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IMPACTS OF MANURE APPLICATION ON SOIL QUALITY, RUSLE EROSION ESTIMATES AND C FACTORS

The topics covered in this Technical Note include: liquid manure considerations including conservation compliance options, dry manure impacts on RUSLE C factor, long term effects of manure application on soil quality.

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I. LIQUID MANURE CONSIDERATIONS

A) C Factor Impacts

Applying solid manure on the surface can have a positive effect on the C factor in the Revised Universal Soil Loss Equation, because of the addition of organic material and ground cover provided. Long term manure application may have a beneficial effect on soil quality because of the potential to increase soil organic matter and permeability.

Because of a low total solids content (typically 0.1 to 5 percent), a large amount of liquid manure would need to be applied to add a significant amount of organic material. Liquid manure is normally injected more than 4" below the surface (RUSLE C factor is not impacted by organic material below 4 inches). Because of these factors it is doubtful that there would be a significant effect on C (refer to Example 1.1). Because of the potential soil compaction and sealing effect liquid manure application can have, there may actually be a negative impact on soil quality.

Example 1.1: Liquid manure injected from a lagoon (unagitated) needed to achieve 3 tons of dry matter/acre

0.25% total solids = 0.0025 lbs dry matter/lb of Lagoon Water (LW)

6000 lbs dry matter/.0025 lbs/lb of LW = 2,400,000 lbs of LW ≅ 10.59 acre-inches/ac (large leaching & runoff potential)

2,400,000 lbs-LW/8.3453 lbs/gal =287,587 gallons

N content = 2.91 lbs/1000 gal x 287,587 gals = 837 lbs-N/Acre x 0.4 = 335 lbs of available N first year

P content = 0.63 lbs/1000 gal x 287,587 gals = 181 pounds of P/Acre x 0.75 = 136 lbs of available P 1st year

Crop needs based on the Ag Waste Management Field Handbook (AWMFH) for 125 bushel corn crop are 113 lb N/ac and 19.6 lb P/ac. Applying at agronomic rates for N, a producer would apply 2024 lbs of dry matter/ac (approximately .077 % addition of organic material in the top 8" of soil).

B) Conservation Compliance Options (Systems) to Consider When Applying Liquid Manure on Soybean Stubble (Corn-Soybean Rotation on Sloping Fields) are as Follows:

Options:

1. Surface apply on corn stalks then incorporate leaving adequate residue.
2. No-till soybeans into corn stalks after liquid manure has been applied in the fall or early spring. Because of the high carbon to nitrogen (C:N) ratio (90:1) of corn stalks versus manure (9-25:1), the stalks will tie up (immobilize) much of the available N, including ammonia. Manure will increase the mineralization rate of the corn residue and make it easier to manage the residue. More N will be available for the next years corn crop because of slower mineralization and immobilization of N (Refer to table 1 for normal manure decay constants). Example - 125 BUSHELS X 56 lb/BU = 7000 lb of corn residue with a 90:1 C:N ratio and 2024 pounds (N rate) of dry basis manure with a 16:1 C:N ratio, would have an average C:N ratio of 45:1 (Assuming that the C:N ratio of manure and residue behaves as if it was mixed). This ratio would still require a significant amount of mineralization before a net release of N would occur.
3. Inject manure with narrow knifes set at wide spacings. This would be similar to the disturbance that would occur when applying anhydrous ammonia with narrow knifes and coulters. If the manure application is on the contour, erosion in the injection slots would be minimized, and if the application is far enough ahead of corn planting, corn can be successfully no-till planted.
4. Apply liquid manure on flatter slopes (B-slope or less on soil survey). Erosion would not be as much of a problem and manure could be incorporated.
5. Add erosion control measures such as terraces, or contour buffer strips, to minimize erosion from incorporation of manure.
6. Add additional years of corn to the rotation. This would allow for additional years of incorporating manure following corn harvest. In the past this was not always feasible because of farm programs. The current farm program will allow producers to plant any crop they desire as long as erosion is controlled to Alternative Conservation System levels.
7. Separate liquids and apply solids separately to lower C factor (very expensive).

