Bulk Density Comparison within a Crop Rotation in Western North Dakota

Lauren Pfenning[1] Eric Brevik[1] Sethuram Soman[1], Songul Senturklu[2], and D.G. Landblom[2]

[1]Dickinson State University, Department of Agriculture and Technical Studies
[2]Dickinson Research Extension Center

PROJECT BRIEF

Bulk density (BD) is a soil factor that affects plants and limits root growth. BD is influenced by; organic matter content, porosity, and soil structure. Root growth limiting bulk density values by soil texture are shown in *Table 1* and soil bulk density values for fields and native range are shown in *Tables 2 and 3*. This study was designed to determine how BD, within a no-till crop rotation (spring wheat, winter triticale-hairy vetch/cover crop, corn, pea-barley, sunflower) differed between a continuous spring wheat control and native range. The BD evaluation is part of a long-term integrated cropping and beef cattle research project supported by a USDA/Sustainable Agriculture Research and Education grant being conducted at the Dickinson Research Extension Center Ranch Headquarters located southwest of Manning, North Dakota.

PROCEDURE

Each field is replicated three times for statistical analysis. Soil sample locations within each field were located using GPS (Garmin handheld device). Six soil samples from each field were collected. Three were collected at 0-4 inches and the other three were collected at 7-11 inches using a slide hammer soil collection core sampler. The core sampler is a metal sliding hammer with a cylinder attached to the bottom. The cylinder has a second cylinder inside with a volume of 427 cm^3. After removing soil surface debris, the sampler is set on the ground with the cylinder down and the sliding hammer pointed up. The sliding hammer was used to pound the cylinder into the ground to collect the BD sample (Fig. 1). Once the cylinder was out, the main cylinder was unscrewed from the sliding hammer and the second cylinder came out. To get accurate measurements, the soil had to be leveled off on both ends of the cylinder and then the soil was put into a marked bag with the field name, date and depth. At the Dickinson State University, the soil samples were transferred to beakers, weighed, and dried in a drying oven at 105º C for 24 hours and reweighed. The weights were recorded in an Excel spreadsheet and BD calculated according to the formula: g/cm^3=dry soil weight (g)/soil volume (cm^3).

Fig. 1: Slide Hammer Sampler

Fig. 2: View of how corn roots are starting to penetrate through the soil

Soil texture was determined for each soil sample collected. The results of the soil texture test are shown in *Tables 2 and 3*, and were compared to *Table 1* to conclude any root limitations with in the crop fields and the native range. The method that was used to determine soil texture was based on Brady and Weil (2008) and Dr. Brevik's soil lab handout, a sample from each individual soil was moistened to form a ball of soil. After a ball of soil was formed, then the ball is squeezed between the thumb and forefinger to make a ribbon until it breaks from its own weight (Fig. 4). The texture by feel was determined as follows:

1. Soil will not stick in a ball- **sand**
2. Soil forms a ball but will not form a ribbon- **loamy sand**
3. Ribbon is dull, breaks off when less than 2.5 cm long, and:
    a. Grinding noise is prominent, feels gritty- **sandy loam**
    b. No grinding noise, smooth floury feel- **silt loam**
    c. Minor grinding noise, slightly gritty- **loam**
4. Soil forms a ribbon 2.5 to 5 cm long and:
    a. Grinding noise is prominent, feels gritty- **sandy clay loam**
    b. No grinding noise, smooth floury feel- **silty clay loam**
    c. Minor grinding noise, slightly gritty- **clay loam**
5. Soil shows significant stickiness and firmness, forms shiny ribbon longer than 5 cm and:
    a. Grinding noise is prominent, feels gritty- **sandy clay**
    b. No grinding noise, smooth floury feel- **silty clay**
    c. Minor grinding noise, slightly gritty- **clay**

