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Nitrogen Mineralization in Compost Mulch Berms on simulated Military training Landscapes

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Abstract - Mineralization of compost mulches can lead to pollution by supplying nitrate and ammonium N. This study investigated the potential for using compost mulch berms on simulated military training landscapes to impact the environment through nutrient enrichment. In carrying out the study, twenty four berms of compost (C), wood chips (WC), pine barks (PB), soil (S), and mixture of the materials in various proportions were constructed. For each berm, internal temperatures were measured at weekly intervals and each month representative samples of materials were dried, ground, sieved and analyzed for pH, conductivity, NH_4^+-N, $N0_3^-$-N, and total N. Result showed that Treatment1 (100% Compost) poses the greatest threat of contributing NH_4^+-N, NO_3^--N, followed by Treatment 8 (33.3% each of Compost, Wood Chips, and Pine Barks),Treatment7 (30% each of Compost, Wood Chips, Pine Barks with10% Soil) and Treatment 6 (25% each of Compost, Wood Chips, Pine Barks and Soil). In conclusion, this study indicates that using a mixture of subsoil, wood chips and pine bark in equal proportions would be the best combination for reducing environmental impacts of training landscapes from nutrient supply under the conditions at the study site.

Key words: Berm, Compost mulch, Mineralization, Nitrate, Ammonium,

1.0 Introduction

Training is an important part of military mission. It is land intensive and can cause significant damage to landscapes. Training maneuvers by military vehicles disrupt stable soil surfaces, create ruts, and compact the soil (Braunack, 1986; Thurow *et al*., 1993; Prosser *et al.*, 2000).. Disruption and compaction of the soil reduce vegetation cover, disturb crusts, and degrade soil aggregates, making the land more vulnerable to wind erosion (Maston, 1988; Grantham *et al*., 2001). Disturbance of landscapes from the training may lead to changes in composition of plant species (Thurow *et al*., 1993; Wilson, 1988) including invasion by alien plant species (Wilson, 1988; Milchunas *et al.*, 2000). In addition, excessive run-off and eroded sediments from within the boundaries of training areas may ultimately affect lands downstream (Bohm, 2003).

The army faces major land management issues in maintaining its training areas to support the training mission (Vachta *et al*., 1990). Some of the approaches adopted include an Erosion Control Management Plan (ECMP), which offers procedures to identify erosion problems, address needs, select appropriate solutions, and compare the costs of alternatives (Vachta *et al*., 1990); predicting location disturbance magnitudes (Guertin *et al*., 2002); the selective breeding of plants aimed at developing plant cultivars resistant to traffic which however, normally takes ten or more years to breed a new plant cultivar for the above purpose and use of compost mulches, which is the subject of this paper.

Compost mulches and other organic waste materials are cost effective alternatives for building berms on simulated training landscapes. Berms, called an earthwork in military terms are common phenomenon in defense engineering construction. It is difficult to advance over a trench and berm construction, and soldiers can use the berms to provide defensive cover. Berms can also control erosion and sedimentation by reducing the rate of surface run-off. The berms either reduce the velocity of the water, or direct water to areas that are not susceptible to erosion, thereby reducing the adverse effects of running waters on exposed top soil. In addition using mulches to construct the berms on lands for training of the military provides alternative means of disposing and recycling organic and inorganic waste materials.

N supply from organic amendments depends on both the initial availability of inorganic N in the amendments and also the longer term rate of mineralization and subsequent immobilization of N. To successfully manage nutrient cycling from organic amendments, it is therefore necessary to know their decomposition rate and the influence this will have on N processes within the soil (Ambus *et al*., 2002; Gabrielle *et al*., 2004). Despite the various benefits of using berms made from compost and other organic materials and soil for simulated military training landscapes, decomposition of these materials may cause environmental degradation by supplying nutrients such as nitrate-N (NO_3^--N) ammonium N, (NH_4^+-N) to the environment on- and off-site ecosystems. The objectives of this paper is to investigate *in-situ* mineralization of nitrogen (N) in compost mulch berms on simulated military training landscapes as well as assess nutrient loading potential of different mixtures of mulch berms.

