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INFLUENCE OF SOIL COMPACTION ON NITROGEN VOLATILIZATION IN A MANAGEMENT INTENSIVE GRAZING SYSTEM: ESTIMATION OF GASEOUS N LOSSES USING MASS BALANCE IN INTACT SOIL CORES

by

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Influence of Soil Compaction on Nitrogen Volatilization in a Management Intensive Grazing System: Estimation of Gaseous N Losses Using Mass Balance in Intact Soil Cores

Introduction

Increasing concern about the environmental impacts of greenhouse gases and PM 2.5 particulates has prompted many researchers to examine the processes of gaseous loss of nitrogen (N) from agricultural land. As agricultural production becomes more competitive and producers strive to become more efficient by reducing input costs, they will increasingly employ practices such as the rotational stocking, also called Management Intensive Grazing (MIG). MIG utilizes high animal stocking rates for short periods of time to efficiently harvest pasture crops. Unfortunately, MIG also produces relatively high concentrations of livestock excreta. This has caused intensive grazing practices to become a focal point of research concerning gaseous losses of N.

Ball et al. (1979) reported that grazing animals excrete 75 to 90% of the N they consume. The N present in urine is of particular concern as it is deposited in a very concentrated area, resulting in fertilizer application equivalent to as much as 1100 kg N ha-1 (Wachendorf, 2005). Cattle in MIG tend to gather around the drinking water source where soil moisture content is generally higher due to leaky watering troughs. This causes high soil compaction rates in these areas. Animals also tend to deposit more excreta in areas where they congregate (Bolan et al., 2004). The compacted soil around watering areas may cause the N present in animal excreta at these locations to be very susceptible to gaseous loss through ammonia volatilization and denitrification.

Ammonia volatilization is of particular concern in grassland soils as ammonia may be more concentrated and susceptible to loss than in arable lands (Whitehead, 1993).

Gaseous loss of N through denitrification and its conversion to nitrate through nitrification represent two microbial soil processes of potential importance to efficient N utilization (Abbasi and Adams, 1998).

Studies have been executed to quantify the potential loss of N from grazed pastures; however, the majority of research has been performed on coarse textured soils of average pH (Akiyama et al., 2004; Breland and Hansen, 1996; De Neve and Hofman, 2000; Melin and Nommik, 1983; Torbert and Wood, 1992). Little research has been performed on heavy textured soils with high pH typical of the Intermountain Region. Intermountain soils have important characteristics that in many cases favor soil processes leading to gaseous loss of N.

Gaseous emissions of N have been found to be up to 20% higher in poorly drained silt-loam soils than in well-drained sandy loam soils (Saggar et al., 2004). Loss can be compounded significantly by soil saturation and compaction (Abbasi and Addams, 2000; D'Haene et al., 2003; Breland and Hansen, 1996; Torbert and Wood, 1992). Soils with a pH greater than 7.5 (common to Intermountain soils) are also at greater risk of N loss through denitrification (Bolan et al., 2004).

Soil condition observations on established grazing research plots as well as the relatively scarce research available concerning N loss in heavy soils in semi-arid regions prompted us to conduct a base-line research experiment to understand the potential N losses from MIG systems in the Intermountain Region of the United States.

Materials and Methods

Experimental Site

A laboratory experiment was conducted to provide base-line data on total N losses resulting from animal urine deposits in grazed pastures. Two soils representative of existing local pastures with differing clay contents were used. The first soil was classified as a silt loam comprised of 17% clay, 28% sand, and 55% silt. The second soil was classified as a loam comprised of 22% clay, 28% sand, and 50% silt.

Soil Preparation

Soil was extracted at field capacity using 14.8 cm diameter x 30.48 cm deep polyvinylchloride (PVC) pipes pushed into the soil using a Giddings soil probe. Twenty-four total cores were extracted, twelve from each soil type. Cores were immediately transferred to the laboratory where any remaining vegetation was cut to soil level. The base of each core was fitted with a screen and PVC end cap and placed on vertical stands in the laboratory. Bulk density samples were taken at the time of sampling to determine that both soils had an existing bulk density of 1.2 Mg m^{-3}. Soil samples were taken at the time of the original core sampling and analyzed for total N content by Leco analysis. Total N levels were 2400 and 900 mg/kg for the loam and silt loam soils, respectively. Soil cores were weighed at filed capacity moisture level before treatments were applied.