Fig. 3: Soil texture classes based on % sand, silt and clay

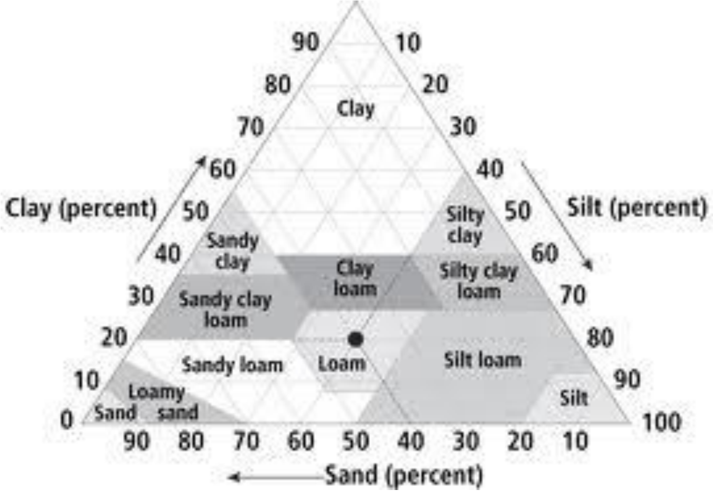
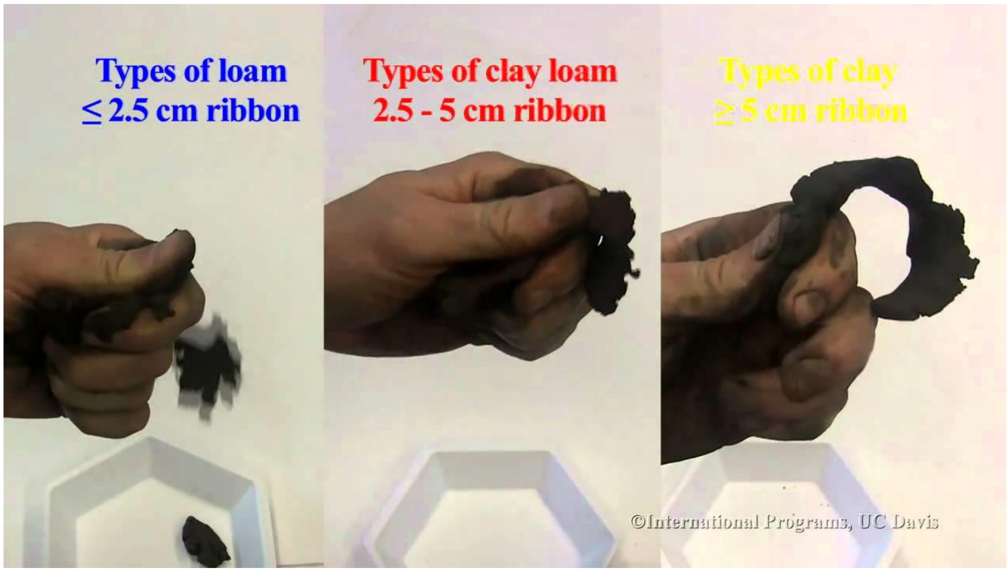


Fig. 4: Forming and ribbon and how to determine texture class from length of ribbon



©International Programs, UC Davis

The statistical analysis of variance (ANOVA) was used to compare the means between the bulk densities of the different crop fields and to determine whether any of those means are significantly different from each other. If the variability between groups is large relative to the variability within groups, then the means of the populations from which the data were drawn are significantly different. When the results are significantly different, it indicates at least one group differs from the other groups. The Tukey test was used to get pairwise comparisons between the means.

RESULTS

The BD study evaluated 3 continuous spring wheat control fields, 15 crop rotation fields, and 3 native range study sites. Bulk density means for native range, spring wheat (Control), spring wheat (Rotation), triticale-hairy vetch/cover crop, pea-barley, corn, and sunflower are shown in *Table 4*. Statistical contrasts are shown in *Table 5* and crop yields are shown in *Table 6*. The results indicated that there was no bulk density difference between the continuously cropped spring wheat control and the other crops grown in the rotation ($P>0.10$). However, when native range was compared to the control and rotation crops, the BD value of native range was significantly less ($P<0.001$) except for corn. The BD for corn in rotation, which was preceded by cover crops [winter triticale-hairy vetch (harvested for hay) and a 7-way cover crop] was not significantly different from native range ($P = 0.178$). The study shows that BD change is slow, but that change is beginning, as evidenced by the comparison between corn and native range.

SUMMARY AND CONCLUSIONS

The foundation research project is a long-term (10 year) investigation to determine the impact on soil quality, among other things, and how the crop rotation used in the study, along with no-till farming and grazing, are collectively improving crop yields while inputs are being reduced. Bulk density is one soil measurement that can be used to measure a soil's potential to limit root growth and penetration and is influenced by organic matter content, porosity, and soil structure. Based on our data, we conclude that the combination of no-till, crop rotation, cover crops, and cattle grazing are collectively resulting in soil quality improvement. The BD measured was not different when the spring wheat control was compared to the rotation crops, but when the rotation crops were compared to native range, corn was not different and pea-barley also tended to not be different. Earth worms are commonly found in healthy soils and contribute to healthy soils. We found earth worms in many of the soils as BD samples were collected and a few of the samples contained earth worms. We conclude that the cropping and grazing methods employed in the study are working and that we expect that BD will continue to decline becoming more like native range over time. How long this will take is unknown, but since change in soil characteristics occur slowly over time we would expect this to be many years.