2. Materials and methods

2.1 Study Location

The study was conducted at the Winfred Thomas Agricultural Research Station, Hazel Green, Alabama, on a Decatur silt loam (clayey kaolinitic thermic, typic paleudults)

2.2 Treatments and Experimental Design

Treatments studied consisted of three organic materials: compost (Compost), wood chips (Wood Chips), and pine bark(Pine Barks) mixed with soil The compost was yard waste compost, the wood chips were hard wood chips from tree trimming operations and the pine bark were shreaded pine bark from pine trees. Different proportions of these materials were thoroughly mixed with the aid of a Bob-Cat front end loader; and were moved using a track loader to an open space where combinations of the materials in different proportions were developed to make eight treatments (Table 1). The treatments were replicated three times giving a total of 24 experimental units used for the study (Table 2). The organic materials and soil were used for constructing berms compacted by the track loader to simulate military training landscape (Figure 1).

The experimental design was a randomized complete block (RCB) design with three replications (Table 2). The experimental units (berms) were spaced out at 3.05 meters intervals to prevent movement of materials between berms. The dimension of each was 9.14 meters long, 4.88 meters wide, and 1.22 meters high. The front face of the berms on the south end was at a 3:1 slope to reduce erosion and to allow for mowing of grass and other vegetation. The other side on the northern end was at 1:1 slope to conserve space (Figure 2).

2.3 Sample processing and Analysis

Samples from the berms were collected using a probe at three random locations every month. The samples collected from each berm were combined and dried to constant weight in an oven at 38^oC. The dried samples were ground and sieved using a 2mm sieve and kept in labelled Ziploc for analysis involving pH, electrical conductivity (EC), NH_4^+-N and NO_3^--N, as well as that of total C and N. Internal berm temperature was measured weekly using 45.7cm probe compost thermometers model AL 2P-0-100f-12. Berm moisture content was measured monthly by the gravimetric method.

The pH of berm materials was measured using a 1:1 ratio of sample and deionized water for soil samples, a 1:2 ratio of sample and deionized water for compost material and 1:5 ratio of sample and deionized water for woody materials. The EC of berm materials was measured using a 1:10 ratio of sample and deionized water. The mixtures were shaken for 30 minutes on an electric shaker before taking reading using the Acumet LX pH/conductivity meter. For each berm, 20 ml of 2M KCl were added to two grams of dried and ground samples and shaken for 30 minutes followed by filteration with a #42 Whatman filter paper. Filterate collected was measured for Ammonium N (NH_4^+-N) and nitrate N (NO_3^--N) using the Timber Line 2800 Ammonia Analyzer.

Total C and N of dried berm powdered samples were measured using the LECO TruSpec CN analyzer (LECO CN analyzer – LECO Corp, St. Joseph Michigan). This data was used to calculate the C/N ratio of the compost berm materials. The data collected in this study were analyzed using the General Linear

Models (GLM) procedures of the SAS ver. 9.3.1 software (SAS, 2007). Treatment means was compared using the LSD mean separation procedure.

3. Results and discussion

3.1 *pH*

Environmental conditions conducive to rapid decomposition and mineralization include a near-neutral pH of 6 and 8 favorable to growth of diverse bacterial population (Murray, 1981). The pH values for the treatments during the study period are shown in Table 3. In Treatment I (100 % Compost) the pH values ranged from 7 at the beginning of the study to 7.2 at the end. This range of pH values implied optimal conditions for mineralization process and resulted in high levels of NH_4^+-N and significantly higher levels of NO_3^--N as shown in Figure 3 and Figure 4 respectively. Treatment 2 (100% Wood Chips) and Treatment 3 (100% Pine Barks) had the highest levels of NH_4^+-N despite their pH values in the near acid range. This might be due to the fact that these treatments are rich in organic residue, the C content (Figure 5) of which is used as energy source to enhance the microbial activities in the mineralization process.

