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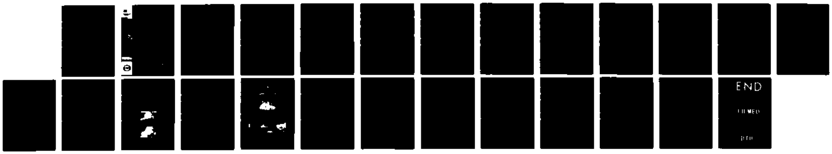

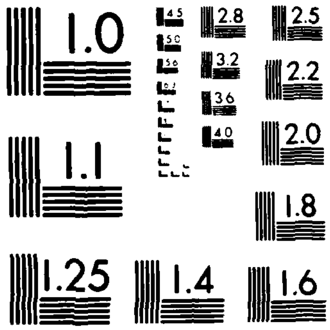

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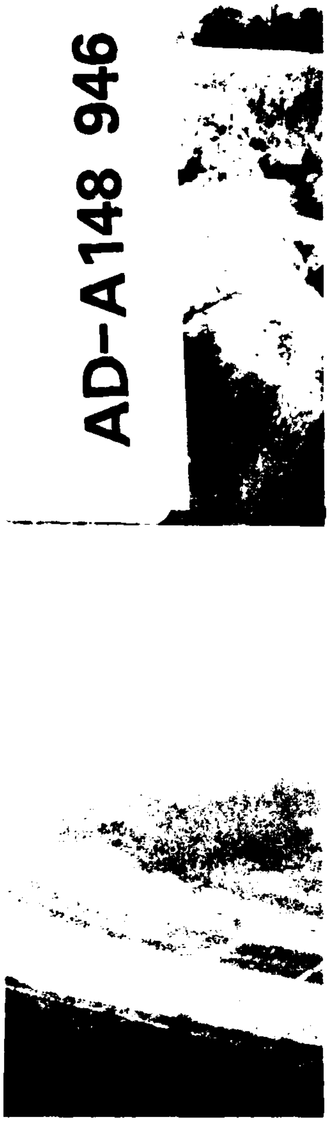

**ENVIRONMENTAL IMPACT
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RESTORATION OF PYRITIC SOILS AND THE QUANTIFICATION OF EROSION CONTROL

by

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Two papers published in the proceedings of the 1983 Symposium on Surface Mining, Hydrology, Sedimentology and Reclamation sponsored by the University of Kentucky are presented. The papers are entitled "Vegetative Restoration of Pyritic Soils" and "Quantification of Erosion Control and Runoff Water Quality from Pyritic Soil Restoration Demonstration Plots." The first paper presents the results of a pyritic soil restoration project designed to demonstrate

(Continued)

20. ABSTRACT (Continued).

restoration methods described in Instruction Report EL-84-1, "Restoration of Problem Soil Materials at CE Construction Sites," developed at the U. S. Army Engineer Waterways Experiment Station (WES). Restoration methods include the use of soil amendments and adapted species for long-term establishment of grasses, legumes, and woody species for erosion control.

The second paper describes a technique employing the WES rainfall simulator to quantify the effectiveness of restoration techniques for controlling erosion and runoff water quality. A laboratory rainfall simulator lysimeter system was developed for estimating soil loss from disturbed soils. These data were then verified in the field using the mobile WES rainfall simulator on the demonstration plots.

PREFACE

These papers were presented at the 1983 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation held in Lexington, Kentucky, on 27 November-2 December 1983 and were published in the symposium proceedings by the University of Kentucky.

These papers presented the results of a pyritic soil restoration demonstration project funded by the Department of the Army under the Environmental Impact Research Program sponsored by the Office, Chief of Engineers (OCE).

The demonstration was conducted at the Tennessee-Tombigbee Waterway, Divide Section, Paden, Mississippi, and at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. The work was conducted by Dr. C. R. Lee, Mr. J. G. Skogerboe, and Mr. D. L. Brandon of the Environmental Laboratory (EL), WES; Mr. J. W. Linkinhoker and Mr. R. B. Sneed of the U. S. Army Engineer District, Nashville; and Mr. S. P. Faulkner of the Mississippi State University Soil Testing Laboratory. Technical assistance was provided by Mr. R. A. Price and LT K. T. Eskew, EL. These papers were prepared under the general supervision of Dr. John Harrison, Chief, EL, and under the direct supervision of Mr. D. L. Robey, Chief, Ecosystems Research and Simulation Division, EL. Dr. R. T. Saucier, EL, was Program Manager, and Dr. J. Bushman, OCE, was Technical Monitor.