IMPLICATIONS

Tillage has been proven to cause compaction and in return decreases soil aggregates, organic matter, decrease in oxygen and nitrogen. These problems result in loss of earth worms, microorganisms, and other biota that create pores in the soil and replenish the soil with the things that plants need to grow. Farming practices that inhibit biological activity in the soil contribute to declining soil quality and associated BD increase. Collectively, the practices to include no-till farming, crop rotation with the four adapted crop types (cool season grass – wheat, cool season broadleaf – pea, warm season grass – corn, and warm season broadleaf – sunflower), multi-species cover crop, and beef cattle grazing are supporting improvement in soil quality as evidenced by soil BD decline in corn and to some extent pea-barley fields compared to native range. These practices are expected to provide support for further decline in BD over time.

ACKNOWLEDGEMENTS

Partial funding for this project was provided by the North Dakota State University, Agriculture Experiment Station, and a USDA/NIFA/Sustainable Agriculture Research and Education grant LNC11-335; and the Dickinson Research Extension Center.

Table 1. Root growth limiting bulk density values by soil texture.

Soil Texture	Root-Limiting Bulk Density (g/cc)
Sand	1.8 G/Cc
Fine Sand	1.75
Sandy Loam	1.7
Fine Sandy Loam	1.65
Loam	1.55
Silt Loam	1.45
Clay Loam	1.5
Clay	1.4

From Tree Root Growth Control Series: Soil Constraints on Root Growth, Kim D. Coder, University of Georgia, 1998, FOR98-10.

Table 2. Fields, soil texture, bulk density (BD) values taken at 0-4” and 7-11”

Sample #	Soil Texture	BD		Sample #	Soil Texture	BD
1913 S1 0-4"	Silty Clay Loam	1.32		1918 S2 0-4"	Silt Loam	1.5
1913 S1 7-11"	Silty Clay Loam	1.39		1918 S2 7-11"	Silt Loam	1.43
1913 S2 0-4"	Silt Loam	1.42		1918 S3 0-4"	Silty Clay Loam	1.45
1913 S2 7-11"	Silt Loam	1.38		1918 S3 7-11"	Silty Clay Loam	1.47
1913 S3 0-4"	Silty Clay Loam	1.47		1919 S1 0-4"	Silty Clay Loam	1.47
1913 S3 7-11"	Silty Clay Loam	1.39		1919 S1 7-11"	Silty Clay Loam	1.51
1914 S1 0-4"	Silty Clay Loam	1.43		1919 S2 0-4"	Silty Clay Loam	1.46
1914 S1 7-11"	Silty Clay Loam	1.37		1919 S2 7-11"	Silty Clay Loam	1.34
1914 S2 0-4"	Silty Clay Loam	1.62		1919 S3 0-4"	Silty Clay Loam	1.43
1914 S2 7-11"	Silty Clay Loam	1.35		1919 S3 7-11"	Silty Clay Loam	1.31
1914 S3 0-4"	Silty Clay Loam	1.46		1920 S1 0-4"	Silty Clay Loam	1.51
1914 S3 7-11"	Silty Clay Loam	1.45		1920 S1 7-11"	Silty Clay Loam	1.35
1915 S1 0-4"	Silty Clay Loam	1.56		1920 S2 0-4"	N/A	1.45
1915 S1 7-11"	Silty Clay Loam	1.42		1920 S2 7-11"	N/A	1.37
1915 S2 0-4"	Silty Clay Loam	1.47		1920 S3 0-4"	Silty Clay Loam	1.41
1915 S2 7-11"	Silty Clay Loam	1.41		1920 S3 7-11"	Silty Clay Loam	1.44
1915 S3 0-4"	Silty Clay Loam	1.46		1921 S1 0-4"	Silty Clay Loam	1.58
1915 S3 7-11"	Silty Clay Loam	1.33		1921 S1 7-11"	Silty Clay Loam	1.48
1916 S1 0-4"	Silty Clay Loam	1.49		1921 S2 0-4"	Silt Loam	1.56
1916 S1 7-11"	Silty Clay Loam	1.51		1921 S2 7-11"	Silt Loam	1.41
1916 S2 0-4"	Silty Clay Loam	1.49		1921 S3 0-4"	Silty Clay Loam	1.65
1916 S2 7-11"	Silty Clay Loam	1.51		1921 S3 7-11"	Silty Clay Loam	1.69
1916 S3 0-4"	Silty Clay Loam	1.54		1922 S1 0-4"	Silty Clay Loam	1.66
1916 S3 7-11"	Silty Clay Loam	1.44		1922 S1 7-11"	Silty Clay Loam	1.49
1917 S1 0-4"	Silty Clay Loam	1.47		1922 S2 0-4"	Silty Clay Loam	1.63
1917 S1 7-11"	Silty Clay Loam	1.49		1922 S2 7-11"	Silty Clay Loam	1.52
1917 S2 0-4"	Silty Clay Loam	1.4		1922 S3 0-4"	Silty Clay Loam	1.53
1917 S2 7-11"	Silty Clay Loam	1.45		1922 S3 7-11"	Silty Clay Loam	1.45
1917 S3 0-4"	Silty Clay Loam	1.53		1923 S1 0-4"	Silty Clay Loam	1.6
1917 S3 7-11"	Silty Clay Loam	1.47		1923 S1 7-11"	Silty Clay Loam	1.51
1918 S1 0-4"	Silt Loam	1.47		1923 S2 0-4"	Sandy Loam	1.69
1918 S1 7-11"	Silt Loam	1.46		1923 S2 7-11"	Sandy Loam	1.59