There was no significant difference in the pH values for Treatment 8 (33.3% each of Compost, Wood Chips, and Pine Barks), Treatment 7 (30% each of Compost, Wood Chips, Pine Barks and 10% Soil),Treatment 6 (25% each of Compost, Wood Chips, Pine Barks and Soil) and Treatment 5 (20% each of Compost, Wood Chips, Pine Barks and 40% Soil) with values ranging from 6 to 7.1. The levels of NH4+-N in Treatment 4 to 8 were lower. This might be due to less supply of organic materials (OM) in these treatments. The acidic pH values for Treatment 4 (100% Soil) and low C content as a sub soil might be responsible for the low NH_4^+-N mineralized in the 100% Soil berm. The relatively high pH values for Treatment 1 (100% Compost) are indicative of basic elements such as potassium (K), calcium (Ca), and magnesium (Mg).

3.2 Internal berm temperature

Optimum temperature favorable to microbial activities for mineralization ranges between 25ºC to 35ºC. Microbial activities and N mineralization generally increase with temperature (Waksman and Gerretsen, 1931; Kirchbaum, 1995), which together with soil moisture is one of the most important factors for decomposition (Stanfor and Epstein, 1974). The chemical reaction taking place in the microbial degradation process of mineralization is exothermic in nature (Figure 6). The berm materials containing organic components were in general actively producing heat showing microbial activity from beginning of study to week 32.

The relatively lower temperature recorded for Treatment 4 (100 % soil) reflected the level of microbial activity which could be due to the low OM content. There was also lower temperature released forTreatment2 (100% Wood Chips) within the same period. This could. be accounted for by the porous nature of the wood chip which are less tightly packed and this allowed for free circulation of air through wetting and drying cycles to pump air in and out of material as a process of frequent renewal of the oxygen supply which aids in the process of decomposition.

Between week 8 and 20 there was almost a double in the ambient temperature compared with the beginning of study. During this period the supply of ambient temperature favored microbial activity. The favorable temperature supply could account for the increased amount of products mineralized. Generally, the rate of mineralization increases rapidly between 10º C and 30º C rise in the temperature; and roughly a doubling of the activity with each rise can be expected in the range from 5 to 35º C (Stanford *et al*, 1973, Katterer *et al*, 1998). As shown in Figure 6 and reflected in Figures 3 and 4, decomposition of materials is reduced under both warmer (Harmsen and Kolembrander, 1965) and colder conditions (Lomander *et al*, 1998). However, downward trend in the heat releasing activity started from week 24. Also, decomposition could slow down when microbes run out of C for energy supply.

Treatment 8 (33.3 % each of Compost, Wood Chips and BP) generated the highest temperature at the first three sampling dates followed by Treatment 7 (30% each of Compost, Wood Chips, Pine Barks and 10%

Soil). This may be due to the composition of the Treatments consisting of high supply of Compost as well as plant residue from Wood Chips and Pine Barks to supply C as energy source to enhance microbial activity compared to Treatment 1 (100% Compost). Considering the effect of temperature on decomposition products, nitrification rates declines above 35°C (Nyle and Ray, 1999). High temperatures were generated by the berms within the periods of optimum temperature supply. However Treatment 1 (100^o Compost) and Treatments containing compost consistently supplied NO_3^--N in amounts which decreased following the decreasing order of composition of Compost. The consistency in nutrient supply could imply that Treatment 1 (100% Compost) and compost containing materials have high nutrient loading potential.