Commander and Director of WES during the preparation and publication of these papers was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

> Lee, C. R., and Skogerboe, J. G. 1984. "Restoration of Pyritic Soils and the Quantification of Erosion Control," Miscellaneous Paper EL-84-7, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

CONTENTS

RESTORATION OF PYRITIC SOILS AND THE QUANTIFICATION OF EROSION CONTROL

PART I: VEGETATION RESTORATION OF PYRITIC SOILS

Introduction

1. The U. S. Army Corps of Engineers (CE) is the largest water resource developer in the Nation. As such the CE disturbs enormous quantities of soil materials at its numerous construction sites. Consequently, soil erosion control is a major concern at most CE project sites. In order to provide state-of-the-art technology for effective soil erosion control at CE construction sites, a comprehensive review and compilation of all existing information on vegetative restoration techniques for problem soils was conducted. From existing information, the most effective restoration techniques were formulated and an instruction report was prepared.[1] These techniques included soil amendments that have been shown to improve soil fertility and structure in combination with tolerant plant species adapted to specific problem soils. Since the restoration techniques were formulated from information from a wide variety of unrelated sources, a need arose to demonstrate the effectiveness of the techniques at specific CE project sites. This paper presents the results of vegetative restoration of pyritic soil material at one such CE project site in northeast Mississippi.

Methods

2. During project construction, excavated soil material was placed in disposal sites adjacent to the project. Two disposal sites were selected near Paden, Mississippi, that were characterized as being extremely acid (pH 2.9), droughty, and severely compacted. Each disposal site was divided into 24 plots measuring 15.2 m × 15.2 m with 12 treatment combinations replicated twice. The treatment combinations consisted of 4 soil amendments and 3 plant species (Table 1).

Soil incorporation

3. Soil amendments were incorporated in the following manner. One half of the fine and coarse lime was spread over the plots. A 9.4-cm disk harrow

Table 1. Soil Amendments and Plant Species Tested.

Soil Amendments
Lime
100 mt/ha fine agricultural limestone
100 mt/ha coarse limestone (passing a 1.9-cm screen)
Lime and manure
Lime as above
79.6 mt/ha chicken manure (35% moist)
Lime and phosphate
Lime as above
6.5 mt/ha rock phosphate (passing a No. 10 sieve)
Lime, manure, and phosphate
Lime as above
Chicken manure as above
Rock phosphate as above

Plant Species	Seeding Rate
Weeping lovegrass	11 kg/ha
Pensacola bahiagrass	38.1 kg/ha
Interstate Sericea lespedeza	33.6 kg/ha

was used in two passes to mix the lime within a 15-cm soil depth. A four-bladed turnplow was then used to invert the top 30- to 45-cm soil depth. The remaining lime was spread and disked twice as before. The turnplow was used again to invert the soil. One half of the manure and phosphate was then applied to appropriate plots. All plots were then disked and turnplowed as before. The remaining half of each material was applied, followed by disking and turnplowing. A five-shank parabolic subsoiler was used before and after the application and incorporation of soil amendments. The plots were then fertilized with 149 kg/ha of ammonium nitrate and 258 kg/ha of 0-17-34, disked with a 7.9-cm disk harrow, cultipacked, seeded, cultipacked, mulched with 6.7 mt/ha of straw, and crimped along the contour.

4. An additional set of 16 plots were established on one disposal site. These plots were designed to evaluate subsoiling, fine limestone, coarse limestone, and chicken manure applications incorporated only with a 9.4-cm disk harrow. The turnplow was not used on these plots. Plots were fertilized and seeded as above with only weeping lovegrass at the rate shown in Table 1. All treatment combinations were replicated twice.

5. Kentucky-31 tall fescue was seeded in the alleyways between plots and in a 3.0-m-wide border around the entire plot areas. Annual rye grass was seeded at a rate of 10 kg/ha over the entire plot areas for a quick temporary cover.

6. After one year, each plot was divided in half and seedlings of ten woody plant species were planted in rows of eight seedlings each. Rows were spaced 1.2 m apart. Seedlings were spaced 1.0 m apart within the row. Survival of each seedling was observed 4 months after planting.

