2020

Soil aggregation as affected by application of diverse organic materials

Maman Garba

Charles S. Wortmann

Humberto Blanco-Canqui

Received: 5 January 2020 | Accepted: 22 July 2020

DOI: 10.1002/agg2.20097

Agrosystems, Geosciences & Environment OPEN ACCESS

ORIGINAL RESEARCH ARTICLE

Agrosystems

Soil aggregation as affected by application of diverse organic materials

Maman Garba[1] | **Charles Wortmann**[2] | **Humberto Blanco-Canqui**[2]

[1] Institut National de la Recherche Agronomique du Niger (INRAN), Niamey BP 429, Niger

[2] Department of Agronomy and Horticulture, University of Nebraska-Lincoln, 279 Plant Science, Lincoln, NE 68583, USA

Correspondence
Maman Garba, Institut National de la Recherche Agronomique du Niger (INRAN), Niamey, BP 429, Niger.
Email: maman_garba@yahoo.fr

Abstract

Application of organic materials can amend soil for improved water infiltration and reduced erodibility with effects varying with soil properties and the organic amendment type and rate. The effects of four livestock manures, three municipal biosolids, and one industrial by-product on dry and wet soil aggregate stability were evaluated at six sites in Nebraska. The amendments had similar C/N ratios but the biosolids had relatively high concentrations of lignin and cellulose. Soil organic matter (SOM) ranged from 21 to 65 g kg^{-1} and soils were silty clay loam, silt loam, or loamy sand. Soil was sampled for the 0- to 0.05-m depth at physiological maturity of the second corn (*Zea mays* L.) crop following amendment application. Aggregation was high with no amendment applied as >95% of the soil was in water stable aggregates (WSA) > 0.053 mm and was not affected by amendments with a few exceptions such as an increase in dry aggregate size and WSA 0.25–2.0 mm at one location. Dry aggregate size was much less for the loamy sand than with other soils. With SOM >60 g kg^{-1} compared with less SOM, there was 42% more WSA >2 mm and 38% less WSA <2 mm diam. It cannot be concluded that organic amendment application will improve aggregation if SOM >20 g kg^{-1} but larger effects may have occurred with: sampling sooner after amendment application; a 0- to 0.025-m sampling depth; or sampling at several months after harvest for reduced effect of the rhizosphere on aggregation.

1 | INTRODUCTION

Soil aggregation is important for rapid water infiltration and to soil resistance to erosion. Land application of organic amendments can improve soil aggregation (Blanco-Canqui & Lal, 2010; Blanco-Canqui et al., 2013; Hernandez, Hernandez, & Garcia, 2017; Lal, 2015; Rabot, Wiesmeier, Schlüter, & Vogel, 2018; Wortmann & Shapiro, 2008) while supplying nutrients and often with benefit to other soil physical, chemical, and biological properties (Blanco-Canqui & Lal, 2010; Sarker, Incerti, Spaccini, Piccolo, & Mazzoleni, 2018). Organic amendment effects on soil aggregation vary with amendment properties and rate (Blanco-Canqui & Lal, 2010; Hernandez et al., 2017; Six, Elliot, Paustian, & Doran, 1998; Wortmann & Shapiro, 2008). For example, addition of manure and

Abbreviations: DMWD, mean weight diameter of dry aggregates; ENREC, Eastern Nebraska Research and Extension Center; GMD, geometric mean diameter of dry aggregates; SOM, soil organic matter; WEF, wind-erodible fraction of soil or aggregates <0.84-mm diameter; WMWD, mean weight diameter of wet aggregates; WSA, water stable aggregates.

compost with abundant microbial biomass contributed more to soil aggregation than crop residues (Hernandez et al., 2017). The extent to which organic amendments affect soil aggregation can also depend on the amendment's C/N ratio and the contents of cellulose, lignin, and polyphenol (Blanco-Canqui et al., 2013; Palm & Sanchez, 1991).

Time after application and soil textural class could also be important determinants of organic amendment effects. For example, Mikha, Hergert, Benjamin, Jabro, and Nielsen (2015) found that application of 27 Mg ha^{-1} yr^{-1} of cattle manure for 70 yr to a sandy loam increased water stable aggregates (WSA) in western Nebraska. However, after 3 yr of application of sheep and cattle manure to a silt loam, there was no effect on both dry and wet aggregate stability in eastern Nebraska (Blanco-Canqui et al., 2014). In a recent review, Blanco-Canqui and Wortmann (2017) found that livestock manure application had mixed effects on the wind erodible fraction (WEF) and dry aggregate stability depending on time after application and soil type.