3.3 Electrical Conductivity

Treatment1 (100% Compost) and Treatment 2 (100 % Wood Chips) consistently have high values of electrical conductivity (Figure 7).These results could be due to the fact that Treatment 1 (100% Compost) was yard waste compost containing mixture of simple and complex organic materials which decompose further to release mineral elements and ions of various salts. The high value of EC for Treatment 2 (100% Wood Chips) could be due to other soluble ions mineralized considering that Treatment 2 had low supply of NO_3^--N (Figure 4). The low EC value for Treatment 3 (100 % Pine Barks) could be attributed to loss of NO_3^--N which could be due to leachate in view of the high moisture content of the treatment (Figure 8) and denitrification (Parkin *et al*, 1996; Eigenberg *et al*. 2000) while the low value of EC for Treatment 4 (100% Soil) could be due to the fact that the soil used in the study was a sub-soil low in organic material to supply energy that could enhance microbial activity for mineralization to form ions. The implication of these results is that, assuming leachate eventually ends up in off site down-stream waters resources such as streams, rivers and lakes, Treatment 1 (100 % Compost) and Treatment 2 (100% Wood Chips) will be of greater significance in the contribution of charged ions to the environment.

3.4 Gravimetric moisture content

Treatment 3 (100 % Pine Barks) had more than twice moisture compared to other materials. Treatment 2 (100% Wood Chips) followed in high water content (Figure 8). Decomposition rate usually decreases with oxygen deficiency (Campbell, 1978) and the high amount of water content could limit oxygen supply to microbes. Nitrification only takes place when oxygen contents are adequate, which occurs at low and intermediate soil moisture content; and, when temperatures are above 5°C (Anderson and Boswell, 1964; Sikora *et al*, 2001).The high water content of Treatment3 (100 % Pine Barks) and Treatment 2 (100% Wood Chips) could contribute to the reduction in the temperature of the treatment during the period of active mineralization and also account for loss of possibly mineralized NO_3^--N considering that considerable N can be lost by denitrification (Parkin *et al*, 1996; Eigenberg *et al*. 2000). Lowest moisture content was however found in Treatment 4 (100 % Soil). It is likely that runoff from soil was greater than from the organic berms, thus infiltration was less.

In summary, results obtained from the study showed that berms made from Treatment1 (100 % Compost) posed the greatest potential to contribute NH_4^+-N, and NO_3^--N to the environment.Treatment 2 (100 % Wood Chips) and Treatment3 (100 % P B) posed the greatest threat to supply NH_4^+-N. Berms made from Treatment 6 (25 % each of Compost, Wood Chips, Pine Barks and Soil) followed by berms from Treatment 7 (30 % each of Compost, Wood Chips, Pine Barks, 10 % Soil) and then berms from Treatment8 (33.3 % each of Compost, Wood Chips and Pine Barks) were next to Treatment 1 (100 % Compost) in their potential to contribute NO_3^--N to the environment. Berms made from Treatment 4 (100% Soil) posed the least potential to contribute NH_4^+-N, and NO_3^--N, to the environment. This study showed that compost material can play a significant role in the supply of nutrients to the environment. Hence, incorporation of compost in the building of berms on training landscapes may enhance the supply of nutrients which can ultimately result in environmental pollution. Since NO_3^--N is the ultimate product of mineralization, berms made from 100 % Pine Barks, 100 % Wood Chips and 100 % Soil were found to have the least potential to supply NO_3^--N. With erosion control to reduce NH_4^+-N transport, these materials may have potential for use to build berms on training landscapes. In conclusion, this study indicates that using a mixture of subsoil, wood chips and pine bark in equal proportions would be the best combination for reducing environmental impacts of training landscapes from nutrient supply under the conditions at the study site. To further reduce nutrient supply, grass cover crops can be planted on the berms to reduce runoff and erosion and further minimize their environmental impacts.

Acknowledgements

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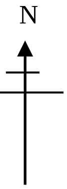
Tables and Figures

Treatment.#	Compost (CP)	Wood Chips (WC)	Pine Bark (PB)	Soil (S)
	%			
1	100.0	0.0	0.0	0.0
2	0.0	100.0	0.0	0.0
3	0.0	0.0	100.0	0.0
4	0.0	0.0	0.0	100.0
5	20.0	20.0	20.0	40.0
6	25.0	25.0	25.0	25.0
7	30.0	30.0	30.0	10.0

Table 1. List of treatments used in the study showing the percentage by volume of each material taken to make a treatment.