Erosion rates for Nora silt loam soils 10%, 200 ft L, in Stanton County (Norfolk climate station) where liquid manure is applied using various management strategies to meet conservation compliance requirements

Conservation compliance allows for the use of Alternative Conservation Systems (ACS's). In Nebraska ACS's for water erosion allows for a RUSLE 'CP' equivalent (RUSLE C x P) to continuous dryland corn using a spring mulch till system up and down hill that leaves 45% cover after planting. This equates to a 'CP' level of 0.13 for compliance planning in Northeast Nebraska. The following are erosion rates and 'CP' levels for option 2-6 which include soybeans in the rotation:

*Option erosion rates:

2. Corn-Soybean rotation, incorporate liquid manure in the fall into corn stalks, drill soybeans leaving 20% cover after planting (C = .13), no-till corn into soybean stubble leaving 40% cover (C = .11). Average C = .12. Erosion Rate = 130x.30x1.98x.12x1.0 (RKLSCP) = 9.3 tons/ac/yr
3. Corn-Soybean rotation, inject liquid manure on the contour into soybean stubble, no-till corn into soybean stubble leaving 30% cover after planting (C = .14), inject liquid manure the incorporate in the fall into corn stalks leaving 30% cover after drilling soybeans (C = .11). Average C = .125. Erosion rate = 130x.30x1.98x.125x1.0=9.6 tons/ac/yr.
4. Corn-Soybean rotation with contour buffer strips (20' grass/80' crop/contouring) (P = .48), incorporate liquid manure in the fall into corn stalks leaving 20% cover after drilling soybeans (C = .13), incorporate manure in soybean residue in the spring leaving 10% cover after planting corn (C = .32). Average C = .225, CP = .225x.48 = .108. Erosion rate =,130x.30x1.98x.225x.48=8.3tons/ac/yr.
5. Corn-Soybean rotation with terraces spaced 120' apart with closed outlets and contouring (LS = 1.51 & P = .37). Same tillage system as previous system. CP = .225 x .37 = .08. Erosion rate = 130x.30x1.51x.225x.37=4.9 tons/ac/yr.
6. Corn-Corn-Soybean rotation, incorporate liquid manure in the fall into corn stalks, when planting corn and drill soybeans into corn stalks leaving 30% cover after planting (C = .17 & .11), no-till corn into soybean stubble leaving 40% cover after planting (C = .10) Average C = .13. Erosion rate = 130x.30x1.98x.13x1.0=10 tons/ac/yr.

*Since liquid manure applied at agronomic rates adds a small amount of organic material, is often injected below 3 inches (Example 1.1), and is very small material which provides little protection from rain drop impact there is little or no effect on C.

II. EFFECT ON RUSLE C FACTOR FROM SURFACE APPLICATION OF DRY MANURE

The following aspects were used for when developing decomposition coefficients for dry manure:

The C factor is affected by addition of organic material to soil. The benefit is two-fold, it can provide surface cover and incorporated organic material bonds the soil and reduces runoff. The total amount of organic material added, and decomposition rate above and up to 4 inches below the surface impacts C. For example wheat straw will decompose much slower than soybean stubble, therefore provides more erosion control. Organic material that breaks down slowly will provide more protection from erosion throughout the year.

To determine the impact manure has on C, decomposition coefficients need to be considered. Decomposition coefficients are derived from the rate of decay (mineralization rates), and residue/manure characteristics (Tables 1 & 2). RUSLE considers both surface and subsurface decomposition rates. The nature of decay of organic material is complex and dependent on many variables. To develop decomposition coefficients for manure, decomposition rates of various types of manure and crop residues were compared.

Analyzing the data from Table 1 several conclusions can be drawn and several cautions should be noted:

- Manure with a low carbon to nitrogen ratio such as poultry and swine manure from a pit decompose much faster than high C:N ratio manure.
- Manure that has already been treated or decomposed in a feedlot will decompose slower because organic material that decomposes easily has already decomposed or digested.
- Manure that has more lignin because of animal diet will break down slower.
- Manure will break down much slower the second and subsequent years, until a point when it will decomposes at a rate similar to soil organic matter
- Subsequent years of applying manure or any other organic material will slow mineralization of manure applied in prior years. This is because competition for easily degradable carbon increases the need for oxygen and along with other factors slows the decomposition process.
- Tillage systems, amount of manure, and manure type will have a major impact on the rate of decomposition.
- Soil factors especially texture, moisture, and organic matter content will impact the rate of mineralization.
- Significant amounts of heavy metals such as Cadmium can slow mineralization rates.
- Climates that are warm and moist will increase the decomposition rates.
- In general decomposition is greater in soils with high residual N.
- Livestock classes have different diets and digest materials in different manners.

