RANGE REVEGETATION PILOT PROJECT, FORT HOOD, TEXAS

Participants:

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Abstract

The Range Revegetation Pilot Project – Fort Hood, TX continues to focus on the development of best management practices using composted dairy manure and recommendations for implementation. The underlying theory that increased fertility on military primary maneuver training areas is being tested to evaluate the use of composted dairy waste as a soil amendment viable for use in restoring these landscapes.

Introduction

Military land managers are challenged to maintain a given amount of land for the purpose of military training and troop readiness. It is well understood that the primary focus for military training lands centers on the development and testing of weapons systems and needs to maintain combat readiness for all military personnel. Thus, in the past, there has been limited emphasis given to soil erosion, water quality/quantity, vegetation management or sustainability. However, current training doctrine and policy focuses significant efforts on maintaining "healthy," stable training lands; recognizing that the health of the lands provides for sustained highest and best training opportunities. Preferably, the training mission should be accomplished in an environmentally sound manner that meets military requirements and, at the same time, promotes the sustainability of ecosystems so that the military mission is not compromised by a degraded landscape (Garten et al., 2003). In essence, 'Healthy training areas equal healthy training!'

Maintaining "healthy" training lands requires a focus on both soil and vegetation characteristics within training areas. Vegetation characteristics and the conservation of landscapes is highly dependent on soil quality; defined as "the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health" (Doran and Parkin, 1994). It has been well documented that vehicular traffic on both agriculture and forest lands can have critical impacts on maintenance of a landscapes soil systems (Barnes et al., 1971; Jakobsen & Moore, 1981; Soane et al., 1981a; Soane et al., 1981b). Disturbance of soil structure followed by a change in the physical properties of the soil is a commonly reported effect associated with the use of heavy vehicles in military training (Iverson et al., 1981; Prose, 1985; Braunack, 1986; Thurow et al., 1993; Milchunas et al., 1999), forestry (Hatchell et al., 1970), and agriculture (Voorhees et al., 1986; Alakukku and Elonen, 1995).

Concurrent to training impacts on soil characteristics and vegetation dynamics, sediment has been identified as an important non-point source pollutant of streams, rivers and lakes. Sediment impacts aquatic organisms, habitat, and can act as a carrier of other non-source pollutants (Ermine & Ligon, 1988). Off-road military traffic is a major issue in the management of the militaries primary training maneuver lands including soil stabilization (Severinghaus et al., 1979, Johnson, 1982, Goran et al., 1983, Braunack, 1986, Shaw & Diersing, 1990, Diersing et al., 1990). Fuchs et al. (2003) found the strongest correlation between total plant cover and cumulative sediment loss in the highly variable climate rangelands of Fort Bliss. Though there are obvious climatic differences between Fort Hood and Fort Bliss, it can be understood that similar relationships occur.

The ongoing activities of the Range Revegetation Pilot Project on Fort Hood, Texas continues to study and refine the benefits of using composted dairy manure as a soil amendment for restoring active military training maneuver lands. The results contained herein, are a compendium of two full years of data collection on vegetation dynamics for treated areas and water quality and soil fertility monitoring across treated landscapes.

Materials & Methods

Water Quality:

Monitoring nutrient in storm runoff from TA 51, SCR 66 compost activities (2002-2004):

Eutrophication caused by excessive nutrient input piques environmental concerns. Therefore, water quality monitoring stations were installed to track nutrient movement from all training areas receiving composted dairy manure applications between 2002 and 2004. Monitoring stations were equipped with ISCO 3700 Automated Water Samplers, ISCO 4230 Bubble Flow Meters, and Texas Electronics tipping bucket rain gauges. Discrete, time-based, water samples were collected during measurable storm runoff events and analyzed via ion chromatography for dissolved nutrients, specifically nitrate and orthophosphate, by the BREC Water Quality Lab. Sampling intervals were site specific and determined by watershed size and associated hydrologic response. Compost application drainage areas were determined with ArcHydro software using a 10 meter digital elevation model.

Vegetation Dynamics:

Pre-plant land preparation was performed by dragging two 8-foot wide railroad irons linked in tandem over the range research plots. Compost was applied with a custom designed tongue-pull 10 cubic yard capacity stainless steel spreader pulled behind a 70 hp tractor (Figure 1). In early March, 2004, range seeding was performed using a broadcast seeder and four-wheeler.

2004 NRCS Recommended Seed Mix (James Alderson & Jeff Goodwin)

Species	% of Mix
Indiangrass	10%
Buffalograss	25%
Big Bluestem	10%
Little Bluestem	10%
Switchgrass	10%
Tall Dropseed	5%
Sideoats Grama	25%
Illinois Bundleflower	2%
Awnless Bush Sunflower	2%
Partridge Pea	1%
Green Sprangletop	1 lb./acre

2005 Proposed (Revised) Seed Mix for Large Area Treatments

Species	% of Mix
Indiangrass	10%
Switchgrass	5%
Big Bluestem	10%
Little Bluestem	15%
Sideoats Grama	35%
Buffalograss	15%
Awnless Bushsunflower	1%
Partridge Pea	1%
Illinois Bundleflower	1%
Engelmann Daisy	1%
Maximilian Sunflower	1%
Green Sprangletop	1 lb./acre

Figure 1. TWRI designed and High Roller built compost spreader for Fort Hood compost project.

Permanent transects were established using a Trimble 6500 GPS unit with each transect having plant species recorded by the step-point methodology at periodic paces. Transect data was recorded at the end of the cool season growing period and the end of the warm season growing period. The means of each species' frequency of occurrence was analyzed with a *t*-test comparison for statistical significance (α=.05) in each transect in the various treatment plots.

Soil Fertility: Because of the extreme variability of soils on training areas, it was important to implement soils collection methodology applicable to both large scale applications (50 acres or more) and smaller research plot design. Composite samples were the preferred sample technique, taken at random locations within each study area. To obtain enough sub-sample to ensure a representative composite sample, at least 5 discrete sub-samples were generally taken in small research plots < 1 acre; for large scale plots, approximately 15 sub-samples per 40 acres was the protocol.

A "T-handled" soil probe was used to penetrate soils to a depth of 6-8 inches. Sub-samples were taken at two distinct depth ranges – 0-2" and 2-6". Both depth ranges were collected / extracted per probe event. Core material was carefully removed from the soil probe, separated by depth range, and submitted to its corresponding 5 gallon mixing bucket. After completing sampling of plot location, sub-samples were mixed well to insure overall homogeneity. Sample aliquots were removed (approximately 1 pint/depth range composite) and placed in the appropriately labeled sample container. Samples were then sent to Texas A&M Soil, Water, and Forage Testing Laboratory for analysis.

Results

Water Quality:

To date no significant nutrient loss has been observed from these demonstrations. EPA lists the maximum contaminant level for nitrate in water as 10 ppm due to its effect on mammalian health. The maximum measured nitrate level seen in runoff from training areas receiving composted dairy manure was 6.3 ppm (1.45 ppm $N\text{-}NO_3$), well below EPA guidelines. Most runoff from these areas exhibited significantly lower nitrogen concentrations (Chart 1). Phosphorus is not regulated by the EPA because it has no toxicological importance. It does however significantly impact water quality through secondary effects, specifically through over-stimulation of algae and aquatic macrophytes. EPA guidelines recommend that phosphorus discharge to streams not directly draining to a lake should be less than 0.1 ppm. Only one event out of 39 measured approached this value (Chart 2) and none of the areas to which compost was applied drained to a stream discharging directly to a lake. All Fort Hood streams were buffered from compost-applied areas by large, vegetated areas and sediment retention ponds. Phosphorus concentrations in the runoff were usually less than 0.05 ppm and frequently below instrument detection limits (reported as 0.00 ppm).