Sampling

7. Soil core samples to 90-cm depth were collected at 15-cm increments from each plot prior to soil amendment application and again 9 months after incorporation. Soil samples were sent to the State Soil Test Laboratory at Mississippi State University for soil analyses. Soil samples were analyzed for pH,[2] % organic matter,[3] conductivity,[4] exchangeable phosphorus,[2] exchangeable potassium,[2] exchangeable calcium,[4] exchangeable magnesium,[4] cation exchange capacity,[4] and texture.[5]

8. Vegetative biomass yield data were collected at the maximum vegetative growth stage of the three plant species tested. Each plot was sampled twice randomly using a 9.4-cm square by harvesting all of the aboveground vegetation within the square. Plant samples were oven dried to constant weights at 70° C and reported.

Results and Discussion

Soil analyses

9. The texture of the soil in the disposal sites was predominantly a fine sandy loam with a cation exchange capacity of 28 milliequivalents/100 g. Generally there were few significant differences across plots for most parameters before soil amendment applications (Table 2). Soil pH before soil

Table 2. Soil Analyses Before and After Soil Amendment Application.

Parameter	Sample	Soil Amendment			
		Lime	Lime, Phosphate	Lime, Manure	Lime, Manure, Phosphate
pH	Before	3.04 aA*	3.22 aA	2.82 aA	2.87 aA
	After**	6.26 aB	5.86 aB	6.14 aB	6.17 aB
Organic matter, %	Before	0.56 aA	0.66 aA	0.54 aA	0.52.aA
	After	0.69 aA	0.69 aA	0.92 aB	0.99 aB
Conductivity, mmhos/cm	Before	1.63 abA	1.44 bA	1.95 aA	2.02 aA
	After	1.83 aA	1.88 aA	2.06 aA	2.12 aA
Phosphorus, ppm	Before	39 aA	26 aA	53 aA	32 aA
	After	14 bA	20 bA	54 aA	62 aB
Potassium, ppm	Before	28 bA	60 aA	26 bA	23 bA
	After	52 bB	53 bA	178 aB	199 aB
Calcium, ppm	Before	1204 aA	1478 aA	1450 aA	1277 aA
	After	3814 aB	3573 aB	3825 aB	3858 aB
Magnesium, ppm	Before	196 aA	240 aA	240 aA	214 aA
	After	228 bA	240 bA	254 abA	276 aB

* Means followed by the same small letter across a row are not significantly different at P = 0.05 . Means followed by the same capital letter within a column indicate no significant difference before and after soil amendment application at P = 0.05 .

** Soil samples collected 9 months after application.

amendment applications ranged from 2.82 to 3.22 (Table 2). Nine months after application and incorporation of soil amendments, soil pH values were raised to a range of 5.86 to 6.26. Lime applications increased soil pH and exchangeable calcium as expected. Manure applications increased percent organic matter and exchangeable potassium (Table 2). Rock phosphate applications showed limited increase in exchangeable phosphorus and only in combination with manure. Rock phosphate is slowly soluble and would be expected to have limited influence on exchangeable phosphorus initially.

Vegetation responses

10. Grass and legume. Chicken manure increased the yield of all plant species to some extent (Table 3). Bahiagrass appeared to respond greater to

Table 3. Effect of Soil Amendments on Yield (kg/ha) of Bahiagrass, Weeping Lovegrass, and Sericea Lespedeza.

Soil Amendment	Plant Species		
	Bahiagrass	Weeping Lovegrass	Sericea Lespedeza
Lime	1636 aA*	2666 abAB	2957 bA
Lime, phosphate	2033 aA	1954 aA	3379 bA
Lime, manure	4963 aB	4382 bB	3828 bAB
Lime, manure, phosphate	4989 aB	3458 bAB	4831 aB

* Means followed by the same small letter across a row are not significantly different at $P = 0.05$. Means followed by the same capital letter within a column are not significantly different at $P = 0.05$.

manure applications than the other two species. Sericea lespedeza appeared to show more response to rock phosphate applications than the other two species (Table 3). Manure applications resulted in enormous growth of weed species such as Johnson grass and lambsquarter throughout the plots during the initial growth season. The persistence of the weed population will be monitored.