Decay constants from various manure sources (Pratt/Willrich/AWMFH) are as follows:

***TABLE 1 DECAY CONSTANTS FOR VARIOUS MANURE TYPES (Pratt/Willrich/AWMFH)**

Manure Source	N Content	Decay Constant	
		Year 1	Year 2
Poultry (hens) 1/	4.5%	.90	.19
Poultry (broilers & turkeys) 2/	3.8%	.75	.05
Swine(PIT) 2/	2.8	.90	.04
Dairy, fresh 2/	3.5	.50	.15
Dairy, anaerobic (liquid) 2/	2.0	.30	.08
Beef feeders, fresh 1/	3.5%	.75	.15
Beef feeders, dry corral 1/	2.5	.40	.25
	1.5	.35	.15
	1.0	.20	.10
Fresh poultry manure /3		.90	.02
Fresh swine or cattle manure /3		.75	.04
Swine or cattle manure in covered storage /3		.65	.05
Cattle Manure w/bedding /3		.60	.06
Manure open lot (cool-humid) /3		.50	.05
Manure open lot (warm-arid) /3		.45	.05

*Decay constants are based on mineralization rates of total N, the numbers represent the % of total N available to the crop the first and second year. Mineralization rates of N are similar to decomposition rates of organic carbon.

1/ Pratt et al.(California)
2/ Willrich et al. (Pacific Northwest)
3/ NRCS AWMFH (Table 11-9)