Laboratory Procedures

Three compaction levels of 1.2, 1.3, 1.4 mg cm^{-3} were achieved by striking the soil surface with a metal plate equaling the inside diameter of the PVC pipe until the desired volume was achieved. Four repetitions of each bulk density level were compacted in this manner. After three days, bovine urine harvested from lactating dairy cows was applied. Urine was analyzed for total N content by Leco analysis and applied at a rate of 1000 lb/acre, representing super-saturation of cattle urine pools under field conditions (Wachendorf, 2005). Leachate produced after urine application was collected and analyzed for total N content. Thereafter, soil moisture was monitored every 2-3 days by weight and distilled water was added to restore soil cores to field capacity using the method describe by Abassi and Adams (1998) and Akiyama et al. (2004). Cores were incubated for 12 weeks in ambient laboratory conditions with day/night temperatures of 65-75° F.

Upon completion of the incubation period, PVC core containers were cut open vertically and soil was removed, mixed, and a representative sample was analyzed for total N content by Leco analysis. Differences between beginning soil N, N present in urine fertilizer, leachate losses, and ending soil N were examined, using a mass balance analysis. Nitrogen not accounted for in the soil or leachate was assumed to have been lost through either ammonia volatilization or denitrification and volatilization of nitrous oxide gasses (NOX).

Results and Discussion

Differences in beginning soil N content of the two soils represented in Table 1 can

Table 1 Average soil N levels and N inputs expressed in grams. Ending soil N and N balance data (differences between beginning and ending N) are expressed as averages across three bulk densities.

Soil Type	Beginning N	Total C	N additions	Ending N	Balance
	grams				
Loam	14.98	228.22	1.91	17.89	1.01
Silt Loam	5.76	499.62	1.91	7.79	0.30

Table 2 ANOVA *significant at .05 level of probability, ** significant at .01 level of probability, NS = Non Significant.

Source	df	SS	MS
Bulk Density	2	13.43	6.72 *
Soil	1	1.97	1.97 NS
Bulk Density x Soil	2	22.90	11.45 **
Error	17	27.74	1.63

be largely attributed to the different cropping systems in existence at the time of sampling. The loam soil cores were extracted from an alfalfa field and the silt loam soil cores were extracted from a grass-covered orchard area that had not been cultivated for a significant period of time. The ending N content of both soils is higher than the beginning content plus the added N. This could be due to mineralization of N in the organic matter of each soil. There is no significant difference between the N balances of the two soils shown in Table 3. Senescence of N-fixing nodules from the alfalfa roots severed during core sampling of the loam soil may have also contributed to increase in N.

Bulk density measurements are expressed in Table 3. The bulk densities of the two soils were significantly different at a probability level of 0.05. Bulk density and soil type interaction was also found to he highly significant at a level of 0.01 (Fig. 1). These two results suggest that soil processes thought to contribute to gaseous N loss are influenced by the texture (balance of sand, silt, and clay) of agricultural soils.

N Mineralization

The two soils represented here, loam and silt loam, differed significantly in beginning N content. Overall means are listed in Table 1 with reference to the total grams of N and carbon (C) found in each soil throughout the experiment. Despite the marked