11. Woody species. Best survival of woody plant species was observed for autumn olive, white ash, black locust, bristly locust, and indigobush (Table 4). Poorest survival was observed for river birch and Virginia pine. The Virginia pine seedlings appeared to be extremely dry around their roots when seedling bundles were opened at planting. Most of the other species had moist roots when unpacked.

12. Survival of seedlings planted in an untreated control area having a soil pH of 2.9 was autumn olive, 31%; white ash, 19%, black locust, 50%; bristly locust, 44%; indigobush, 44%; bur oak, 31%; black alder, 62%; northern red oak, 44%; river birch, 6%, and Virginia pine, 0%.

Soil depth incorporation

13. Grass species. Mixing soil amendments to a depth of 45 cm increased the yield of weeping lovegrass for both soil amendments (Table 5). The greater depth of improved growth media appeared to significantly enhance plant growth and yield. This effect should be even more pronounced during droughty periods of limited soil moisture.

Table 4. Effect of Soil Amendments on the Percent Survival of Woody Plant Species.

Plant Species	Soil Amendment: Lime	Lime, Phosphate	Lime, Manure	Lime, Manure, Phosphate	Species Means
Autumn olive	100 aA*	98 aA	92 bAB	100 aA	97 A
White ash	100 aA	90 aA	100 aA	100 aA	97 A
Black locust	98 aA	98 aA	98 aA	100 aA	98 A
Bristly locust	96 abA	98 aA	83 bAB	96 abA	93 A
Indigobush	94 aA	98 aA	92 aAB	96 aA	95 A
Bur oak	83 aA	85 aA	77 aB	81 aAB	82 B
Black alder	79 aAB	62 aB	75 aB	83 aAB	75 B
Northern red oak	94 aA	77 abAB	54 bc	67 abB	73 B
River birch	62 aB	21 bC	29 abD	42 abC	38 C
Virginia pine	35 aC	31 aC	38 aCD	29 aC	33 C
Soil amendment means	84 a	76 b	74 b	79 ab	

* Means followed by the same small letter across a row are not significantly different at P = 0.05 . Means followed by the same capital letter within a column are not significantly different at P = 0.05 .

Table 5. Effect of Depth of Incorporation on Vegetative Biomass Yield (kg/ha) of Weeping Lovegrass for Two Soil Amendments.

Incorporation Depth	Soil Amendment: Lime	Lime, Manure
0-15 cm	2561 bA*	4594 aA
0-45 cm	4224 bB	6626 aB

* Means followed by different small letters across a row are significantly different at P = 0.05 . Means followed by different capital letters under each soil amendment are significantly different at P = 0.10 .

PART II: QUANTIFICATION OF EROSION CONTROL AND RUNOFF WATER QUALITY FROM PYRITIC SOIL RESTORATION DEMONSTRATION PLOTS

Introduction

16. Long-term soil erosion control measures for construction sites have emphasized the establishment of vegetation as quickly as possible following construction. This has often been difficult when problem soils were present such as those containing large quantities of pyrite. Much of the soil at these sites has been eroded away before adequate vegetation could be established.

17. An instruction report has been prepared from existing literature by the U. S. Army Engineer Waterways Experiment Station (WES) and provides effective long-term restoration techniques for problem soils encountered at Corps of Engineers project sites. Some of these techniques have been demonstrated at Corps sites, such as on the Tennessee-Tombigbee Waterway, Divide Section. This site was characterized as pyritic, extremely acid (pH 2.5-3.5), droughty, and severely compacted. Erosion problems had developed when previous attempts to vegetate the area failed using standard agronomic techniques.

18. While the addition of more soil amendments will be more expensive initially, the added cost will be compensated in the long term by increased vegetation yields and erosion control. The use of organic matter, particularly organic wastes, may create runoff water quality problems, however. A monitoring program was conducted to quantify the effectiveness of these restoration techniques in establishing vegetation[6] and controlling erosion and runoff water quality.

19. Using the WES rainfall simulator, data were collected to determine the relative effectiveness of different soil amendments and plant species in controlling erosion. Simulated storm events were applied to laboratory lysimeters planted with Kentucky-31 tall fescue and weeping lovegrass. Runoff data were collected to determine hydrographs and suspended solids (SS) concentrations and loads at different biomasses for each species.

20. Field rainfall simulations were conducted to provide field verification of laboratory lysimeter data as well as to evaluate the effects of different soil amendments on runoff water quality. This paper presents the results of this study.