Figure 2. Nitrate nitrogen in runoff from field compost demonstrations

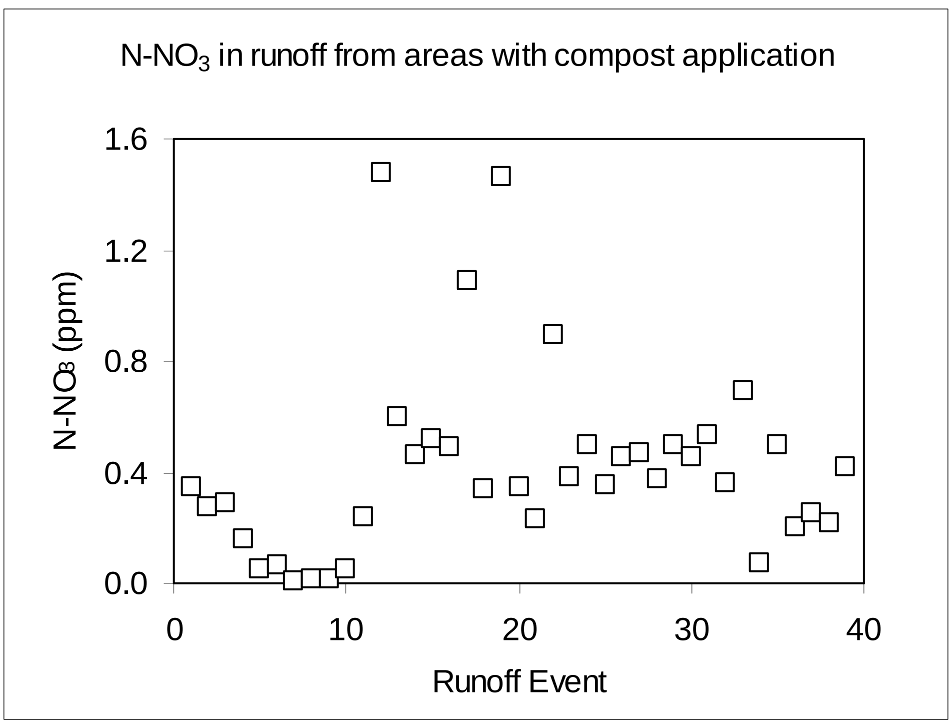
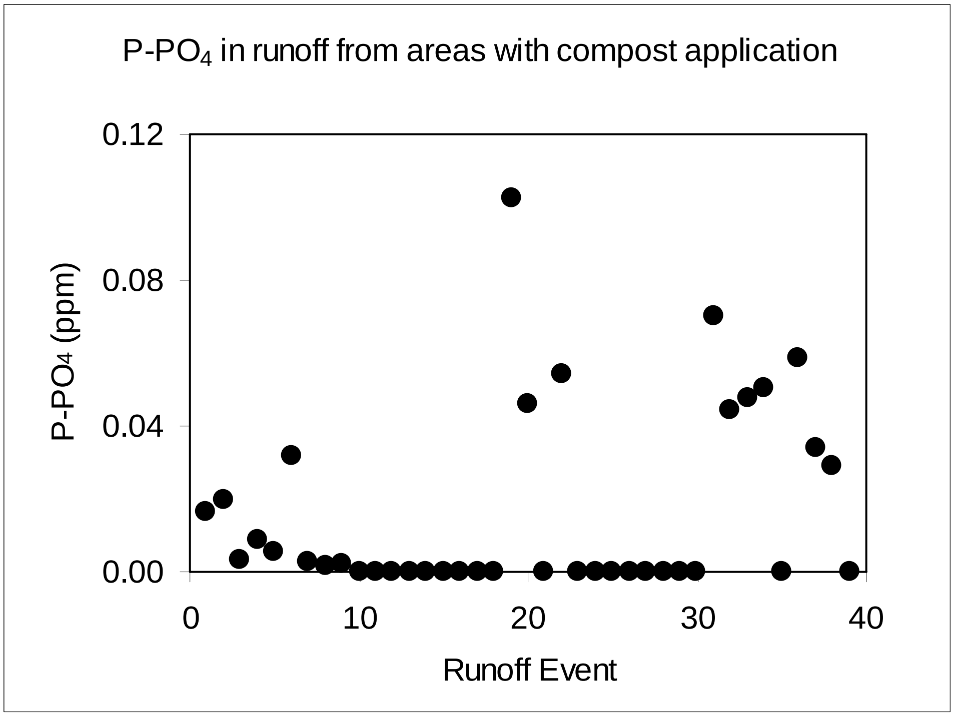


Figure 3. Orthophosphate phosphorus in runoff from field compost demonstrations



Nutrient loss from compost applications to micro-watersheds, TA44 (2005)

Three 0.75 acre micro-watersheds were installed in TA 44 by placing a one foot earthen berm around the perimeter of each area (Figure 9). They were located on upland soils with a 3% to 4% slope. Each micro-watershed was outfitted with a one foot H-flume for measuring storm runoff and automated water sampling equipment for collecting nutrient data. All collected storm runoff samples were analyzed for nitrate and orthophosphate concentration in the BREC Water Quality Lab. Storm water runoff data were combined with nutrient concentration data to determine the total nutrient losses from each bermed plot.

Three treatments applied to the micro-watersheds included: control (no compost), 15 y^3/Acre compost, and 30 y^3/Acre compost. Cumulative edge of field runoff, measured between January 27, 2005 and June 3, 2005, contained between 6 and 11% of the nitrogen and between 7 and 13% of the phosphorus applied as composted dairy manure. Nutrient losses ranging from 30 to 70% (of the cumulative total loss) occurred during the first runoff event. Significant runoff events immediately following application, of any fertility treatment, will result in nutrient loss. Treated areas should be placed with care.

Compost studies have been specifically located in areas buffered by grassy areas and sediment control ponds to prevent runoff from directly entering steams. This minimizes potential stream eutrophication. All in-stream monitoring data from nearby composting activities indicate no elevated nutrient concentrations within storm flows (Charts 1 and 2).

Vegetation Dynamics:

Training Area 51 (Georgetown & Manning Mtn. Road)
<u>Demonstration Sites (~5, 8 & 10 tons/ac, respectively)</u>

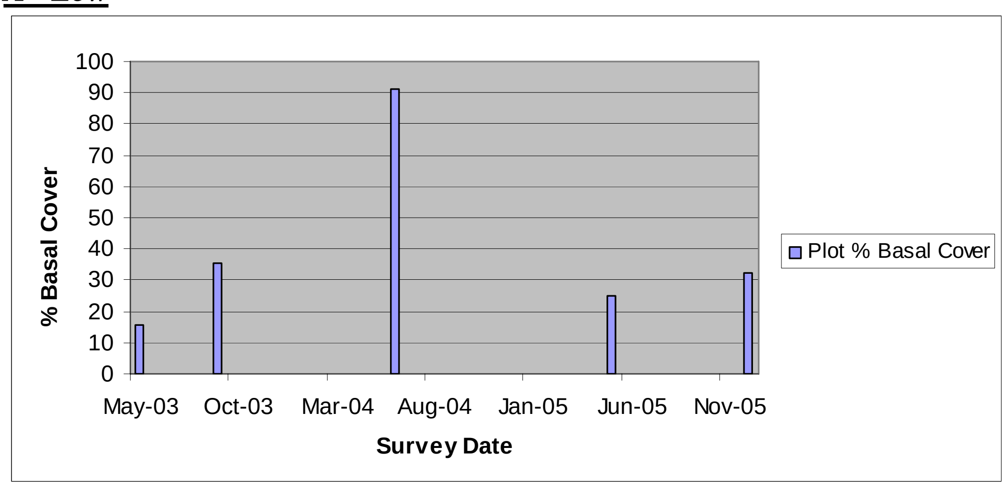
<u>Plant Basal Cover</u>

The original demonstration site was initiated in May of 2003 to establish that it is possible to transport and apply composted dairy manure on Fort Hood's primary training maneuver lands. Due to timing and circumstances, it was not possible to obtain baseline vegetation data on these sites; thus, results indicated illustrate the change in plant basal cover and bareground over time and do not make comparisons across treatments. This site continues to be monitored as a demonstration site to increase anecdotal evidence of the long-term impacts of restoration on heavily trained areas. From the time of establishment until winter 2005, this site was not heavily disturbed by military training. Subsequently, it has incurred significant training activities.

