2		Rain #3	6/28/95											
Sample #	Cover %	Rainfall Intensity (cm/h)	Coefficient of Uniformity	Total Rainfall Applied (L)	Total Runoff Collected (L)	Total Solids Collected (g)	Volatile Solids Collected (g)	TKN Collected (g)	Phosphorus Collected (g)					
A1	0	3.54	0.74	1605.74	702.03	4532.00	244.75	5.38	1.20					
A3	30	3.22	0.81	1462.59	234.49	216.00	52.99	1.18	0.19					
A5	80	3.84	0.87	1742.66	103.20	211.00	19.76	0.61	0.16					
B1	0	3.81	0.81	865.11	355.56	2199.00	109.97	2.95	0.30					
B3	30	2.92	0.86	1325.67	97.85	218.00	31.66	0.62	0.15					
B5	80	3.51	0.71	1593.29	87.91	93.00	21.84	0.40	0.07					
C2	0	5.92	0.71	1344.34	392.46	971.00	114.13	2.37	0.41					
C3	30	2.92	0.81	1325.67	35.24	106.00	11.63	0.12	0.03					
C5	80	3.15	0.79	1431.47	99.01	91.00	24.80	0.40	0.08					

Appendix G.
Multislot Divider Box Data

Accuracy results from divider boxes at various flow rates & time lengths.

STORM CYCLE FLOW

Test Number	Length min.	Actual Gallons	Calculated Gallons	Error %
A	15	47.32	48.25	2.00
B	15	20.13	20.38	1.30
C	15	20.59	20.59	1.23
D	15	21.05	21.05	2.70

STATIC FLOW

Test Number	Length min.	Actual GPM	Predicted GPM	Error %
1	3.00	0.04	0.19	0.79
2	3.00	0.14	0.29	0.51
3a	3.00	0.32	0.37	0.15
3b	3.00	0.31	0.74	0.58
3c	3.00	0.29	0.61	0.54
3d	3.00	0.29	0.62	0.53
4	2.00	1.06	1.11	0.05
5	1.50	1.65	1.73	0.05
6a	2.00	2.60	3.31	0.21
6b	2.00	2.59	3.30	0.22
6c	2.00	2.73	3.44	0.20
7a	3.00	5.94	6.44	0.08
7b	3.00	5.94	6.53	0.09
7c	3.00	5.94	6.36	0.06
8	1.42	7.70	6.91	-0.11
9	2.50	7.42	7.47	0.01
10	2.00	9.51	9.89	0.04
11	2.00	9.87	10.74	0.08

Regression Output:

Constant	0.297571
Std Err of Y Est	0.389278
R Squared	0.988343
No. of Observations	18
Degrees of Freedom	16
X Coefficient(s)	1.005554
Std Err of Coef.	0.027301

Tests comparing the sediment division accuracy of the divider boxes.

Test #	Flow Rate gpm	Application Rate	Time (sec)	Calculated Sediment Mass (Dry) (g)	Actual Sediment Mass (Dry) (g)	Error %
1	20	Slow		2336.79	2452.75	-4.73
2	20	Fast	73	8153.81	7848.80	3.89
3	20	Fast	30	2398.04	2452.75	-2.23
4	20	Slow	130	7065.41	7848.80	-9.98
5	20	Fast	80	7450.98	7952.80	-6.31
6	20	Slow	107	7423.24	7952.80	-6.66
7	20	Fast	34	2457.26	2485.25	-1.13
8	20	Slow	54	2377.34	2485.25	-4.34
9	10	Slow	210	8439.75	7867.2	7.28
10	10	Slow	210	8228.95	7938.4	3.66
11	10	Slow	150	2386.68	2458.5	-2.92
12	10	Slow	150	2351.67	2480.75	-5.20

VITA

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