Methods

Rainfall simulator

21. The WES rainfall simulator was used for erosion and runoff water quality tests on lysimeter and field plots. It is a rotating disk type rainfall simulator designed to accurately simulate the kinetic energy of natural rainfall at impact on the soil surfaces.[7] It is capable of delivering 0 to 7.4 cm/hr over an area 4.57 m × 1.22 m (5.57 m^2).[8] The simulator has proven very effective in erosion prediction[9] and runoff water quality[10] from Corps project sites.

Lysimeter tests

22. Soil was collected at the field site, transported back to the WES, and placed in lysimeters, 4.57 m × 1.22 m (5.57 m^2), Figure 1. Lime and fertilizer were applied and incorporated to simulate the application and incorporation of soil amendments in the field plots. A different species of vegetation was planted in each lysimeter: Kentucky-31 tall fescue and weeping lovegrass.

Figure 1. The laboratory rainfall simulator - lysimeter system.

23. Rainfall simulations were conducted at 5.3 cm/hr for 1 hr when vegetation attained a sufficient biomass. After each simulation, the vegetation was cut to a lower height, oven dried, and weighed to determine the biomass. The first series of rainfall simulations conducted on Kentucky-31 tall fescue evaluated different intensities, slopes (2 to 15 percent), and soil moistures. These variables proved to have little statistically significant effects on SS concentrations compared to biomass effects.[9] Later simulations, using weeping lovegrass, were conducted at 5.3 cm/hr on a 5 percent slope. Runoff from the lysimeter flowed into a collection box and through a pipe where runoff rates were measured and samples collected. Suspended solids were determined according to Standard Methods.[11] The data were used to calculate the hydrographs and SS concentrations and loads for each species and biomass.

Field simulations

24. Simulator test plots were established at the Tennessee-Tombigbee Waterway, Divide Section, on 8 field demonstration plots planted with weeping lovegrass and having 4 combinations of soil amendments (Figure 2). An additional simulation plot was constructed on an area with no soil amendments and on 2 limed plots planted with Sericea lespedeza and Pensacola bahiagrass. Areas, 4.57 m × 1.22 m (5.57 m^2), were marked on the field plots and galvanized steel sides hammered into the soil, 10 to 15 cm deep. A runoff collection box was placed at the bottom of each plot where a pump was used to collect runoff and measure runoff rates. The slopes of each plot were measured using a transit and averaged about 5 percent, the same as the lysimeter. The rainfall simulator was moved from plot to plot using a specialized tractor-trailer rig (Figure 3).

25. Two rainfall simulations were conducted on each plot at 5.3 cm/hr for 1 hr each. The second simulation started about 4 hr after the first run, so each plot was subjected to a rainfall event at the same antecedent soil moisture. Runoff rates were measured and samples collected as in the lysimeter tests. Samples were analyzed for SS, pH, ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total Kjeldahl nitrogen (TKN), total phosphate (TP), and potassium. Biomass samples were collected from each simulation plot by harvesting all the vegetation in three 1.22-m^2 areas within the plot. Biomass samples were oven dried and weighed.

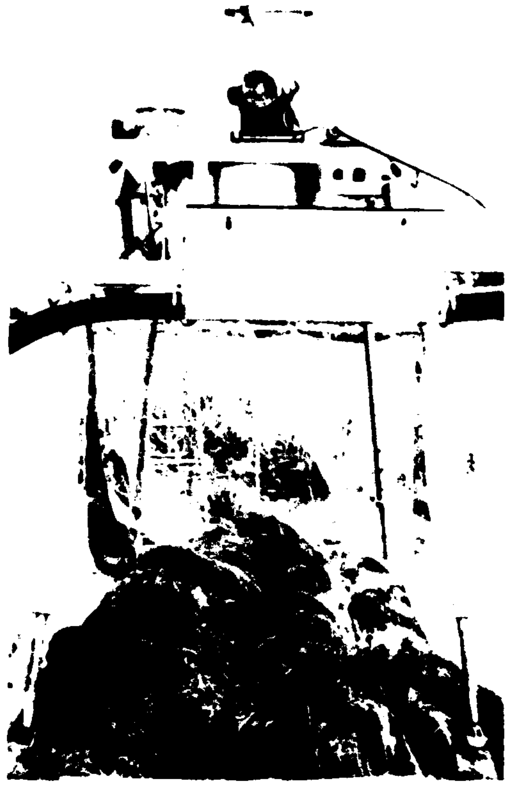

Figure 2. A field rainfall simulator plot with the rainfall simulator.