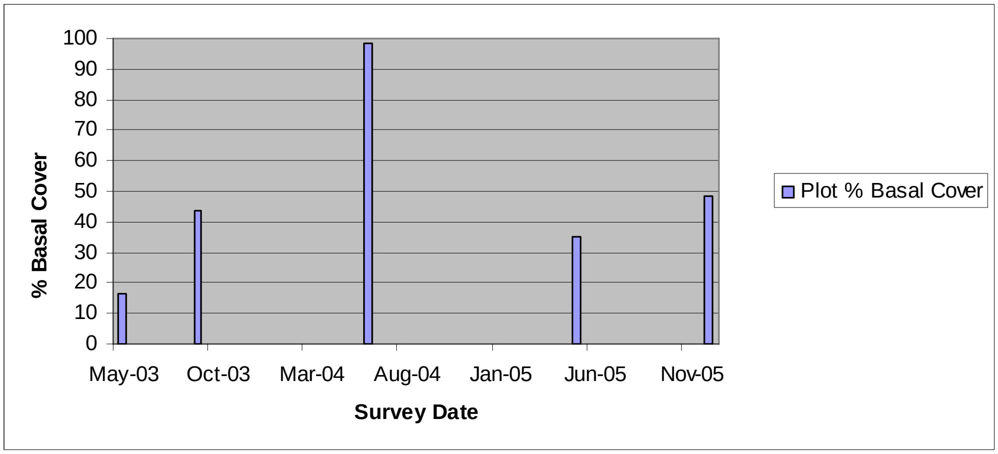
The data (Figure 4a,b,c) seem to indicate, albeit circumstantial, that there was an increase in vegetation taking place between treatment time (May 2003) and return training time (January 2005). Post-training in winter 2005, it appears that the system has settled back to a level similar to 5-months post-treatment. Indications are that without significant training, the system had the potential to increase vegetation cover and reduce bareground. However, it appears heavy training post-treatment will revert the system to a stage similar to 5-months post-treatment for all treatments. Anecdotally, we feel that this starts to place parameters on the efficacy time of the treatment at or about 1.5-2 years, without heavy training. Further monitoring on subsequent sites, included herein, will have this indication expanded upon.

Figure 4 a, b, c. Comparisons of % plant basal cover over time for low, moderate and heavy treatments (~5, 8 & 10 tons/ac, respectively) on Demonstration Site established in May 2003

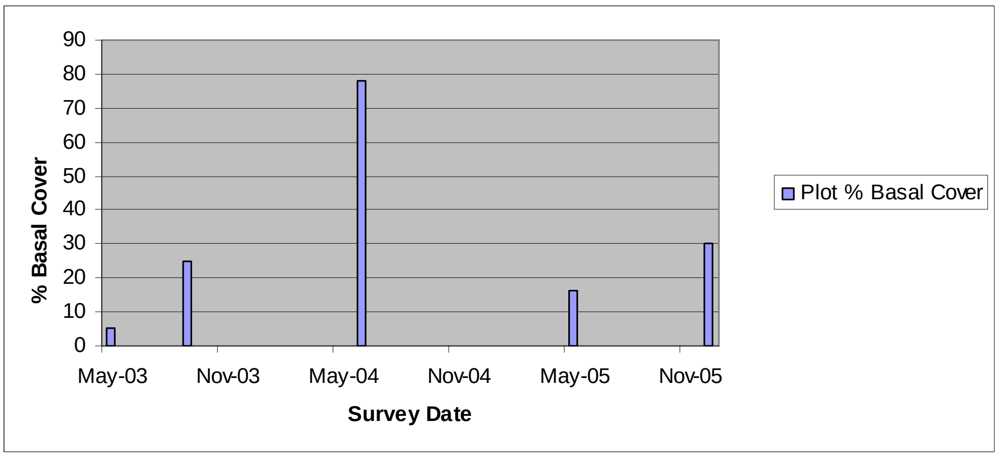
<u>A - Low</u>



B - Moderate



C - High



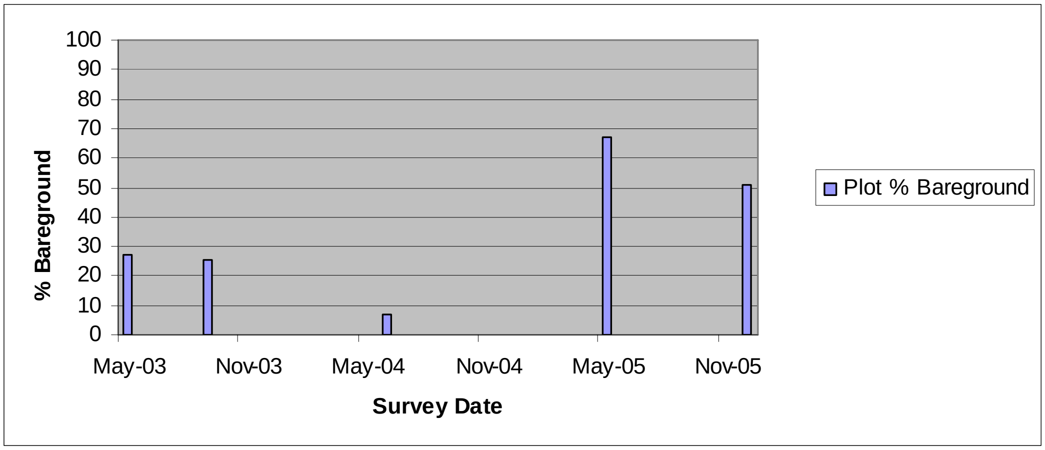
Bareground

Bareground (Figure 5a & b) has varied considerably over the time of these demonstration sites (Figure 6a,b,c). Initially bareground was relatively uniform across all treatment plots with it being slightly higher on the heavy treatment plot. It decreased considerably between the initial treatment and the point at which heavy training was resumed on the plots. The apparent discrepancy between plant basal cover and bareground is explained by a shift in the amount of litter on the soil surface. Due to site preparation, there were high levels of plant litter on all treatments immediately post-treatment (at the time of initial vegetation data collection). As the site recovered, litter was greatly reduced and replaced by plant basal cover. Upon the initiation of training maneuvers, bareground became the dominant ground cover class and has remained so through subsequent collections periods. This would indicate that site preparation techniques, leveling and disking promote litter accumulation; whereas, military maneuver training promotes increases in bareground. Again, these data are not compared to baseline or control sites, so all suppositions are anecdotal, but further analysis of later experimental plots may reveal this more thoroughly.

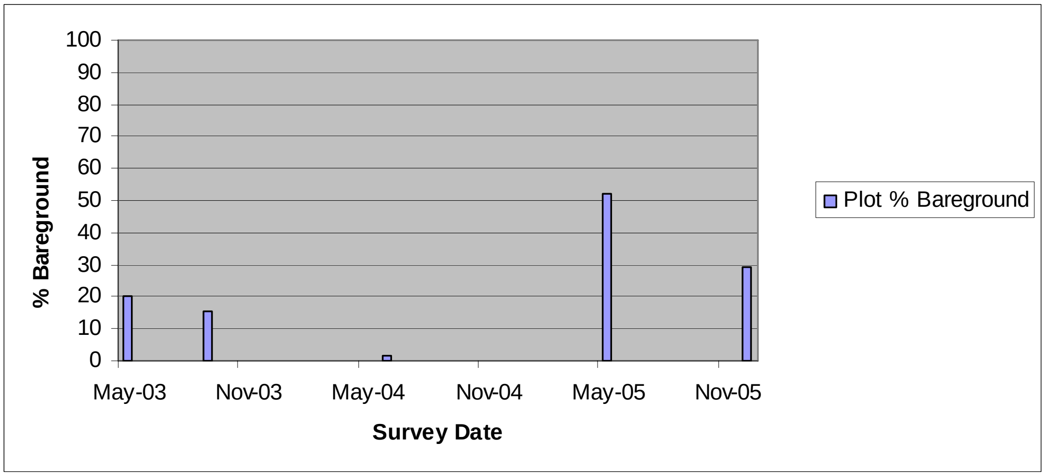
Figure 5a. Post-Site Preparation **5b. 1-year Post-Treatment**