Plot #	treatment	Description ………%............				Plot #	treatment	Description ……..%............				
		CP	WC	PB	S			CP	WC	PB	S	
1	3	0.0	0.0	100	0.0	5	8	33.3	33.3	33.3	0.0	BLOCK I
2	5	20	20	20	40	6	1	100	0.0	0.0	0.0	
3	6	25	25	25	25	7	4	0.0	0.0	0.0	100	
4	7	30	30	30	10	8	2	0.0	100	0.0	0.0	
9	5	20	20	20	40	13	4	0.0	0.0	0.0	100	BLOCK II
10	8	33.3	33.3	33.3	33.3	14	6	25	25	25	25	
11	2	0.0	100	0.0	0.0	15	7	30	30	30	10	
12	1	100	0.0	0.0	0.0	16	3	0.0	0.0	100	0.0	
17	3	0.0	0.0	100	0.0	21	5	20	20	20	40	BLOCK III
18	6	25	25	25	25	22	2	0.0	100	0.0	0.0	
19	4	0.0	0.0	0.0	100	23	1	100	0.0	0.0	0.0	
20	8	33.3	33.3	33.3	33.3	24	7	30	30	30	10	

Table 2. Arrangements of the berms as experimental units into plots by randomized complete block design

Number of weeks												
Treatment	0	4	8	12	16	20	24	28	32	36	40	44
1 100% CP	7.0a	7.1a	7.3a	7.5a	7.3a	7.4a	5.9ab	7.2a	7.3a	6.9a	7.6a	7.2a
2 100%WC	5.5e	5.8d	5.5d	6.8b	5.8c	6.2b	6.9a	5.4c	5.7c	5.3c	6.7b	6.3b
3 100% PB	4.5g	4.9e	4.9e	5.1d	5.5c	5.8bc	5.5b	5.3c	5.3cd	5.5c	5.9c	5.4c
4 100% S	4.9f	4.7e	4.9e	5.9c	4.9d	5.7c	5.9ab	4.9c	4.9d	4.8d	5.3d	5.1c
5 20% CP,WC PB,40% S	6.0d	6.4c	6.3c	6.8b	6.4b	7.0a	6.8a	6.6b	6.7ab	6.3b	6.9b	7.0a
6 25% CP,WC, PB,S	6.2cd	6.6bc	6.6bc	6.9b	6.6b	7.2a	6.8a	6.7b	6.8ab	6.5ab	6.6b	6.8a
7 30% CP,WC, PB, 10% S	6.3bc	6.5bc	6.3c	6.8b	6.6b	7.1a	6.5ab	6.5b	6.7b	6.4b	7.0b	6.6ab
8 33.3%CP,WC PB,	6.5b	6.9ab	6.8b	6.8b	6.7b	7.1a	6.8ab	6.7ab	6.9ab	6.5b	7.1ab	6.9ab

Table 3. pH values of field berm samples measured at each sampling period of every month.

Means with the same letter are not significantly different at $P \leq 0.05$

Figure 1. A field of berms arranged into plots
by randomized complete block design