Figure 3. The tractor-trailer rig used for transporting and operating the rainfall simulator in the field.

Results and Discussion

Lysimeter rainfall simulations

26. The lysimeter rainfall simulations were designed to predict erosion from field plots and reduce the time and cost of field work. Regression analysis of the log of SS concentrations and loads revealed high correlations for both Kentucky-31 tall fescue and weeping lovegrass (Table 6). There were significant differences in erosion control between species (Figures 4 and 5). The best erosion control was obtained from fescue. Weeping lovegrass erosion control was inferior to fescue, probably because of its longer, thinner leaves which intercepted less rainfall.

Table 6. Suspended Solids Versus Biomass Relationships from the Laboratory Rainfall Simulator - Lysimeter System.

	SS Concentrations			SS Loads		
Species	Slope	Intercept	R^2	Slope	Intercept	R^2
Weeping lovegrass	-2.36×10^{-4}	562	0.96	-2.86×10^{-4}	2371	0.98
KY-31 tall fescue	-5.83×10^{-4}	617	0.96	-6.15×10^{-4}	380	0.94

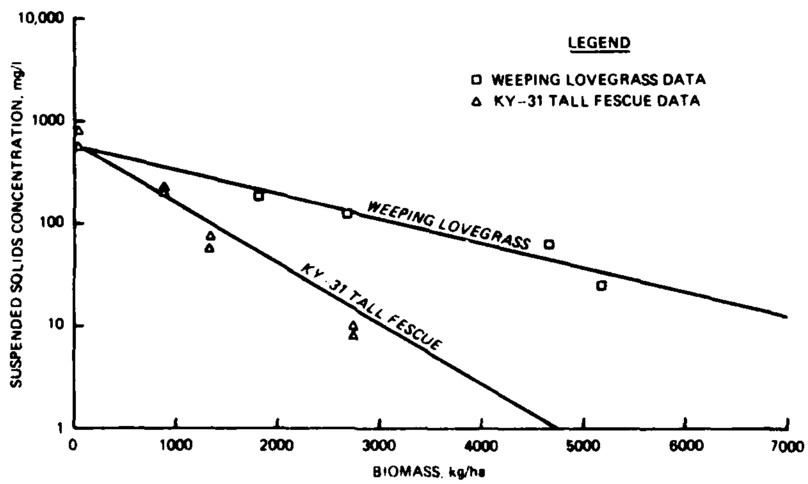

Figure 4. Suspended solids concentrations from lysimeter simulations.

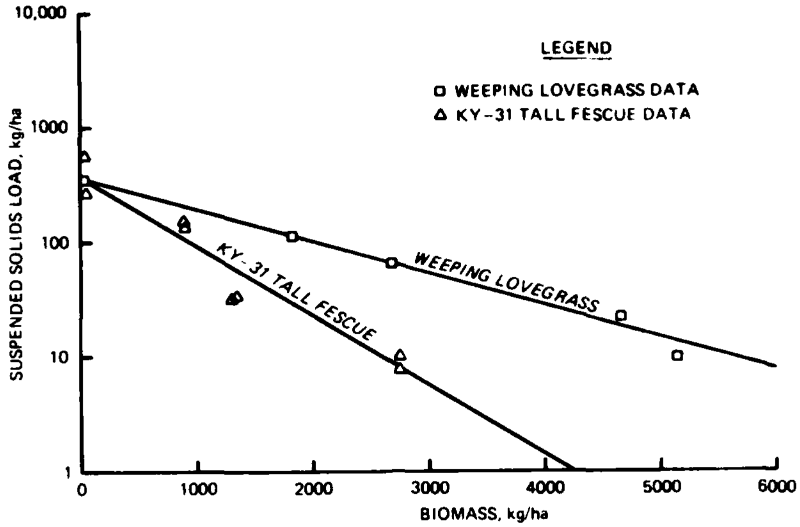

Figure 5. Suspended solids loads from lysimeter simulations.