Figure 6 a, b, c. Comparison of % bareground over time for low, moderate and heavy treatments (~5, 8 & 10 tons/ac, respectively) on Demonstration Site established in May 2003

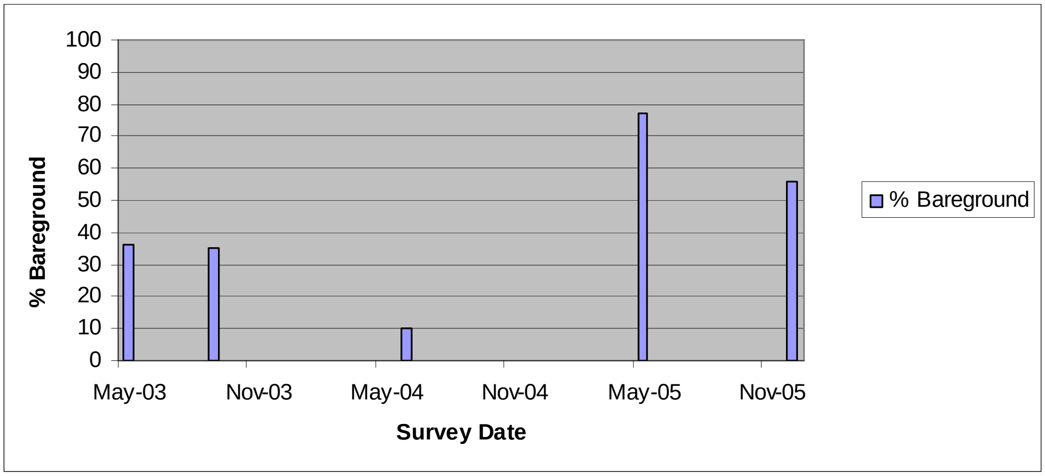
A - Low



B - Moderate



C - High



Training Area 51 (base of Manning Mountain S of new tank trail)
30 Acre Treatment Sites (Control, Compost-only, Seed-only & Seed+Compost – 15cy/ac equivalents for all compost treated plots)

Plant Basal Cover

Comparisons across different treatments were necessary to establish and understanding that the use of compost as a soil amendment is producing an effect on ground cover dynamics (plant basal cover/bareground). Comparisons between control and compost-only, seed-only and compost+seed were analyzed by testing the means in December 2005 to establish treatment effects of the experimental plots. A statistical *t*-test of means indicated significant differences in control/seed-only and control/seed+compost (Tables 1 & 2). Heavy training at the end of 2004 and throughout 2005 have, most likely, had an impact on results (Figure 7).

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	43.022	32.834
Variance	12.96767	53.94053
Observations	5	5
Pooled Variance	33.4541	
Hypothesized Mean Difference	0	
df	8	
t Stat	**2.785058**	
P(T<=t) one-tail	0.011869	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.023739	
t Critical two-tail	**2.306004**	

Table 1. Statistical output for testing means between control and Seed-only plots 2.5 years post-treatment (December 2005 data set)

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	48.172	32.834
Variance	113.7469	53.94053
Observations	5	5
Pooled Variance	83.84372	
Hypothesized Mean Difference	0	
df	8	
t Stat	**2.648521**	
P(T<=t) one-tail	0.014662	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.029323	
t Critical two-tail	**2.306004**	

Table 2. Statistical output for testing means between control and Seed+Compost plots 2.5 years post-treatment (December 2005 data set)

Figure 7. TA 51 post-training exercises in March 2005. Training activities took place shortly after heavy rainfalls occurred in the area compounding the impacts on the environmental factors monitored.

Training Area 51 (base of Manning Mountain S of new tank trail)

<u>100 Acre Site (Original plans had this site identified to evaluate different seed sources provided by NRCS. Due to circumstances the seed mix study was not implemented and the site was treated with 15 cy/ac and NRCS recommended seed mix)</u>

Due to unforeseen circumstances (limitations in amount of seed source) the original intent of this site, seed mix comparison, was not established. However, baseline vegetation data had already been collected so ground cover monitoring has continued on the site to look at long-term impacts of currently recommended compost rate of 15 cy/ac. A single factor analysis of variance was performed to analyze the dynamics of ground cover between initiation of the study, 14-months post-treatment and 18-months post-treatment (Tables 3-5).

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	5	103.79	20.758	19.53457
Column 2	5	278.44	55.688	112.3637
Column 3	5	169.74	33.948	42.10012

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3111.181	2	1555.591	**26.82078**	3.73E-05	**3.885294**
Within Groups	695.9934	12	57.99945			
Total	3807.174	14				

Table 3. ANOVA output comparing over time the change in plant basal cover category.

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	5	251.06	50.212	95.72787
Column 2	5	157.8	31.56	62.92555
Column 3	5	119.6	23.92	46.2953

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1829.227	2	914.6133	**13.38793**	0.000878	**3.885294**
Within Groups	819.7949	12	68.31624			
Total	2649.021	14				

Table 4. ANOVA output comparing over time the change bareground category.

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	5	133.4	26.68	67.45115
Column 2	5	49.79	9.958	8.85332
Column 3	5	192.58	38.516	56.15543

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2058.793	2	1029.396	**23.31414**	7.35E-05	**3.885294**
Within Groups	529.8396	12	44.1533			
Total	2588.632	14				

Table 5. ANOVA output comparing over time the change litter category.

Outputs of ANOVA analysis indicate significant changes in all three categories from the initiation of the experiment to December 2005 data collection period. It is assumed that climatological and other abiotic parameters remained constant on the site as it is all within the same subwatershed on similar soils.

SCR66 (Georgetown Road just S or intersection with West Range Road)
<u>100 Acre Site (Initial rate determination study site)</u>

This site was chosen to establish the first "rate" study comparing varying rates of compost and impacts on plant basal cover, bareground and litter. The study site includes six treatment plots with one 25 acre control site.

Plant Basal Cover:

Plant basal cover has increased significantly 18-months post-treatment for treatment plots receiving 15cy/ac or greater of compost (Figure 8,9). Significance increases for those plots with 20-30cy/ac as they were established on a ridgeline at the highest extent of the subwatershed and had very little vegetative cover prior to treatment. Much of the higher areas currently are dominated by annual grasses, demonstrating that secondary succession has begun on the sites where little topsoil remained prior to treatment.

Figure 8.