Table 3. Fields, soil texture, bulk density (BD) values taken at 0-4” and 7-11” (continued)

Sample #	Soil Texture	BD		Sample #	Soil Texture	BD
1923 S3 0-4"	Silty Clay Loam	1.64		1928 S3 7-11"	Sandy Loam	1.66
1923 S3 7-11"	Silty Clay Loam	1.54		1929 S1 0-4"	Sandy Loam	1.63
1924 S1 0-4"	Sandy Loam	1.73		1929 S1 7-11"	Sandy Loam	1.55
1924 S1 7-11"	Sandy Loam	N/A		1929 S2 0-4"	Sandy Loam	1.6
1924 S2 0-4"	Sandy Loam	1.47		1929 S2 7-11"	Sandy Loam	N/A
1924 S2 7-11"	Sandy Loam	1.5		1929 S3 0-4"	Sandy Loam	1.64
1924 S3 0-4"	Sandy Loam	1.57		1929 S3 7-11"	Sandy Loam	1.54
1924 S3 7-11"	Sandy Loam	1.55		1930 S1 0-4"	Sandy Loam	1.67
1925 S1 0-4"	Sandy Loam	1.63		1930 S1 7-11"	Sandy Loam	1.61
1925 S1 7-11"	Sandy Loam	1.66		1930 S2 0-4"	Sandy Clay Loam	1.66
1925 S2 0-4"	Sandy Loam	1.58		1930 S2 7-11"	Sandy Clay Loam	1.62
1925 S2 7-11"	Sandy Loam	1.47		1930 S3 0-4"	Silt Loam	1.6
1925 S3 0-4"	Silty Clay Loam	1.63		1930 S3 7-11"	Silt Loam	1.53
1925 S3 7-11"	Silty Clay Loam	1.62		67B-21 S1 0-4"	Sandy Loam	1.14
1926 S1 0-4"	Silty Clay Loam	1.59		67B-21 S1 7-11'	Sandy Loam	1.26
1926 S1 7-11"	Silty Clay Loam	1.57		67B-21 S2 0-4"	Silty Clay Loam	1.07
1926 S2 0-4"	Silty Clay Loam	1.63		67B-21 S2 7-11'	Silty Clay Loam	1.11
1926 S2 7-11"	Silty Clay Loam	1.67		67B-21 S3 0-4"	Silty Clay Loam	1.27
1926 S3 0-4"	Silty Clay Loam	1.42		67B-21 S3 7-11'	Silty Clay Loam	1.52
1926 S3 7-11"	Silty Clay Loam	1.47		69B-16 S1 0-4"	Silty Clay Loam	1.3
1927 S1 0-4"	Silty Clay Loam	1.62		69B-16 S1 7-11'	Silty Clay Loam	1.33
1927 S1 7-11"	Silty Clay Loam	1.44		69B-16 S2 0-4"	Silty Clay Loam	1.41
1927 S2 0-4"	Sandy Clay Loam	1.67		69B-16 S2 7-11'	Silty Clay Loam	1.16
1927 S2 7-11"	Sandy Clay Loam	1.71		69B-16 S3 0-4"	Silty Clay Loam	1.22
1927 S3 0-4"	Sandy Loam	1.71		69B-16 S3 7-11'	Silty Clay Loam	1.36
1927 S3 7-11"	Sandy Loam	1.54		81B-19 S1 0-4"	Sandy Loam	1.63
1928 S1 0-4"	Sandy Loam	1.6		81B-19 S1 7-11'	Sandy Loam	1.6
1928 S1 7-11"	Sandy Loam	1.57		81B-19 S2 0-4"	Sandy Loam	1.56
1928 S2 0-4"	Sandy Loam	1.6		81B-19 S2 7-11'	Sandy Loam	1.58
1928 S2 7-11"	Sandy Loam	1.65		81B-19 S3 0-4"	Sandy Loam	1.54