Lysimeter versus field

27. Even though SS concentrations and loads versus biomass correlated very well in the lysimeter data, some field calibration was necessary to verify the lysimeter relationships. Different soil amendments produced wide ranges in biomass, similar to the range of biomasses obtained in the laboratory lysimeters. Linear regression analysis was applied to both the lysimeter data and the field data. Comparison of SS concentrations versus biomass lovegrass data from the field and lysimeter showed greater variability in field data (Table 7); however, the regression line was almost identical to the lysimeter data (Figure 6). Slopes and intercepts for the field and lysimeter data were identical. Analysis of SS loads versus biomass, however, shows the lysimeter and field data having the same slope but different intercepts (Table 7). The relationship developed from lysimeter data accurately estimated SS concentrations but overestimated SS loads from field plots (Figure 7). The overestimation was primarily caused by reductions in runoff volumes on field plots caused by surface storage of runoff. Lysimeter soil surfaces were easily controlled and had few depressions and furrows. Field plots were contour plowed using heavy tractors and plows, creating many small depressions and furrows to retain and store surface runoff. On smoother field plots, runoff volumes and SS loads would approach or equal lysimeter estimates but would never exceed them. The lysimeter, therefore, did predict the

maximum potential SS loads possible from field plots. To compensate for this effect a surface storage coefficient of 0.5 was calculated from field and lysimeter lovegrass data.

Table 7. Suspended Solids Versus Biomass Relationships of Weeping Lovegrass from Field and Laboratory Lysimeter.

Site	SS Concentrations			SS Loads		
	Slope	Intercept	R^2	Slope	Intercept	R^2
Lysimeter	-2.36×10^{-4}	562	0.96	-2.86×10^{-4}	372	0.98
Field	-2.47×10^{-4}	562	0.83	-3.04×10^{-4}	182	0.75

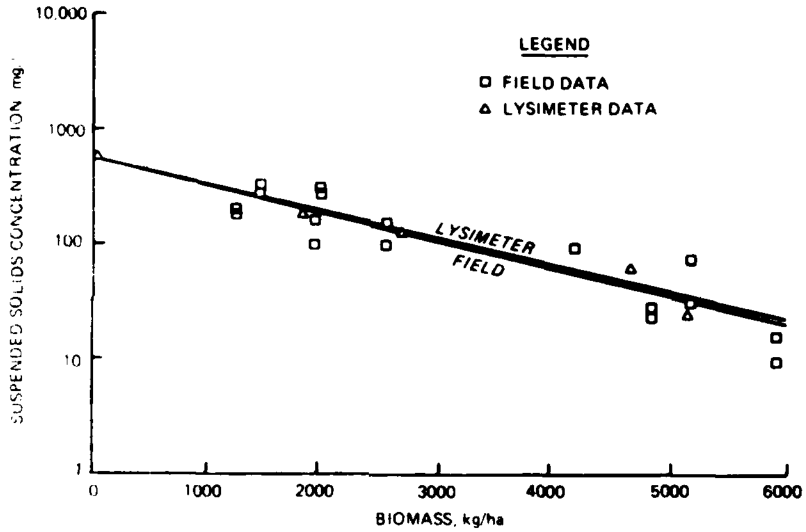

Figure 6. Suspended solids concentrations from field versus lysimeter simulations.

Erosion control effectiveness of field plots

28. Vegetation biomass yields were determined for the first-year growth on pyritic soil restoration plots (Table 8). Using the average yield for each soil amendment and plant species, soil loss for each treatment was calculated from prediction equations developed with laboratory lysimeter data (Table 8). The addition of chicken manure to field plots produced higher yields of weeping lovegrass, enough to reduce soil loss by more than 50 percent over nonmanure plots.