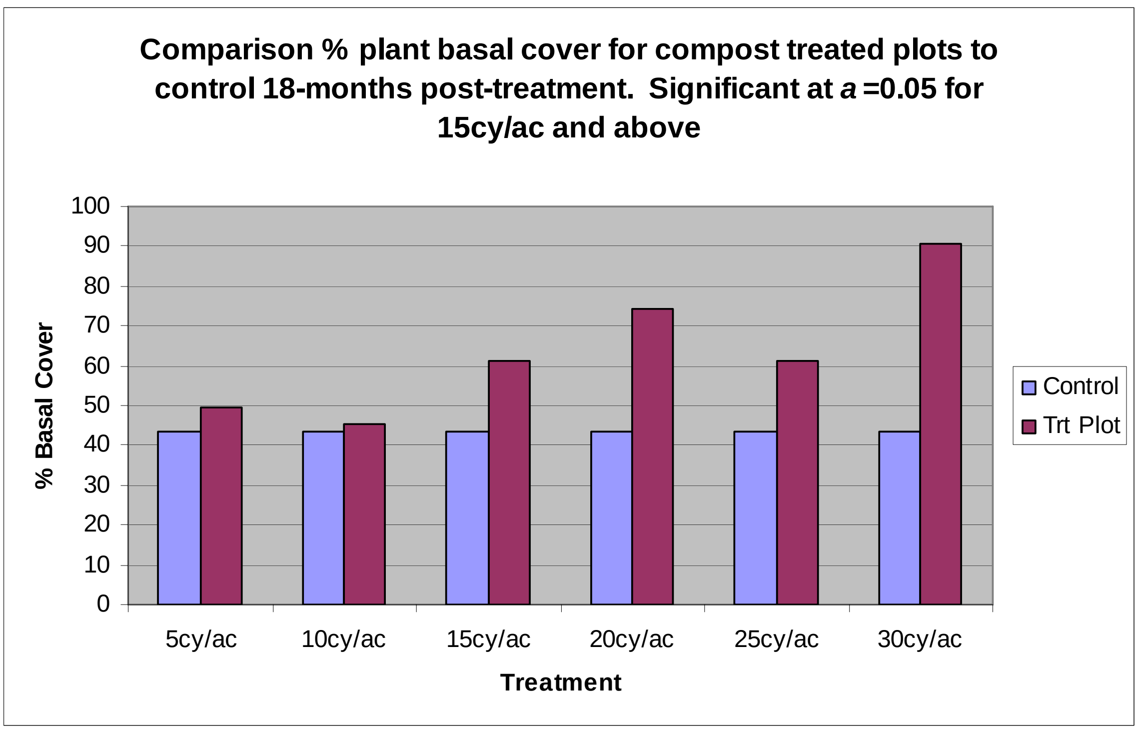
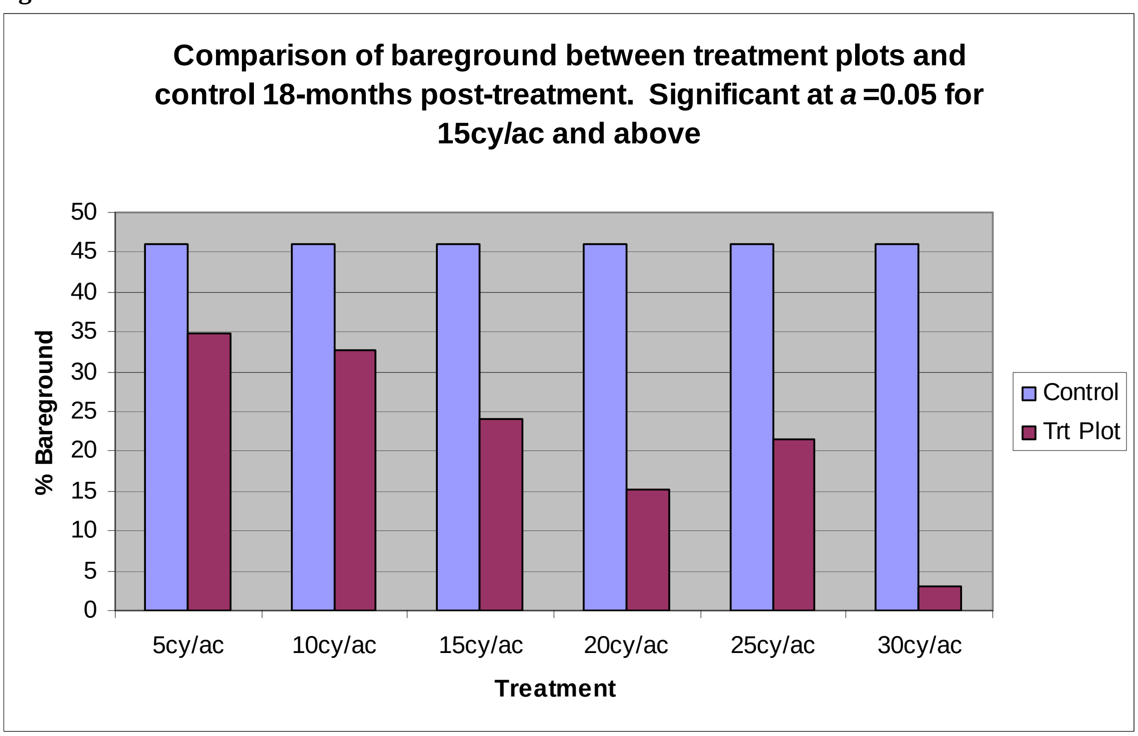


Figure 9. Close-up of compost treated site receiving 20 cy/ac. Seedling establishment verified.

Bareground:

Bareground decreased significantly for all treatment plots receiving 15cy/ac or greater compost application (Figure 10). The inverse relationship between bareground and plant basal cover indicates that, compared to the control plot, there appears to be a direct substitution of plant basal cover for bareground. These results combined with literature reviews influenced the current thinking that 15cy/ac is the most feasible treatment for this potential best management practice.

Figure 10.



TA 44 Replicated Watersheds (S of Elijah Road and E of FM Hwy 116)
3 replications of 2/3 Acre Sites with one replication bermed and instrumented for water quality studies (evaluation of high rate impacts – 0, 15, 30, 60 & 90 cy/ac)

Initial study included three replications of the experimental treatments. Due to contractor error, replication 1 was double treated and has been removed from this analysis. Replications 2 and 3 have been analyzed for ground cover dynamics comparing treatment with control and across replications. The data set is limited at this time for regression comparisons, but will be robust enough after 2006 data collection season. Figure 11 illustrates the bermed watersheds with ISCO water sampling instrumentation.

Figure 11. Bermed watershed in TA 44

Plant Basal Cover & Bareground Comparisons:

At this point we have not collected sufficient data to make comparisons between treatments and control replicates. We anticipate the 2006 field season will provide necessary data to compare these sites and analysis will be included in the 2007 annual report. However, there are some indications that site parameters (soil series, slope, etc.) may be influencing some of the relationships between treatments and across replicates. Further analysis of the site characteristics will provide a greater understanding in relationship to assumptions made for future analysis.

TA 43 Replicated Vegetation Treatment Plots (S of Elijah Road and E of FM Hwy 116)

5 replications of 2/3 Acre Sites split into 1/3 acre subtreatments (established to compare control, compost and commercial fertilizer impacts)

This replicated experiment was established in August of 2005. At this time we have insufficient data to make ground cover analysis feasible. However, we have initiated a sub-experiment on this site to evaluate soil pathogens and their presence or absence. Preliminary analysis provided by the USDA-ARS laboratory in College Station indicates no soil contamination across all treatments by *E. coli* or *Salmonella* microbes. As a side analysis, with interest in anti-microbial resistance of soil bacteria in mind, the ARS scientists identified and analyzed several naturally occurring soil bacteria to determine the presence of anti-microbial resistance forming. To our surprise, preliminary analysis indicates that there are present some naturally occurring soil bacteria that are exhibiting anti-microbial resistance. Since these lands are commonly grazed, it is plausible that these microbes are developing the resistance due to human influence. However, in partnership with ARS scientists, we are beginning a new study to evaluate soil bacteria from across grazed and ungrazed lands to determine if the pattern is consistent with our early findings. This study has been discussed with Washington, D.C. representatives of the Natural Resources Conservation Service, US Forest Service and Bureau of Land Management as well as potential collaborators in Texas and California. Further details of this study are pending, but the results of initial work performed in association with the Fort Hood project have led to great interest in this phenomena.

Preliminary Economic Analysis:

Preliminary economic analysis is based upon costs incurred for all aspects of the compost purchase, transportation, application and seeding activities.