Further study of the effects of applying organic amendments of different characteristics on dry aggregation and WSA across different soil texture classes and management conditions was justified. The objectives of this study were to determine impacts of one-time application of eight organic amendments on dry soil aggregate size and WSA for six soils under rainfed or irrigated continuous corn (*Zea mays* L.) production in Nebraska. We hypothesized that a single application of organic amendment would increase mean dry aggregate size and WSA, that higher cellulose and lignin content would increase the amendment effect, and that the effects of organic amendment are affected by sand content, pH, and initial soil organic matter.

Core Ideas

- Organic amendments had limited effects on near-surface dry and wet aggregate properties.
- Dry aggregate properties including WEF are much affected by soil sand content.
- Organic amendments could have had more effect on soil aggregation on marginal soils.

2 | MATERIALS AND METHODS

2.1 | Study sites

The study was conducted at six sites in eastern Nebraska. Three fields in Saunders County included: a rainfed site (Eastern Nebraska Research and Extension Center [ENREC], 41.156, 96,410, 347 m) with a Filbert silt loam (fine, smectitic, mesic Vertic Argialbolls); an irrigated site (41.389, 96.794, 420 m) with Yutan silty clay loam (fine-silty, mixed, superactive, mesic Mollic Hapludalfs); and another rainfed site (41.344, 96.793, 430 m) with Pohocco silty clay loam (fine-silty, mixed, superactive, mesic Typic Eutrudepts) (Table 1). Two sites in Colfax County included: an irrigated site (41.456, 97.134, 420 m) with Lawet silt loam (fine-loamy, mixed, superactive, mesic Typic Calciaquolls) and a rainfed site (41.504, 97.079, 430 m) with Alcester silty clay loam (fine-silty, mixed, superactive, mesic Cumulic Haplustolls). The third irrigated site was in Antelope County (42.370, 97.836, 520 m) with Boelus loamy fine sand (sandy over loamy, mixed, superactive, mesic Udic Haplustolls). All sites except for ENREC were on farmers' fields with farmer management except for fertilizer-N and amendment application.

2.2 | Experimental design

At each site, the experimental design was a randomized complete block design with four replications. The plot size was 3.8 by 12.2 m. The treatments were: (a) raw feedlot manure, (b) dry beef feedlot scrapings, (c) raw poultry manure, (d) composted dairy manure, (e) Lincoln municipal biosolid, (f) Fremont composted biosolid, (g) Fremont dewatered biosolid, (h) Novozyme by-product, and (i) a control with no organic amendment (Table 2). The organic amendments were applied either in late fall 2015 or early spring 2016. The trials were established for the additional objective of improving applied organic N use efficiency (Garcia-Montealegre, Wortmann, Schepers, & Little, 2019). The sites were in continuous corn since 2015. The rates of amendment application were determined to achieve similar fertilizer N substitution. The sites were disc-tilled following application of the organic amendments but had no further tillage. The plots with organic amendment applied did not receive fertilizer-N but 120 kg ha^{-1} fertilizer N was applied for the control.

2.3 | Soil sampling and analyses

Composite soil samples of about 2 kg were collected with a squared-end shovel for the 0- to 0.05-m soil depth. The samples were for dry aggregate size and WSA determination and collected from inter-row, non-tracked positions at physiological maturity of corn in September or October 2017.

The dry aggregate size was determined with approximately 1 kg of soil air dried at 60 °C in a forced air oven

TABLE 1 Initial soil properties for the 0- to 0.2-m depth for six studies conducted in Nebraska (Garcia-Montealegre et al., 2019)

Sites	Soil texture	pH	Organic matter	CEC
			g kg^{-1}	cmol$_c$ kg^{-1}
Rainfed				
ENREC	Silt loam	5.7	40.2	19.6
Saunders	Silty clay loam	6.3	63.0	22.3
Colfax	Silty clay loam	6.0	28.5	15.6
Irrigated				
Saunders	Silty clay loam	6.0	35.5	19.7
Colfax	Silt loam	7.9	65.5	40.4
Antelope	Loamy fine sand	5.5	21.0	12.0

Note. CEC, cation exchange capacity; ENREC, Eastern Nebraska Research and Extension Center.