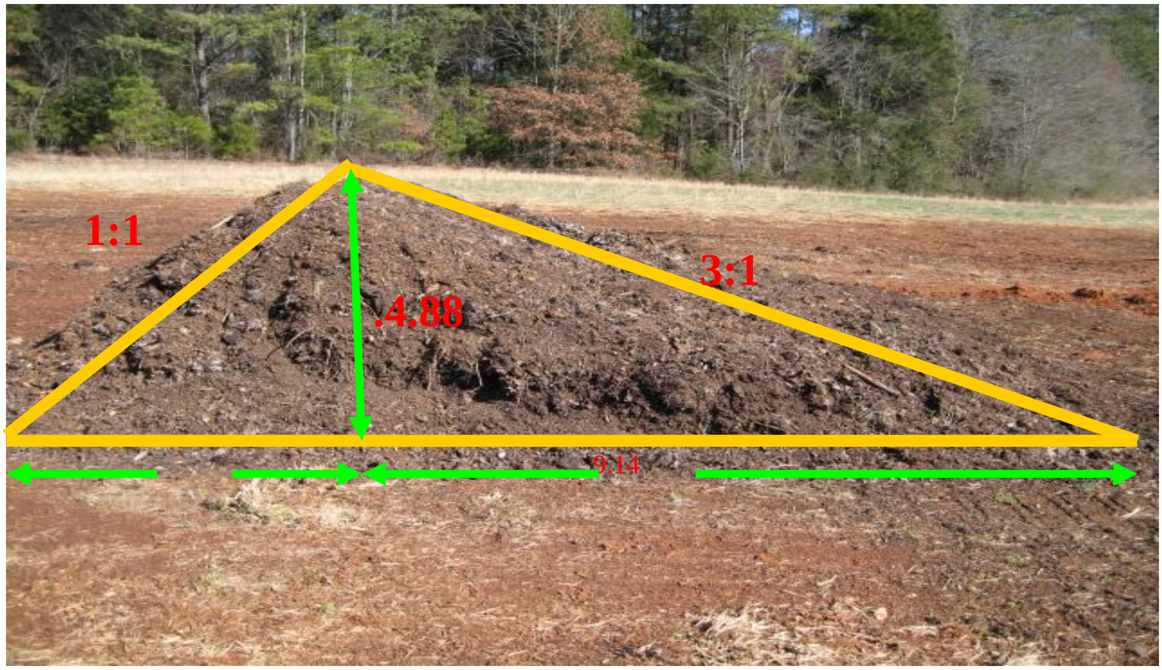


Figure 2. Layout of constructed berms

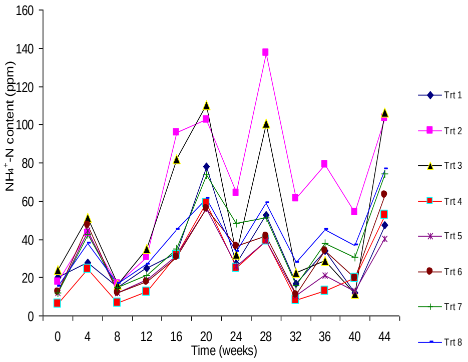


Figure 3. Ammonium N (NH_4^+-N)content mineralized by the field berm samples

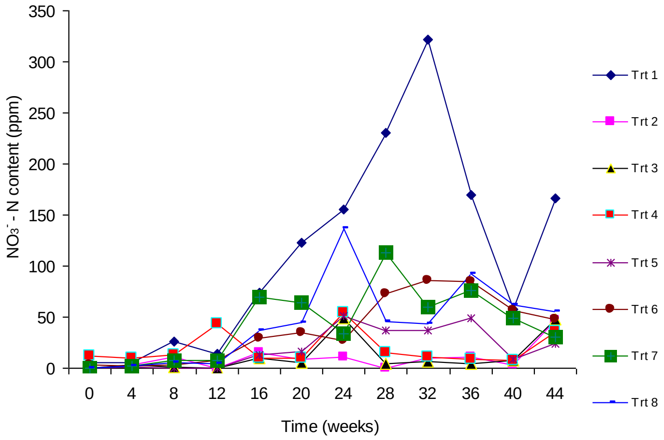


Figure 4.Nitrate N (NO_3^--N) content mineralized by field berm samples

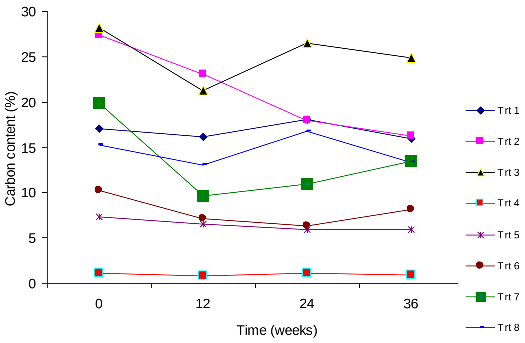


Figure 5. Total Carbon Content of field berm samples

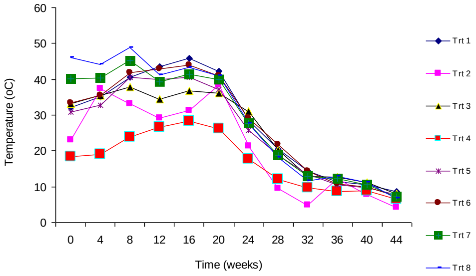


Figure 6 Heat energy released during mineralization of field berm samples

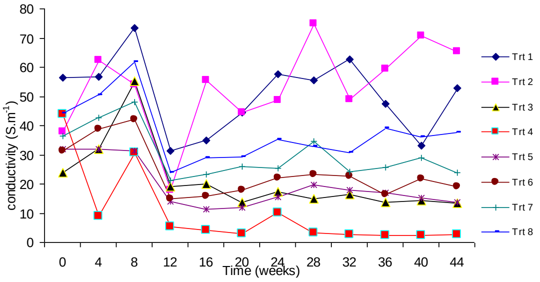


Figure 7.Electrical Conductivity (EC) value of field berm samples

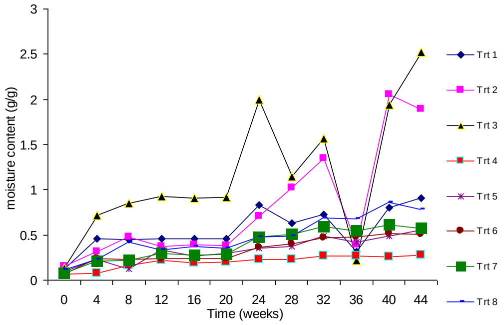


Figure 8. Gravimetric Moisture content of field berm samples

References

Ambus, P., Kure, L. K. and Jenson, E. S. 2002. *Gross Nitrogen transformation after application of household compost and domestic sewage sludge on agricultural soils*. Agronomie 22: 723-730.

Anderson, O. E. and Boswell, F. C. 1964. *The influence of low temperature and various concentrations of ammonium nitrate on nitrification in acid Soils*. Soil Sci. Soc. Am. Proc. 28: 525-532.

Bohm, A. 2003. *Soil erosion and erosion protection measures on military lands. Case study at combat Maneuver Training Center, Hohenfels, Germany, Physiogeovgraphica,* Basler Beitrage Zur physiogeographie 31: 1-141