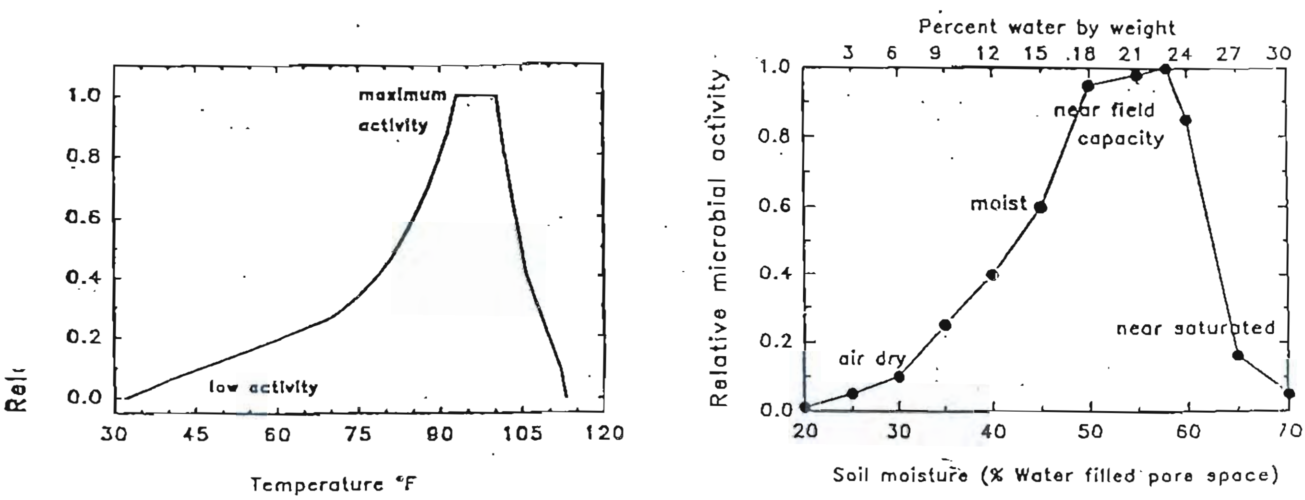
***TABLE 2 CROP RESIDUE DECOMPOSITION BASED ON RUSLE (NO TILLAGE)**

Material	Decomposition Coefficient	Location	Decomposition after 1 yr	Corn Equivalent 1/
Corn residue	0.016	Lincoln	.88	1.0
Corn residue	0.016	Scottsbluff	.71	1.0
Wheat residue	0.008	Lincoln	.66	1.34
Wheat residue	0.008	Scottsbluff	.46	1.54
Soybean residue	0.025	Lincoln	.97	.92
Soybean residue	0.025	Scottsbluff	.86	.83
Alfalfa residue	0.02	Lincoln	.93	.95
Alfalfa residue	0.02	Scottsbluff	.79	.90
Vegetable (tomato) residue	0.03	Lincoln	.98	.90
Vegetable (tomato)	0.03	Scottsbluff	.90	.79
Straw/newspaper surface applied (slow)	0.008	Lincoln	.66	1.34
Straw/newspaper surfaced applied (slow)	0.008	Scottsbluff	.46	1.54
Manure surface applied (mod-slow)	0.017	Lincoln	.90	.98
Manure surface applied (mod-slow)	0.017	Scottsbluff	.73	.97
Manure, surface applied (moderate)	0.03	Lincoln	.98	.909
Manure, surface applied (moderate)	.03	Scottsbluff	.90	.79
Manure, surface applied (fast)	0.048	Lincoln	1.00	.89
Manure, surface applied (fast)	0.048	Scottsbluff	.98	.91

*(Developed using RUSLE database with no operations)

1/ Relative value to 1 pound of corn residue

The three major factors affecting the decomposition of organic material are: 1) soil moisture, 2) temperature, and 3) carbon to nitrogen ratio. The amount of organic material added from manure also needs to be known. An estimate can be made using the NRCS Ag Waste Management Field Handbook. Organic materials decay the fastest when soils at or near field capacity, and soil temperatures near 90 degrees. (refer to Figures 1 and 2 -ARS/NRCS, Akron CO).



1. Relative soil microbial activity as affected by soil temperature and soil moisture (water filled pore spac

Manure with a low N content is likely to have a high carbon to nitrogen ratio. Manure with a high C:N ratio will cause rapid immobilization of mineralized N by micro-organisms in the early part of the growing season. There are several equations to estimate N mineralization based on the N content of a manure. Most research indicates that animal manure has an equivalent amount of N and carbon mineralized. Because of this, the mineralization rate for N can be used to estimate the amount of organic carbon decomposed. This information can be used to develop decomposition coefficients for various types of manure for use in development of C factors.

RUSLE deomposition coefficients are important because they predict how long the organic material will be present on both the surface and subsurface (up to 4 inch depth). The more resistant the material is to breakdown the more protection there is against sheet and rill erosion. Considerations that are taken into account by RUSLE include: % moisture, C:N ratio, material size, decomposition rate, lignin and straw content, and other factors.

Dry manure has a larger surface area for microbes to work on than crop residue, but may be more resistant to breakdown (Tables 1, 2) because it has been digested in livestock. This is especially true for cattle manure. Even though some manure may break down slower than crop residue it is not as effective against water erosion. It is much smaller than residue and doesn't protect soil against the impact of raindrops as well. However, it will bond soil together better than residue that hasn't decomposed. Based on this reasoning surface applied dry manure types were grouped in three coefficient categories and assigned relative values of fast-.048, moderate-.03, and slow-.017. Manure in the .03 category is considered to be similar to vegetable residue, and the .017 category similar to forages/cover crop residue (Table 3).

TABLE 3 RUSLE DECAY COEFFICIENTS

Crop/Manure Type	%solids (manure only)	C:N Ratio	Decomposition Coefficient	Decompos. Category
Small Grain Cover Crop (killed)			017	
Forages (brome/alfalfa)			.017	
Corn		80-90:1.	016	
Wheat			.008	
Soybeans			.025	
Vegetables			.030	
Poultry Litter	60%	9:1	.048	Fast
Compost	60%	6-8:1	.048	Fast
Swine/Beef/Dairy settling basin	10-13%	10:1	.030	Moderate
Swine with bedding	50-60%	10-15:1	.017	Mod. Slow
Beef Feedlot	55%	13:1	.017	Mod. Slow
Dairy Loafing Barn	50-60%	10-14:1	.017	Mod. Slow
Newspaper/Straw			.008	Slow

C FACTOR CALCULATIONS: To compute C, planting tillage and harvest dates, total residue, type of residue, crop canopy development, residue and manure above and below the soil surface, decomposition rates of residue and manure above and below the soil surface (3 inches or less), final canopy cover, root mass, erosive energy, timing of events and other factors discussed below were considered. Tables 4A, 4B, and 4C show an example calculation used to develop C factor in Nebraskas FOTG.