TABLE 2 Rates (wet weight) of application and properties of organic amendments for the six studies in Nebraska (Garcia-Montealegre et al., 2019)

Amendment	Rate wet weight	pH	C/N ratio	Organic C[a]	Organic N
	Mg ha^{-1}			g kg^{-1}	
Stockpiled feedlot manure	39	7.8	10.3	89	8.4
Dry feedlot scrapings	22	7.9	11.8	137	11.3
Raw poultry manure	7	6.4	9.5	408	38.3
Dairy manure compost	15	8.0	9.0	147	16.0
Novozyme by-product	12	12.4	6.0	176	29.9
Lincoln municipal biosolid	16	6.4	7.1	366	45.3
Fremont composted biosolid	32	8.9	9.7	217	21.0
Fremont dewatered biosolid	16	6.6	8.3	392	44.6

[a]The mean cellulose plus lignin concentration was 296 g kg^{-1} for manure amendments and 488 g kg^{-1} for biosolid amendments.

for 72 h. The soil was dry-sieved in duplicate using a Ro-Tap sieve shaker (López, de Dios Herrero, Hevia, Gracia, & Buschiazzo, 2007) for 5 min and separated into aggregate diameter fractions of <0.425, 0.425–0.84, 0.84–2.2, 2.2–6.3, 6.3–14, 14–45, and >45 mm. The geometric mean diameter (GMD) and the mean weight diameter of dry aggregates (DMWD) was computed (Nimmo & Perkins, 2002). The wind erodible fraction (WEF) was computed as the amount of soil in dry aggregates of <0.84 mm diam. divided by the total dry soil mass.

The wet aggregate stability was determined by breaking the soil apart by hand along natural cleavage lines and air drying at 60 °C in a forced air oven for 72 h. The soil was sieved to remove aggregates of >8 mm (Nimmo & Perkins, 2002). A 50 g sieved sample was placed on a filter paper on the top sieve of a stack of five sieves with 4.75, 2.0, 1, 0.25, and 0.053 mm diam. openings. The soil was wetted by capillarity for 10 min and then the filter paper was removed. The stack of sieves was then rotated in water for 10 min at 30 rotations min^{-1}. The aggregates retained on each sieve were transferred to beakers, oven-dried at 105 °C, and weighed. These aggregate samples were then treated with Na hexametaphosphate to disperse soil aggregates and passed through sieves with 0.053-mm openings to recover sand particles which were oven dried at 105 °C for sand content correction (Nimmo & Perkins, 2002). The dry weight for each WSA size fraction and the mean weight diameter of wet aggregates (WMWD) were determined using the mass and amount of each WSA size fraction (Nimmo & Perkins, 2002).

2.4 | Statistical analysis

Prior to statistical analysis, outlying extreme values were identified as deviating from the treatment mean for the trial by more than two times the standard deviation of the trial and removed. There were 216 samples and the number of outliers removed were 5 for WEF, 5 for DMWD, 3 for GMD, 2 for WMWD, 3 for WSA >2 mm, 3 for WSA 0.25–2 mm, 2 for WSA 0.053–0.25 mm, and 2 for WSA >0.25 mm. Analyses of variance of all soil aggregate indices determined were conducted combined across five of the sites with blocks as random variables and sites and treatments as fixed factors using Statistix 10 (Analytical Software). The data for the loamy fine sand of Antelope County was analyzed separately due to lack of homogeneity of variance with other sites. Contrast analyses were used to compare means by location of different types of amendments including the means of all amendments compared with no amendment; livestock manure compared with municipal biosolid amendments; and biosolid amendments compared with no amendment. Sample data were analyzed to determine Pearson correlation coefficients for the relationships of soil sand content to soil aggregate properties. Effects were considered significant with $P \leq .05$.

3 | RESULTS

The effect of amendments on dry aggregate properties was not significant with a few exceptions (Table 3). The mean dry aggregates were 6.47 mm GMD, 16.5 mm DMWD, and 263 g kg^{-1} WEF. The GMD and DMWD were higher for the mean for amendments applied than with no amendment for ENREC but not for the other sites. The GMD was greater with biosolid than manure amendment for the rainfed site in Saunders County. Biosolid amendment increased DMWD compared with no amendment for the loamy fine sand soil which had small dry aggregates of 0.84 mm GMD, 4.4 mm DMWD, and 769 g kg^{-1} WEF. The WEF for biosolids compared to manures was higher at ENREC but lower at the loamy fine sand site. The lack of much difference in effects of amendments with high compared with low cellulose plus lignin concentration indicated that this characteristic was not important on soil structural indices under the conditions of this study.

Sixty-eight percent of the sand-free soil was in WSA >2 mm and 21% was in WSA 0.25–2 mm with a MWDW of 3.4 mm. Application of amendments did not affect MWDW but there were some effects on WSA fractions (Table 4). Amendments resulted in 10.2% more sand-free soil in WSA >2 mm accompanied by a 6.4% decrease in WSA 0.053–0.25 mm for the irrigated site in Saunders County. There was 7.3% more soil in WSA 0.25–2 mm with amendment, primarily due to biosolids, at ENREC. The only case of biosolid differing from manure was for WSA 0.25–2 mm at the rainfed site in Saunders County indicating that the variation in cellulose plus lignin concentration was not important to WSA.