Braunack, M. W. 1986. *Changes in physical properties of two dry soils during tracked vehicle passage*. J. Terramech 23: 141-151

Campbell, C. A. 1978. *Soil organic carbon nitrogen and fertility. 173-271. In. Schnitzer, M. and Khan, S. U. (ed) soil organic matter*. Developments in Soil Sciences. Elsevier, New York.

Deneve, S. J. Van De Steene, R. Hartman, R. and Hofman, G. 2000. *Using time domain reflectometry for monitoring mineralization of nitrogen from soil organic matter*. Eur. J. Soil Sci. 51: 295-304.

Eigenberg, R. A., Doran, J. W., Nienaber, J. A., Woodbury, B. L. 2000. *Soil conductivity maps for monitoring temporal change in agronomic field in Proceedings of the 8th International Symposium on Animal Agriculture and Food Processing Wastes.* Des Moines, IA,9-11 October 2000, 249-265..

Gabrielle, B. J., De-Silveria, S., Hout and Francou, C. 2004. *Simulating urban waste compost effects on Carbon and Nitrogen dynamics using a biochemical index*. J. Environ. Qual. 33:2333-2342.

Grantham, W. P., Redente, F. F., Bagley, C. F. and Paschke,M. W. 2001. *Tracked vehicle impacts to vegetation structure and soil erodibility*. J. Range Manage 54:711-716.