TABLE 4A, 4B, & 4C EXAMPLE C FACTOR CALCULATION (fast-.048 (poultry litter)):
The following calculations are an example of the operations used and other inputs from a C factor calculation. The example shown below is based on applying 5 tons of (dry basis) poultry litter using a decomposition coefficient of .048.

TABLE 4A

Crop	start date	end date	%EI	C factor
125 bu corn, 120 day, 30" rows	10/11/90	10/21/91	101.0	.176
35 bu soybeans, 30" rows	10/21/91	10/11/92	99.0	.138
		Rotation C factor		.157

TABLE 4B

Year 1 corn into soybeans (calculations)					
operation	% cover after oper	oper. date	date next oper	soil loss ratio	%EI
no operation	73%	10/11/90	4/20/91	.077	6.5
anhydrous appl	31%	4/20/91	5/5/91	.241	3.3
planter dbl dsk op	27%	5/5/91	6/5/91	.292	13.1
cultivate	11%	6/5/91	10/20/91	.162	78.0
harvest	93%	10/20/91	10/21/91	.020	0.1
		Crop C Factor	**=**	**0.176**	

TABLE 4C

Year 2 soybeans into corn & applying 5 dry tons of poultry litter (calculations)					
operation	% cover after oper	oper. date	date next oper	soil loss ratio	%EI
no operation	93%	10/21/91	11/10/91	.020	1.3
manure surface apply 5 tons	99%	11/10/91	11/20/91	.017	0.4
disk harrow-tandem	73%	11/20/91	11/30/91	0.0	0.0
subsoiler	59%	11/30/91	5/5/92	.042	7.1
disk harrow-tandem	28%	5/5/92	5/15/92	.013	2.7
planter dbl dsk op	24%	5/15/92	6/15/92	.215	18.5
cultivator	16	6/15/92	10/10/92	.131	69
harvest	74	10/10/92	10/11/92	.052	0.1
		Crop C factor	**=**	**.138**	

TABLE 5 CLIMATE INFO & EROSIVE ENERGY THAT OCCURS IN NORFOLK NEBRASKA

Month	Mean P inches	Average Temp °F	15 Day %EI Curve		
January	0.52	19.0	0.00	0.00	R Factor 125
February	0.77	24.4	0.00	0.00	
March	1.86	35.7	1.0	1.0	10 year EI: 80
April	2.29	49.7	2.0	3.0	
May	3.68	60.9	6.0	10.0	elevation: 1551
June	4.46	70.3	17.0	29.0	
July	3.22	75.4	43.0	55.0	freeze-free: 156
August	2.55	72.6	67.0	77.0	days/yr
September	2.45	63.1	85.0	91.0	
October	1.60	51.4	96.0	98.0	
November	1.01	36.2	99.0	100.0	
December	.074	22.8	100.0	100.0	

- Other considerations that would have a positive impact on RUSLE C factor:
- delay tillage as long as possible
- use tillage implements that leave as much ground cover as possible
- don't incorporate manure (in contrast to nutrient mgt. goals)
- time manure and tillage events when erosive rains are less likely to occur or minimize the time of the year that soil is bare.

III. IMPACTS ON SOIL FROM MANURE APPLICATION

Application of livestock manure can have many positive factors on soils such as:

- Increase or stabilize soil organic matter content
- Increase infiltration due to increased organic matter
- Increased microbial activity
- Increase or stabilize soil pH on low pH soils
- Improve soil tilth
- Replace the need for inorganic fertilizers including micro-nutrients
- Increased crop yields
- Reduce bulk density

Some of the negative impacts that can occur are as follows:

- Increased soil erosion when incorporating manure
- Compaction of soils
- Increased runoff due to compaction and sealing soils
- Excessive salt and nutrient levels
- Decrease soil tilth
- Decreased production
- Increase pH on high pH soils