Table 4. Native range, spring wheat control, and crop rotation bulk density values

	Native Range	Spring Wheat Control	Spring Wheat Rotation	Triticale Hairy Vetch/Cover Crop	Pea-Barley	Corn	Sunflower
Bulk Density (0-11”)^{b}	1.375^{b}	1.552^{a}	1.545^{a}	1.538^{a}	1.49^{a}	1.473^{ab}	1.543^{a}

^{c}Means within a row with unlike superscripts differ ($P < 0.05$).

Table 5. Bulk density statistical contrasts P-Values for Table 4

Contrasts:	Crops	SEM	P-Value
Native Range	Corn	0.0394	0.178
versus	Spring Wheat	0.0394	0.001
	Pea-Barley	0.0394	0.06
	Sunflower	0.0394	0.001
	Triticale-H-Vetch/cover crop	0.0394	0.001
	Spring Wheat Control	0.0394	0.000
Spring Wheat Control	Corn	0.0394	0.407
versus	Spring Wheat	0.0394	1.000
	Pea-Barley	0.0394	0.725
	Sunflower	0.0394	1.000
	Triticale-H-Vetch/cover crop	0.0394	1.000
	Native Range	0.0394	0.000

Table 6. Crop yields

	2011	2012	2013	Average
Corn	15.00	55.30	88.90	52.74
Spring Wheat	30.10	45.10	34.30	36.50
Pea-Barley	-	3.11	4.52	3.82
Sunflower	891	1590	1959	1480
Triticale-H-Vetch	2.71	1.59	0.00	1.43
Cover Crop	0.00	4.25	2.84	2.36
Spring Wheat Control	28.03	55.70	45.17	42.97

REFERENCES

Brevik, Eric C. *Forty Years of Soil Formation in a South Georgia, USA Borrow Pit.* Soil Horizons. 2013.

Brown, Katharine. *Bulk Density-Measuring.* SoilQuality.org.au. Fact Sheet. Updated: N/A. Retrieved: 8 April 2014. http://soilquality.org.au/factsheets/bulk-density-measurement.

Coder, Kim. D, University of Georgia. *Tree Root Growth Control Series: Soil Constraints on Root Growth.* March 1998. University of Georgia Cooperative Extension Service Forest Resources Publication.

Crop Rotation. *Soil Association.* Updated: 2013. Retrieved: 19 March, 2014. https://www.soilassociation.org/whatisorganic/organicfarming/croprotations

Houston, Anna, G. Tranter, I. Miller. *Bulk Density*. Principle. Updated: N/A. Retrieved: 19 March, 2014. http://www.usyd.edu.au/agric/web04/Bulk%20density%20the%20final.htm

Logsdon. Sally D. and Douglas L. Karlen. *Bulk Density as a Soil Quality Indicator During Conversion to No-Tillage.* Science Direct. 2004. Retrieved: 19 March, 2014.

Managing Cover Crop Profitability 3rd edition. June 2012. Sustainable Agriculture Research and Education (SARE) program.

Pikul, J.L. Jr., R. Schwartz, J. Benjamin, L. Baumhardt, and S. Merrill. *Soil Physical Characteristics of Contrasting Cropping Systems in the Great Plains: Preliminary Findings.* Dynamic Cropping Systems Symposium 2003. Retrieved: 19 March 2014.

Stockdale, Elizabeth. *Making Sense of Physical Indicators.* SoilQuality.org.au. Fact Sheet. Updated: N/A. Retrieved: 8 April 2014. http://soilquality.org.au/factsheets/making-sense-of-physical-indicators

USDA/NRCS/Farming in the 21st Century. 2010. A practical approach to improve SOIL HEALTH. Developed by the Soil Quality National Technology Development Team.

Zuber, Stacy M. *Long-Term Effect of Crop Rotation and Tillage on Soil Properties.* University of Illinois Urbana-Champaign. 2013. Retrieved: 9 April 2014. https://www.ideals.illinois.edu/bitstream/handle/2142/46708/Stacy_Zuber.pdf?sequence=1