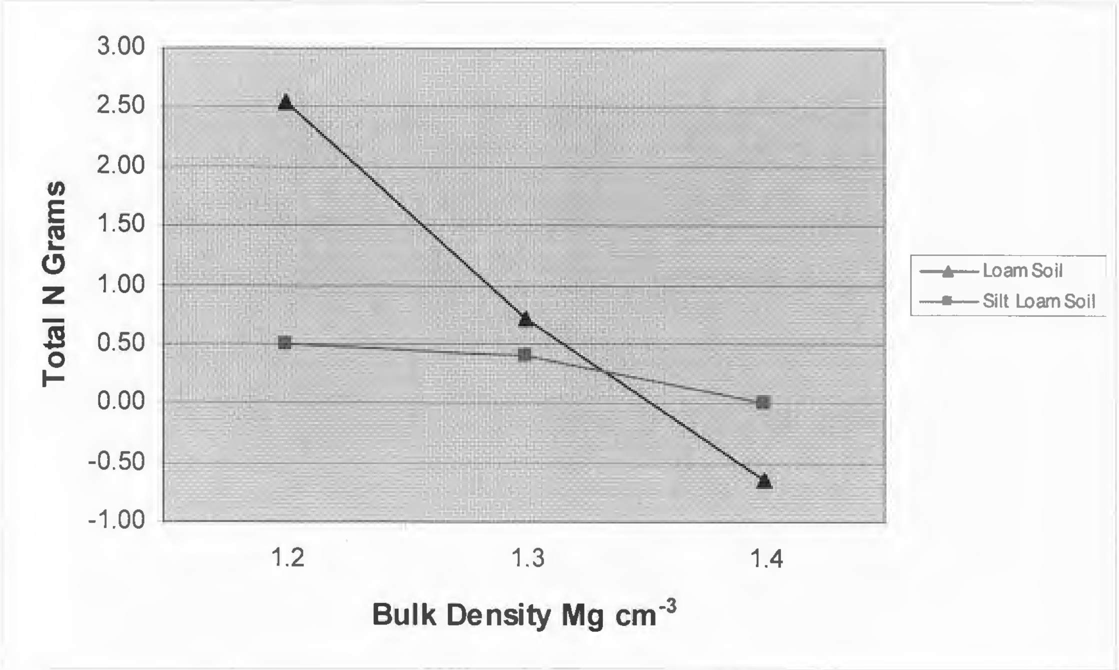

Figure 1 Correlation between increasing bulk density and the average N Balance of the two soil types Loam Soil and Silt Loam Soil.

difference in beginning soil N levels, average N balance for each soil was not significantly different at 1.01 g in the loam soil and 0.30 g in the silt loam soil. This added N was probably due to N mineralization. In a study examining N mineralization in several agricultural soils differing in N and C content, Sano et al. (2006) found that in soils where ample organic N was available low C content restricted the N mineralization rate. In contrast, soils with limited amounts of organic N were not restricted in N mineralization by C content but by the amount of available organic N. Minimal differences may also be due to soil moisture content. De Neve and Hofman (2000) reported that N mineralization rates are optimal at a soil moisture content of 75% of field capacity (FC). Soil moisture content was not quantified in this study and may not have been in the optimal range, but was maintained at or below FC. The results for N and C