Preliminary Economic Analysis - Fort Hood Revegetation Pilot Project

FY 2005	**Per Unit Cost**	**Quantity**	**Total**	**Total/Ac**
200 acres	15 cy/ac applied rate			
Compost	$8.53	5,000	$42,650.00	$213.25
Transportation	$6.25	5,000	$31,250.00	$156.25
Application	$82.50	200	$16,500.00	$82.50
Seed	$38.02	200	$7,604.00	$38.02
Land Preparation	$0.00	0	$0.00	$0.00
Totals	$135.30		**$98,004.00**	**$490.02**
FY 2004				
230 acres	Rates from 5-30 cy/ac across multiple treatments			
Compost	$8.53	4,000	$34,120.00	$170.60
Transportation	$5.68	4,000	$22,720.00	$113.60
Application	$61.76	205	$12,660.80	$63.30
Seed	$27.32	205	$5,600.60	$28.00
Land Preparation	$0.00	0	$0.00	$0.00
Totals	$103.29		**$75,101.40**	**$375.51**
FY 2003				
75 acres	Average 9 cy/ac applied rate			
Compost	$8.98	1,200	$10,776.00	$53.88
Transportation	$237.50	39	$9,262.50	$46.31
Application	$151.40*	75**	$11,355.00	$56.78
Seed	$27.21	100	$2,721.00	$13.61
Land Preparation	$0.00***	0	$0.00	$0.00
Totals			**$34,114.50**	**$170.57**

*Average cost for application
**Total Acres treated for demonstration plots
***This amount is not available at this time, but will be obtained

Table 6. Cost comparison for treated areas by year and action.

Soil Fertility:

Soil fertility has been monitored on all sites included in the compost evaluation studies. However, some data is currently lacking for several sites. Materials reported below are representative for sites within the demonstration plot and 30 acre treatment study site (TA 51) (Figures 12-15).

SOIL PHOSPHORUS

PLOT NAME	**AREA (ACRES)**	**PreTreatment Value**	**PostTreatment Value**	**Post Late Value**
Low (5 T/A)	25	23	27	23
Med (8 T/A)	25	23	21	28
High (10 T/A)	25	30	24	22

SOIL NITROGEN

PLOT NAME	**AREA (ACRES)**	**PreTreatment Value**	**PostTreatment Value**	**Post Late Value**
Low (5 T/A)	25	9	17	5
Med (8 T/A)	25	9	19	6
High (10 T/A)	25	7	16	5

Table 7. Soil N and P content pre-treatment, 6-months post-treatment and 12-months post-treatment for demonstration site (TA 51).

Figure 12. Soil N content changes over time for demonstration site (TA 51).

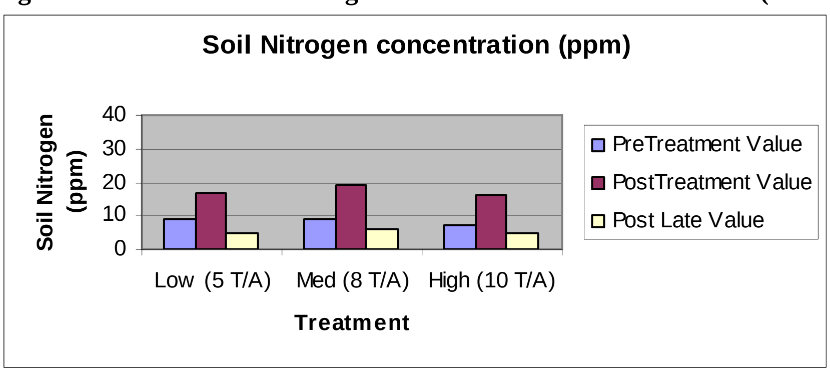
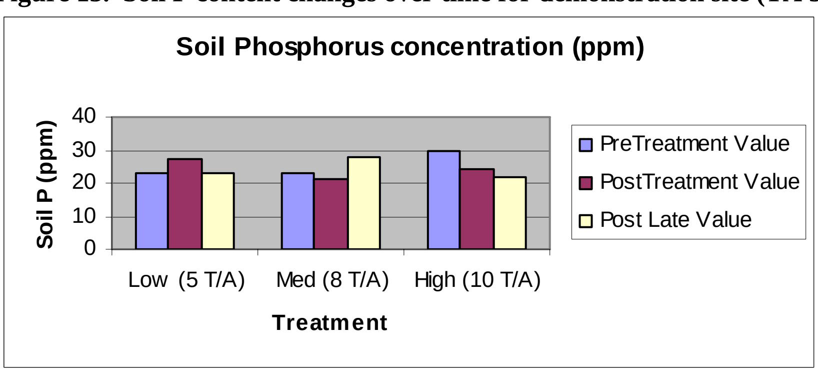


Figure 13. Soil P content changes over time for demonstration site (TA 51).



<u>SPRING 2004 -- 30 ACRES -- T.A. 44A</u>
JULY 2004 DESIGNATION: T.A. 50

Samples analyzed by A&M Soils Lab in College station.
Results reported in PPM

SOIL PHOSPHORUS

PLOT NAME	AREA (ACRES)	TREATMENT	Pre-Treatment Value	Post-Treatment Value
30 ACRE PLOT 1	7.5	SEED ONLY	8.00	11.00
30 ACRE PLOT 2	7.5	12CY/AC.	6.00	7.00
30 ACRE PLOT 3	7.5	12CY/AC. + SEED	9.00	16.00
30 ACRE PLOT 4	7.5	CONTROL	9.00	10.00

SOIL NITROGEN

PLOT NAME	AREA (ACRES)	TREATMENT	Pre-Treatment Value	Post-Treatment Value
30 ACRE PLOT 1	7.5	SEED ONLY	5.00	5.00
30 ACRE PLOT 2	7.5	12CY/AC.	6.00	9.00
30 ACRE PLOT 3	7.5	12CY/AC. + SEED	6.00	9.00
30 ACRE PLOT 4	7.5	CONTROL	5.00	14.00

Table 8. Soil N and P content pre-treatment and 6-months post-treatment 30 acre treatment study site (TA 51).

Figure 14. Soil N content changes over time for 30-acre treatment study site (TA 51).

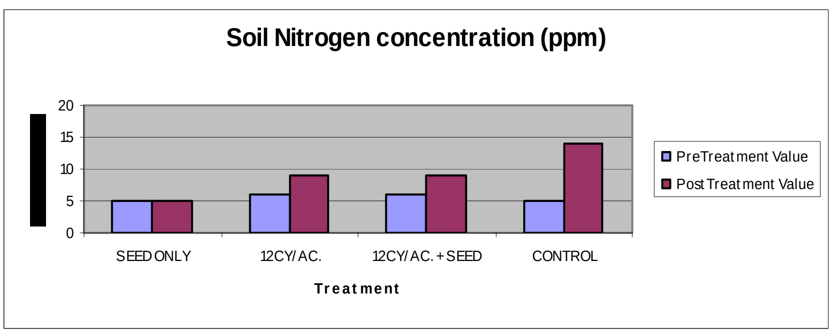
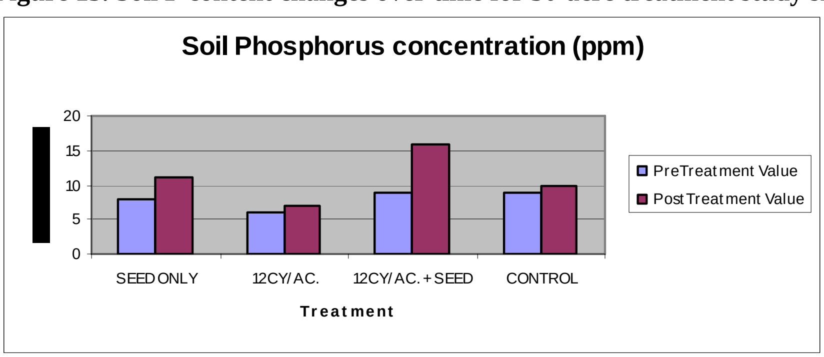


Figure 15. Soil P content changes over time for 30-acre treatment study site (TA 51).



Conclusions

The 2005 calendar year brought to a conclusion Phase I of the Range Revegetation Pilot Project for Fort Hood, TX. Phase I focused on determining three major issues:

1) Can compost amendments on military training lands have a significant impact on revegetation?