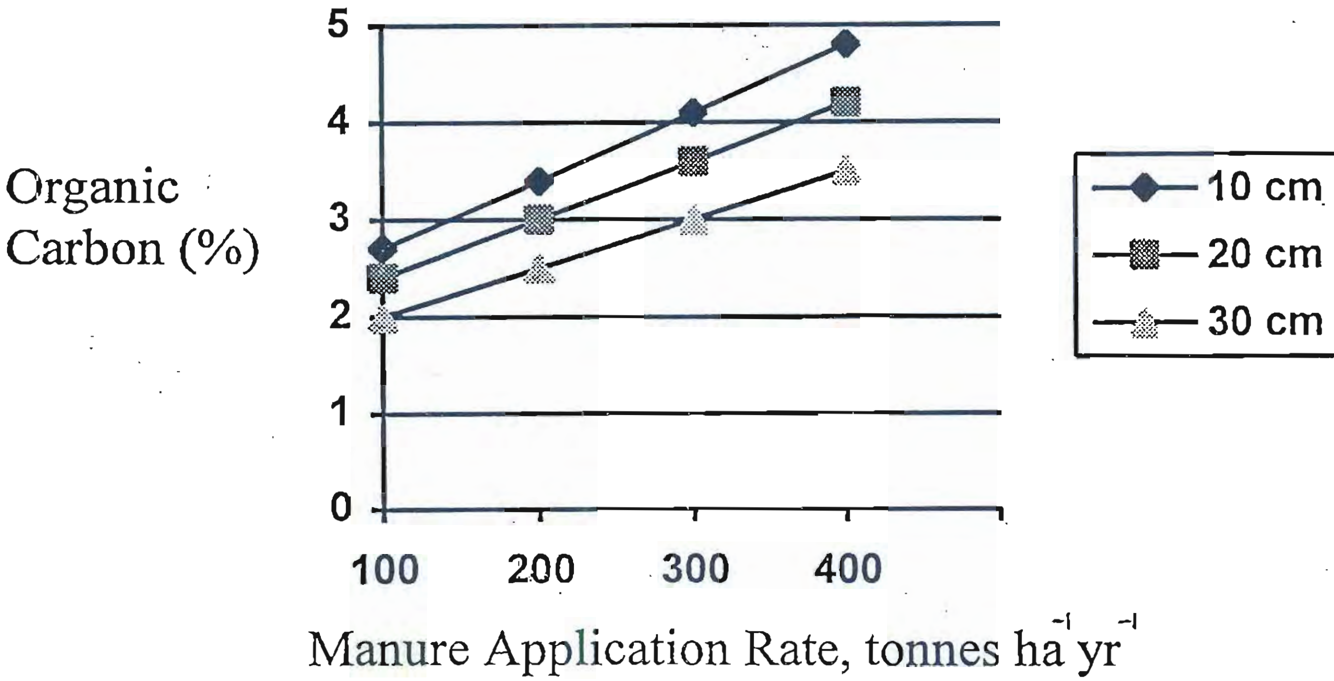
A) Long-Term Beneficial Effects of Manure Application to Soil
(Provided by Dr. Dennis Schulte Professor of Biological Systems Engineering University of Nebraska Lincoln)

1. Increase aggregate stability of soil
2. Reduce bulk density of soil
3. Increase infiltration rate of soil:
   Feedlot Manure (Nebraska) 3-yr study

Non-Manured	1.6 cm/hr (.63 inches/hr)
Manured*	13.0 cm/hr (5.12 inches/hr)

   * 360 tonnes/ha/yr (160.7 tons/ac) (far exceeds agronomic rates)
4. Increase organic matter content of soil (Refer to Figure 3)

Figure 3



In Manitoba (Red River Valley, 4-yr study)
6.9%→7.3% SOM.
In Missouri (a 50-yr study)

5.5 tonnes/ha/yr	1370 kg N*
None	895 kg N*

* in top 18 cm of soil, continuous corn

5. Increase or maintain yield
   In Manitoba (41-year study, Red River Valley) showed a 10-15% yield increase over fertilized and non-fertilized treatments

In England (98-year study)	Yields
Manure (31 tonne/ha)	520 kg/ha
Fertilizer*	560 kg/ha
None	210 kg/ha