Guertin, Patrick J., Meyer, William D. 2002. *Sustainable Army training Lands carrying capacity*. Defense Technical information Center.

Harmsen, G. W. and Kolenbrander, G. J. 1965. *Soil Inorganic nitrogen.* 43-92. In. Bartholomew, W. V. and Clark, F. E. (ed). Soil nitrogen. Agron. monogr. 10. ASA, Madison, W.I.

Katterer, T., Reichstein, M. Andreb, O. and Lomander, A. 1998. *Temperature dependence of organic matter decompostion: A critical review using literature data analysed with different models.* Biol. Fertil. Soils 27:258-262.

Kirchmann, H. 1991. *Carbon and nitrogen mineralization of fresh, aerobic and anaerobic animal manures during incubation with soil.* Swed. J. Agric. Res. 21: 165-173.

Kirschbaum M.F., 1995.*The temperature dependence of organic-matter decomposition.*Soil Biol Biochem 38: 2510-2518

Lomander. A., Katteses, T. and Anderson, O. 1998. *Carbon dioxide evolution from top and sub-soil as affected by moisture and constant and fluctuating temperature. Soil Biol*. Biochem. 30: 2017-2022.

Maston, R. A. 1988. *Maneuver caused wind erosion impacts. South Central New Mexico.* Ln. Nickling, W. G. Editor. 1986 Aeolian geomorphology, Allen and Unwin: 273-290.

Milchunas, D. G., Schultz, K. A. and Shaw, R. B. 2000. *Plant community structure in relation to long-term disturbance by mechanized military maneuvers in semi arid region.* Environ manage 25 (2000) 525-539.

Murray, J. .J. 1981. *Utilization of composted Sewage sludge in sod production*. In. R. W. Sheard (ed.) Proc. Int. Turfgrass Res. Conf., 4th University of Cuelph, ON 1981. Ontario Agric College, University of Guelph and the Int. Turfgrass Soc. Guelph ON. 554.

Nyle, C. B. and Ray R. W. 1999. *The nature and properties of soil*. Pentice Hall, Upper Saddle river, New Jersey p 500.

Parkin, T. B., Doran, J. W., Franco-Vizcaino, E. 1996. *Field and laboratory tests of soil respiration. Ln. Doran J.W., Jones. A .J. (eds.). Method for assessing soil quality.* Soil Sci. Soc. Am. Special Publication 49; SSSA, Madison, W.I.

Prosser, C. W., Sedivec, K. K. and Barker, W. T. 2000. *Tracked Vehicle effect on vegetation and soil characteristics.* J. Range Manage 53

Sikora, L. J. and Szmidt, R. A. K. 2001. *Nitrogen sources mineralization rates, and nitrogen nutrition benefits to plants from compost*: 287-305. In Stoffella, P. J. and Kahn, B. A. (ed) Compost utilization in horticultural cropping systems. Lewis Publ., New York.

Stanford, G. and Epstein, E. 1974. *Nitrogen mineralization-water relations in soils.* Soil Soc. Am. Proc. 38: 103-107.

Stanford, G., Frer, M. H. and Schwaninger, D. H. 1973. *Temperature Coefficient of Soil nitrogen mineralization*. Soil Sci. 115: 121-123.

Thurow, T. I., Warren, S. D. and Carison, D. H. 1993. *Tracked vehicle traffic effects on the hydrologic characteristics of Central Texas rangeland.* Trans Am. Soc. Agric. Eng 36: 1645-1650

Vachta, Eunice, G. Riggins, Robert, E. 1990., *Erosion Control Management Plan for Army Training defence Technical Information*

Waksman, S. A. and Gerretsen, F. C. 1931. *Influence of temperature and moisture upon the nrature and extent of decomposition of plant residues by microorganisms*. Ecology 12: 33-60.

Wilson, S. D. 1988. *The effects of military tank traffic on Praurie: A management model,* 1988. Environmental Manager 12: 397-403