2) Does use of compost for revegetation projects on Fort Hood constitute a danger regarding negative impacts on water quality?

3) Can practices be designed to deliver compost on such difficult terrains?

Two years of comprehensive work on multiple sites, have demonstrated that there are significant vegetation increases on sites receiving 15cy/ac of compost and seeding treatments and that bareground has decreased. Second, water quality and soil fertility monitoring data indicates that there are no increases in bulk nutrients on a subwatershed scale and those elevations in soil N and P occur over a short time and return quickly to pretreatment levels. The prototype heavy-duty compost spreader developed for this project has demonstrated that compost application on severely disturbed Fort Hood terrains is possible.

The development of "Standard Operating Procedures" for compost application has begun and a draft of the manuscript is included in Appendix A. The following are summary conclusions that have been developed during Phase I of the project:

- Best Management Practices (BMP's) on military training areas achieves significant vegetative ground cover increase and bareground decrease using dairy compost at rates of 15 or more cubic yards per acre.
- Application rates of dairy compost below 15 cubic yards per acre resulted in no significant difference in vegetative ground cover or bareground for the training areas treated
- Large-scale land application approaches requires a minimum time interval of 12-18 months to achieve a significant change in ground cover
- Vegetation data analysis prior to 12-18 months will exhibit limited to no significant changes in ground cover categories
- Based upon bulk water quality monitoring, nutrient loadings from treated watersheds do not exceed the normal range of variation of surrounding waterbodies
- Soil fertility appears to spike immediately post-treatment and returns close to pre-treatment nutrient levels shortly after treatment (within 6-months)

2006 Activities:

Current activities for the calendar year 2006 are outlined in Appendix B. These activities are subject to minor changes as collaborating scientists conduct site visits to refine the ideas presented in the plan of work.

Where Do We Go in the Future:

The team feels that there is valuable research to be conducted in Phase II of the project that focuses on the development of specific strategies for use of compost in association with other best management practices. Work continues in evaluating the impacts of compost associated with NRCS contour ripping practices, development of vegetative buffer strips using compost amendments to establish vegetation. The use of large-scale land application has been verified; however, the need to optimize practices and costs remain. Future endeavors for this project will refine the general concepts that compost is a valid best management practice on selected sites to aid in revegetation of primary training maneuver lands.

Literature Cited

Alakukku, L & P. Elonen. 1995. Long-term effects of a single compaction by heavy field traffic on yield and nitrogen uptake of annual crops. Soil Tillage Research. 36:141-152.

Barnes, K.K., W.M. Carleton, H.M. Taylor, R.I. Throckmorton & G.W. VandeBerg. 1971. Compaction of Agricultural Soils. American Society of Agricultural Engineers. St. Joseph, MI.

Braunack, M.V. 1986. The residual effects of tracked vehicles on soil surface properties. Journal of Terramechanics. 23(1): 37-50.

Diersing, V.E., J.A. Courson, S.D. Warren, D.J. Tazik, R.B. Shaw & E.W. Novak. 1990. A climatic basis for planning military training operations and land maintenance activities. USA-CERL Tech. Rep. N-90/13. U.S. Army Corps of Eng., Champaign, IL.

Doran, J.W. & T.B. Parkin. 1994. Defining and assessing soil quality. In: Doran, J.W., D.C. Coleman, D.F. Bezdicek and B.A. Steward (Eds.), Defining Soil Quality for a sustainable environment. Soil Science Society of America, Madison, WI.

Ermine, D.C. & F.K. Ligon. 1988. Effects of discharge fluctuation and the addition of fine sediment on stream fish and macroinvertebrates below a water filtration facility. Environmental Management 12(1):85-97.

Fuchs, E.H., M.K. Wood, T.L. Jones & B. Racher. 2003. Impacts of tracked vehicles on sediment from a desert soil. J. of Range Management. 56(4):342-352.

Goran, W.K., L.L. Radke & W.D. Servinghaus. 1983. An overview of the ecological effects of tracked vehicles on major U.S. Army installations. USA-CERL Teck. Rep. N-142. U.S. Army Corps of Eng. Champaign, IL.

Hatchell, G.E., C.W. Ralston & R.R. Foil. 1970. Soil disturbances in logging. Journal of Forestry. 68:772-775.

Iverson, R.M., B.S. Hinckley, R.M. Webb & B. Hallet. 1981. Physical effects of vehicular disturbance on arid landscapes. Science. 212:915-917.

Jakobsen, B.F. & G.A. Moore. 1981. Effects of two types of skidders and or a slash cover on soil compaction by logging Mountain Ash. Journal of Australian Forestry Research. 11(3-4):

Johnson, F.L. 1982. Effects of tank training activities on botanical features at Fort Hood, Texas. Southwest Natur. 27:309-314.

Milchunas, D.G., K.A. Schulz & R.B. Shaw. 1999. Plant community response to disturbance by mechanized military maneuvers. Journal of Environmental Quality. 28:1533-1547.

Prose, D.V. 1985. Persisting effects of armored military maneuvers on soil soils of the Mohave Desert. Environmental Geology & Water Science. 7:163-170.

Severinghaus, W.D., R.E. Riggins & W.D. Goran. 1979. Effects of tracked vehicle activity on terrestrial mammals, birds and vegetation at Fort Knox, KY. USA-CERL Spec. Tech. Rep. N-77. Champaign, IL.

Shaw, R.B. & V.E. Diersing. 1990. Tracked vehicle impacts on vegetation at the Pinon Canyon Maneuver Site. Colorado J. of Environmental Quality. 19:234-243.

Soane, B.D., P.S. Blackwell, J.W. Dicson & D.J. Painter. 1981a. Compaction by agricultural vehicles: a review. I – Soil and wheel characteristics. Soil Tillage Research. 1(3):

Soane, B.D., P.S. Blackwell, J.W. Dicson & D.J. Painter. 1981b. Compaction by agricultural vehicles: a review. II – Compaction under tires and other running gear. Soil Tillage Research. 1(4):

Thurow, TlL., S.D. Warren & D.H. Carlson. 1993. Tracked vehicle traffic effects on the hydrologic characteristics of central Texas rangeland. Trans. ASAE 36:1645-1650.

Voorhees, W.B., .W. Nelson & G.W. Randall. 1986. Extent and persistence of subsoil compaction caused by heavy axle loads. Journal of Soil Science Society of America. 50:428-433.

Appendix A

Land Restoration on Military Training Areas
Dairy Compost as a Soil Amendment
-Draft Version of SOP Development-

Overview

Soil nutrients play a vital role in land management and are commonly used to enhance plant growth and production. However, nutrients in the form of commercial fertilizers and composted animal waste are a source of nitrate, which can contaminate ground water. Other major components of commercial fertilizer and compost, such as phosphorus are not generally a ground water contamination concern but may contaminate surface water if not properly managed. The use of composted dairy manure on military training areas is a means to restore basic soil processes to improve current vegetation and establish new vegetation.

Objectives:

The primary benefit of improved vegetation on training areas is to combat accelerated erosion due to soil disturbance by military vehicles in an effort to sustain training areas for future use. The primary objective of applying composted dairy manure to military training areas where vehicle traffic has resulted in soil compaction, loss of vegetation and soil erosion is to improve vegetation and reduce soil erosion by storm water. Benefits include stabilization of soils through the introduction of organic matter, increase in soil nutrients and ultimately increased vegetation cover.

Conditions Where Practice Applies

The practice applies on all military lands where the use of vehicles has the potential to significantly increase natural erosion processes. Though potentially beneficial on all landscapes, it is anticipated that the practice is most conducive for level to gently rolling rangeland systems in semi-arid and arid regions of the western United States.