   * 101, 78, 112 kg N, P_2O_5 and K_20 per ha
6. Decrease susceptibility to wind and water erosion (water erosion discussed in this paper)

B) Soil Quality Impacts

Soil Organic Matter (organic fraction of soil consists primarily of organic carbon)
SOM is affected by tillage, soil moisture, climate, soil organic matter, soil texture and other physical characteristics of a soil. The impact on soil organic matter from manure application would be more of a long term impact and probably would not impact soil organic matter in the short term (refer to Figure 3). The top eight inches of soil over one acre weighs approximately 2.6 million pounds. In order to add 1% SOM, 26,000 pounds of humus (organic matter) per acre would need to be accumulated.

Cropping systems that include low residue crops i.e. soybeans, sugar beets, sunflowers, corn silage make it easier to impact organic matter content with manure. The type of tillage system will also have a major impact on the mineralization rate of manure and crop residues. Conventional tillage systems with manure applied, aerate the soil and will mineralize organic materials faster than no-till systems. The impact of cropping systems and tillage systems will have a significant impact on SOM and must be factored in when considering the impact that manure will have on SOM.

In most cases the amount of dry material added will not be significant when manure application is based on P. For example; 36500 animal units (one hundred 1000 pound steers for one year) x .094 lbs P/Day x 0.75 = 2573 pounds of available P (first year), and 36500 AU x 6.04 lbs Volatile solids/DAY (AWMFH) = 198560 pounds of volatile solids. The minimum number of acres needed to apply manure on a P basis for 125 bushel corn is 131.3 acres at 19.6 pounds/acre of P. Applying manure at this rate would amount to 1512 pounds VS/acre. This would equate to an addition of 0.06 % of SOM in the top 8", if all of the volatile solids remained as organic matter.

With minimum till and applying dry manure at agronomic rates there could be an increase in SOM, however, it would primarily be in the top 2-3 inches. Even though the SOM content in the top 8 inches may not differ appreciably, additions of dry manure can increase SOM in the top 2-3 inches which will decrease crusting, increase water infiltration, reduce bulk density and reduce erosion. The extent that this will occur is variable and will change with erosion, application rates, tillage systems, cropping systems, other management practices, moisture, climate, and other factors. If dry manure is added above agronomic rates, SOM in soils not eroding above "T" would increase (refer to Figure 3). This has been documented in many fields where organic matter is as high as 5% SOM in the top 8", where manure has been applied in excess of agronomic rates, while the same soils without manure application are 2-3% SOM (Various producer soil tests in Northeast Nebraska)

A soil conditioning index procedure currently under development by NRCS, that uses research from Renner Texas, is being used to predict the effects of crop selection, yield, tillage, and erosion rates on the maintenance of SOM. Using RUSLE to extrapolate climatic effects, it would take about <u>2099 pounds</u> of corn equivalent residue in Lincoln and <u>1685 pounds</u> in Scottsbluff without tillage or erosion to maintain SOM at current levels. Adjustments to residue amounts that are needed to maintain SOM would have to be made for soil moisture, current SOM, and tillage effects.

Permeability (Ability of Soils to transmit water)
Any management that significantly increases organic matter will improve permeability and increase water holding capacity (refer to figure 3 and long term benefits section). Some of this could be due to increased microbial activity or increased earthworm numbers. The most important part of permeability is that the surface of the soil have the ability to intake rainfall. Additions of manure or residues can also decrease the potential for crusting or sealing of the soil surface. If manure is applied when fields are subject to compaction, the soil could seal and become less permeable. Additions of excessive amounts of salts (especially sodium) from waste can lead to unfavorable chemistry for water penetration (lower permeability) depending on the salinity and sodium absorption ratio of the soil.

REFERENCES

- NRCS Agricultural Waste Management Field Handbook (AWMFH)
- Animal Waste Utilization on Cropland & Pastureland-a manual for evaluating agronomic and environmental effects (USDA Utilization Research Report No. 6)
- RUSLE Handbook/RUSLE Software AH-703
- USDA Ag Handbook 537
- Conservation Tillage Fact Sheet #3-95 USDA ARS (Akron CO), USDA NRCS
- Long Term Beneficial Effects of Applying Manure provided by Dr. Dennis Schulte University of Nebr