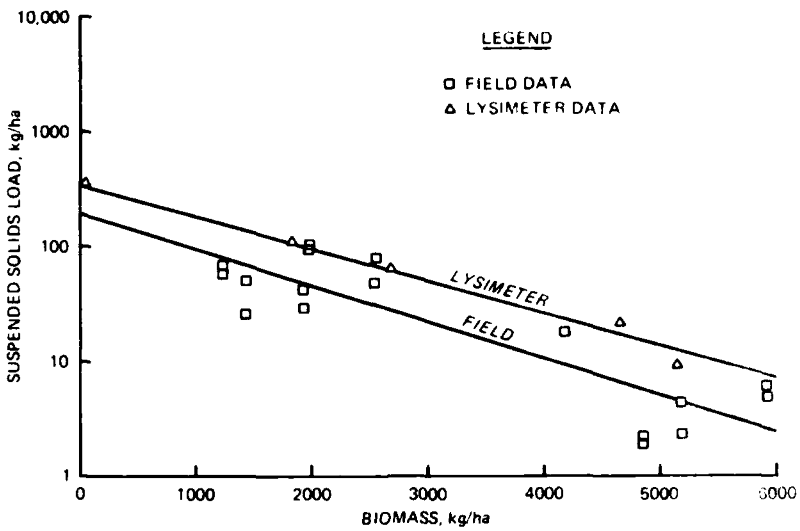

Figure 7. Suspended solids loads from field versus lysimeter simulations.

Table 8. Soil Loss from Field Plots Calculated from Laboratory Lysimeter Relationships and Field Vegetation Biomass Yields.

Treatment	Yield kg/ha	SS Concentrations mg/ℓ	SS Loads kg/ha
Lime	2666	132	31
Lime, phosphate	1954	194	50
Lime, manure	4382	52	10
Lime, manure, phosphate	3458	86	19

Runoff water quality

29. The use of organic matter as a soil amendment can significantly increase vegetation biomass yields and erosion control. Some types of organic materials produce undesirable contaminants in runoff such as excessive nutrients, which could cause eutrophication of waterways. Runoff samples from field rainfall simulations were analyzed for nutrients to determine undesirable effects from chicken manure and rock phosphate. Chicken manure applications tended to increase runoff concentrations of TKN, TP, and K. Large variations in NH_4-N and NO_3-N data resulted in very little statistical differences at $P = 0.05$ among soil amendments (Table 9).

Table 9. Nutrient Concentrations in Runoff Water from Field Restoration Plots.

Treatment	Runoff Concentrations, mg/ℓ				
	NH_4-N	NO_3-N	TKN	TP	K*
Lime	0.12 ab**	0.05 a	0.88 bc	0.17 b	4.68 bc
Lime, phosphate	0.07 b	0.04 a	0.65 c	0.25 b	2.68 c
Lime, manure	0.54 a	0.38 a	1.60 a	0.44 a	11.82 a
Lime, manure, phosphate	0.28 ab	0.13 a	1.47 ab	0.48 a	10.67 ab

* K concentrations are in µg/ℓ.

** Means under a column followed by different letters are significantly different at P = 0.05 using Duncan's Multiple Range Test.

30. Runoff water quality loads were calculated from estimated runoff volumes and concentrations. Runoff volumes were calculated for each soil treatment using a regression equation from field simulation data:

$$\text{Runoff Volume} = 10^{-0.000058(\text{Biomass}) + 2.26}$$

$$R^2 = 0.31$$

Nutrient loads from manure plots were elevated over nonmanure plots (Table 10).

Table 10. Vegetation Yield, Runoff Volume, and Nutrient Loads in Runoff Water from Field Restoration Plots.

Treatment	Vegetation Yield kg/ha	Runoff Volume ℓ/ha	Loads, g/ha				
			NH_4-N	NO_3-N	TKN	TP	K
Lime	2666	227,800	27.3	11.4	200.5	38.7	1.07
Lime, phosphate	1954	251,100	17.6	10.0	163.2	62.8	0.67
Lime, manure	4382	183,000	98.8	69.5	292.8	80.5	2.16
Lime, manure, phosphate	3458	206,300	57.8	26.8	303.3	99.0	2.20

Conclusions

31. The use of more extensive soil amendments will increase restoration costs initially. This can often be compensated by an increase in vegetation yield and erosion control. The WES rainfall simulator determined the effectiveness of restoration techniques recommended by an instruction report being developed at WES. Organic matter such as chicken manure can produce higher yields and decreased soil loss by 50 percent or more. Higher nutrient concentrations and loads were observed in runoff water from chicken manure amended plots at the Tennessee-Tombigbee Waterway field plots during the first year following application.

32. Yearly vegetation yield data will continue to be collected from field plots for different plant species and soil amendments. Additional runoff data will be collected for Pensacola bahiagrass and Sericea lespedeza using a lysimeter. Long-term erosion control data will, thus, be collected for all restoration plots on the Tennessee-Tombigbee Waterway, Divide Section.

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