PLANNING CONSIDERATIONS

1. Soil characteristics: texture, nutrients, etc.
2. Landscape characteristics: slope, vegetation, drainage, terrain etc.
3. Proximity of compost supply: local supply, transportation, etc.
4. Method of application: equipment needs, time required, etc.
5. Climate: weather patterns, access for vehicles, etc.
6. Quality of material: organic matter, nutrient values, amt. of mineral, etc.
7. Economics: cost of material, cost of application, cost of transportation, etc.
8. Training Scheduling and Grazing Management: ITAM Out-area programs
8. Others

Erosion is a naturally occurring phenomenon on all rangeland systems. This process is offset by the genesis of soils from underlying parent material. The process becomes a challenge when erosion is accelerated outside the range of natural variation. During the process of military training activities associated with secondary impacts including livestock and wildlife grazing, the natural variation of erosion is often exceeded. In these cases, it becomes necessary for land management to decrease the erosion rate to sustain the land area resources. The use of soil amendments by land resource managers provides a major tool available to influence land process, and in coordination with other practices, provides a strategic approach to minimize soil erosion.

Land Evaluation**:** Land Evaluation must be carried out to determine:

1. Extent of area where selected land management practices may be applicable for implementation.
2. Current rate of erosion in comparison to the natural rate of variation associated to specific soil series.
3. Current landscape characteristics including soils, slope, vegetation, drainage patterns, terrain and other aspects that might influence the beneficial impacts of management practices.
4. Historical climatic patterns that may influence the actual application of the management practices or impact the outcomes (i.e. nutrient loading in runoff).
5. Economic feasibility in comparison to other best management practices designed to counteract the erosion process.
6. Matching nutrient applications to land nutrient needs is critical. Nutrients of any form should not be over-applied. Soils should be tested prior to selecting the rate of composted manure to apply.

It is recommended that caution must be taken during the planning process to evaluate potential impacts deleterious to the successful implementation of a management practice. The primary concern is increased nutrient loads in area streams and waterbodies. This process has the potential, at high levels, to increase waterbody nutrient loads, resulting in increased cost and management of drinking water resources. Climate also plays a significant role and must be addressed in the planning process to ensure timely implementation of the activities associated with the practice.

DESIGN CONSIDERATIONS

In many cases, restoration of soil and vegetation characteristics will require a concerted effort across multiple activities including soil reconditioning (compost) and physical containment (check dams, retention ponds, etc.). Therefore, the solutions for combating soil erosion must include a strategic view incorporating multiple BMP's as well as training schedules and grazing management.

Site Preparation

Site preparation may be necessary in some areas due to the extreme disturbance that has taken place (tank dig areas, extreme rutting, erosion etc.). However, it is recommended that site preparation be limited to those areas that are strategically located to increase the efficacy of the soil stabilization activities due to the higher costs of extensive site preparation.

Where feasible and necessary, it is recommended that sites be prepared by the use of railroad rails placed in tandem behind a tractor and drug across the treatment areas to level the land by filling ruts to allow easier access of compost spreaders and reseeding equipment.

Compost Quality & Acquisition

Properly composted dairy manure requires that providers follow a set of guidelines for development of the product. This includes turning of material five times within fifteen days with the material reaching between 140^o-160^o F between turns. Assurances should be made that vendors are properly manufacturing materials.

Compost Application

Application of compost provides one of the most challenging aspects of using the material for large-scale land application on military primary training maneuver areas. The expected disturbance to the terrain through the use of military heavy tracked vehicles is easily understood. Equipment requirements focus on the use of heavy tractors pulling compost spreaders capable of withstanding the unusual and unpredictable terrain associated with training areas. Prototypical spreaders have been designed and built for evaluation and are available for review and demonstration.

Re-seeding Activities

Reseeding is a common practice employed by military personnel to combat the loss of vegetation due to regular training maneuvers. In many cases, reseeding is critical to revegetation on drastically disturbed sites. The decision to reseed is contingent on site specific indicators including the vegetation cover prior to training and the potential of the seedbank to provide the basis for revegetation.

Caution must be taken in addressing seed mixes and species used including consideration of origin (e.g. native vs. perennial), purpose (e.g. minimizing soil erosion), and secondary uses (e.g. wildlife/livestock).

Preliminary results indicate that reseeding may not be necessary in coordination with compost application where suitable seedbanks are in place to provide the basis for restoration activities. Evaluation of seedbanks prior to use may be necessary to further understand the need of seeding in restoration practices on military primary maneuver areas.

Vegetation Monitoring

Pre-treatment development of a vegetation monitoring system is required for comparison of outcomes from soil amendments in evaluating efficacy of the practice on particular areas. Development of a systematic protocol of line transects for gathering data from is recommended including species composition, cover class and other vegetation related indicators (e.g. annual/perennial).

Periodic monitoring post-treatment will provide a basis upon which efficacy of soil amendments can be compared to pre-treatment status. It is recommended that monitoring occur at least twice per year with assessments taking place to optimize impacts on vegetation in both cool and warm seasons.

Monitoring Soil Erosion and Water Quality

Plans to use composted dairy waste in a restoration project should include a watershed management and protection plan that contains a water quality monitoring component. The water constituents of greatest concerns to track watershed conditions are erosion processes and nutrient losses. Monitoring nutrient losses in runoff will assist land managers to determine appropriate nutrient rates for the areas being restored. Water quality data can also be used to evaluate the effectiveness of various Best Management Practices implemented during the restoration program. Sediment and phosphorus are of the greatest concern. Sediment losses need to be assessed on a watershed basis. Runoff water in streams containing phosphorus concentrations between 0.01 and 0.03 mg/L are considered to be non-eutrophic and not in danger of suffering degraded water quality. According to EPA guidelines, discharges to streams should not contain phosphorus levels higher than 0.1 mg/L. If the stream empties into a lake, discharges should not exceed 0.05 mg/L and discharges directly into a lake should not contain phosphorus concentrations greater than 0.025 mg/L.

MAINTENANCE …

Glossary

Filter strip: A gently sloping grass strip planted between edge of field and drainage ways to streams and managed to filter runoff. Runoff is distributed uniformly across the high end of the strip and allowed to flow through the strip. Nutrients and suspended material remaining in the runoff water are filtered through the grass, absorbed by the soil and ultimately taken up by the plants. Filter strips must be designed and sized to match the characteristics of the land.

Infiltration: The entry of water through the soil surface.

Percolation: The downward movement of water through the soil.

Runoff control system: A combination of management practices that can be used together to prevent water pollution from livestock yard runoff. Practices may include diverting runoff from the yard or roofs, using roof runoff systems, shaping yards, using settling basins, and planting filter strips or buffer areas.

Soil drainage class: A description of the frequency and duration of periods of saturation or partial saturation that exist in soils, as opposed to human-altered drainage. Different classes are described by such terms as 'excessively drained', 'well-drained', and 'poorly drained'.

Soil permeability: The quality that enables a soil to transmit water or air. Slowly permeable soils may have fine-textured materials, such as clays that permit only slow water movement. Moderately or highly permeable soils commonly have coarse-textured materials, such as sands, that permit rapid water movement.

Soil texture: The relative proportions of the various soil separates (clay, sand and silt) in a soil. Described by such terms as sandy loam and silty clay.

Appendix B

Calculated Nutrient Equivalencies for Compost Nitrogen and Phosphorus

Pounds N, P & K/ton of compost

$$\frac{\%N}{100} x2000 = \frac{lbsN}{ton}$$

$$\frac{\%P(wet)}{42} x2000 = \frac{lbs.P2O5}{ton} x\%drymatter$$

$$\frac{\%K}{83} x2000 = \frac{lbsK2O}{ton} x\%drymatter$$

15 cy/acre	≈217 lbs N/ac ≈127 lbs P/ac
30 cy/acre	≈443 lbs N/ac ≈254 lbs P/ac
45 cy/acre	≈650 lbs N/ac ≈381 lbs P/ac
60 cy/acre	≈867 lbs N/ac ≈509 lbs P/ac
75 cy/acre	≈1083 lbs N/ac ≈636 lbs P/ac
90 cy/acre	≈1300 lbs N/ac ≈763 lbs P/ac

Based upon analysis of compost purchased for the current project. These estimations do not presume to be representative for all compost providers.