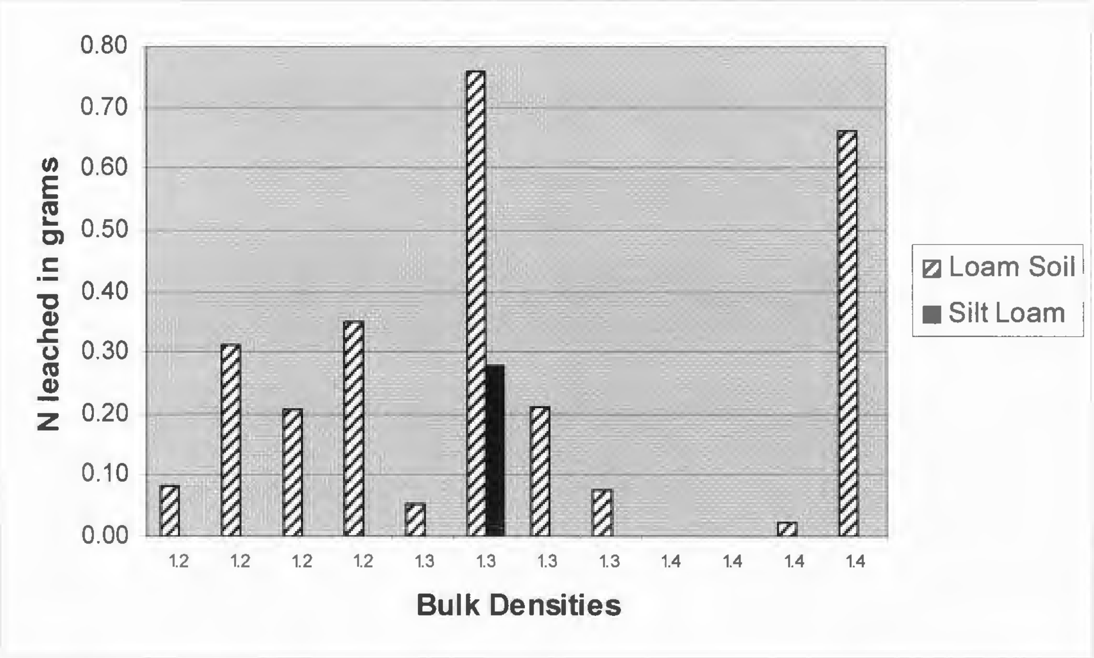

Figure 2 Total N leached from all soil cores based on bulk density and soil type.

reported in Table 1 suggest mineralization may have been limited in the silt loam soil by available N.

Ammonia Volatilization

Ammonia volatilization losses amounting to 71% of total N application in cattle slurry have been reported (Thompson and Meisinger, 2004). For this reason, it was surprising to find a positive N balance in our study after the application of cattle urine. This study did not include the quantitative measurement of NH_3 losses, but in ammonia volatilization was probably limited. Ammonia volatilization has shown a highly positive correlation to temperature, crop residue, and sand content (Thompson and Meisinger, 2004; Whitehead and Raistrick, 1993). Laboratory temperatures were comparatively moderate at 65-70° F, crop residue was minimal, and sand content in both soils was relatively low. Additionally, as represented in Figure 2, the loam soil experienced greater

Table 3 Total N balance in grams based on 3 soil bulk densities in Mg cm^{-3}

	Bulk Density Mg cm^{-3}			
Soil Type	1.2	1.3	1.4	Average N
		Total N g		
Loam	2.54	0.71	-.064	**1.01**
Silt Loam	0.49	0.40	0.01	**0.30**
	1.52	**0.56**	**-0.26**	

leachate losses. Some urine may have leached between the PVC side wall and the soil because of the difficulty in obtaining intact cores from this soil. Such losses would minimize contact with the soil which would inhibit the transformation of the NH_4 present in the urine to NH_3.

Denitrification

High correlations have been reported between denitrification N loss as NOX and soil compaction (Abbasi and Adams, 1998; Bolan et al., 2004; Torbert and Wood, 1992). The data represented in Figure 1 as well as the data in Table 2 appear to be consistent with this research. Average soil N balance for bulk density levels of 1.2, 1.3, and 1.4 were 2.54, 0.71, and -0.64 respectively for the loam soil and 0.49, 0.40, and 0.01 for the silt loam soil. Because no quantitative data were obtained through this study in relation to either ammonia volatilization or denitrification it is difficult to determine where the losses occurred.

It was mentioned earlier that the difference in ending N balance between the two soils may have been due to differences in ammonia volatilization. It is also possible that the differences occurred in denitrification rates. Studies have shown that organic carbon concentration has a positive correlation with denitrification rate (Beck and Christiansen, 1987; D'Haene et al., 2003; Robertson et al., 1987). This may be another reason for the difference in ending N balance between the two soils.

Although denitrification losses in the two soils appears minimal, similar findings were experienced by Luo et al. (2000). According to previous research findings denitrification begins at a water filled pore space of 60% and increases with increasing soil moisture content (D'Haene et al., 2003; Torbert and Wood, 1992). Minimal losses may be due again to the soil moisture content. Soil moisture content was assumed to be at 100% FC but no quantitative methods were performed to ensure this parameter. Soil temperature could also have had a negative effect on the denitrification rate as room temperature in this study was maintained at 65-70 degrees F.

Conclusion

A positive correlation was observed between increasing bulk density and change in N balance. Interaction of N balance with bulk density was also observed between the two soil types. The specific causes of these correlations and interactions, however, are outside the parameters of this study. Differing ending N balances between soils may have been due to the interacting processes of N mineralization, denitrification, nitrification, and ammonia volatilization, which are all subject to soil properties such as pH, cation exchange capacity, texture, water filled pore space, carbon content, native N content and cattle urine properties. Further research should be performed in order to quantify the trends represented by the data in this study.

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