The sand-free WSA where soil organic matter (SOM) was >60 g kg^{-1} compared with other sites had 42% more WAS >2 mm and 38% less WSA <2 mm. Soil pH ranged from 5.5 to 7.9 (Table 1) but there was no evidence of soil pH effects on soil aggregation. Soil sand content was related to WEF (r = .93), DMWD (r = −.61) and GMD (r = −.59) with sand content for the loamy fine sand greatly affecting these relationships. Sand content did not affect sand-free WMWD but most of the loamy fine sand was retained as sand on the 0.53-mm sieve. Aggregate properties did not differ for irrigated compared with rainfed sites once the loamy fine sand was excluded from the comparison.

4 | DISCUSSIONS

Interpretation of these results showing little organic amendment effect on soil aggregation needs to consider that all sites: (a) had highly productive soils with much crop residue returned to the soil annually (Garcia-Montealegre et al., 2019); (b) were sampled at physiological maturity of the second corn crop and >17 mo after the one-time application of amendments; (c) had no tillage in the year of sampling; (d) had well-aggregated soil with most soil in WSA >2 mm even without amendment; and (e) were sampled for the 0.00- to 0.05-m depth rather than for a shallower depth.

In the current study, <5% of the soil passed through the 0.053-mm sieve during the WSA evaluation and 85% of the soil was in WSA >0.25 mm without amendment which was high compared with other results from eastern Nebraska (Quincke et al., 2007; Wortmann, Drijber, & Franti, 2010; Wortmann & Shapiro, 2008). This left little opportunity for increasing WMWD (Table 4). The high sand-free soil aggregation with and without amendment at physiological maturity of the corn was likely more affected by corn root-mycorrhyzal biomass and length, and by root exudates (Blanco-Canqui, Sindelar, Wortmann, & Kreikemeier, 2017; Le Bissonnais et al., 2017), than if the sampling were done in the spring following some degradation of the rhizosphere influence. The regular return of corn crop residues with substantial cellulose and lignin content to the surface soil likely contributed to soil aggregate size and stability and masked the effects of the organic amendments. No tillage in the year of sampling may have contributed to aggregation but tillage would likely have an inconsistent and short duration effect for these soils (Quincke et al., 2007). The effect of organic amendments diminishes over time and effects are likely to be greater in the 0.0- to 0.025-m than the 0.0- to 0.05-m depth since the disk tillage incorporation left the amendment mostly concentrated in the 0.0- to 0.025-m depth (Scanlan & Davis, 2019; Wortmann & Shapiro, 2008; Wortmann & Walters, 2007).

With the loamy fine sand excluded, the means were 7.61 mm GMD, 18.9 mm DMWD and 162 g kg^{-1} WEF, compared to an average of 350 g kg^{-1} WEF for 13 other studies with medium texture soil (Blanco-Canqui & Wortmann, 2017) (Table 3). These values indicated strong aggregation. Site differences for WEF were related to soil texture with the highest WEF for the loamy fine sand and the lowest WEF with a silt loam and a silty clay loam.

TABLE 3 Geometric mean diameter (GMD) and the site means for the mean weight diameter (DMWD) of dry soil aggregates and the wind erodible fraction (WEF; <0.84-mm diam.) as affected by organic amendments at six sites in eastern Nebraska

Treatment	ENREC	Saunders		Colfax		Antelope	Mean
	Rain	Rain	Irrigation	Rain	Irrigation	Irrigation	
	mm						
No amendment	5.60	7.42	5.25	6.08	7.67	0.45	5.41
Stockpiled feedlot manure	10.81	6.19	6.11	6.87	7.69	0.96	6.44
Dry feedlot manure scrapings	10.07	6.41	5.58	6.01	12.28	0.93	6.88
Raw poultry manure	11.21	4.99	6.71	5.93	10.43	0.64	6.65
Dairy manure compost	8.84	4.33	5.84	6.67	9.99	0.86	6.09
Novozyme by-product	10.00	4.40	5.78	6.02	9.96	0.91	6.18
Lincoln municipal biosolid	9.48	9.11	8.26	7.61	12.20	0.76	7.90
Fremont composted biosolid	8.72	9.58	6.25	6.87	10.29	1.15	7.14
Fremont dewatered biosolid	6.36	5.04	7.03	7.75	6.63	0.94	5.63
Site means							
GMD, mm	9.01	6.38	6.31	6.65	9.68	0.84	6.47
DMWD, mm	25.5	14.6	15.3	17.8	21.3	4.4	16.5
WEF, g kg^{-1}	188.8	143.9	159.2	194.3	125.0	769.5	263.5
Significant contrast differences[a]							
All–control							
GMD	3.84*	−1.17	1.19	0.63	2.27	0.45	1.20
DMWD	9.17**	−5.41	1.93	−1.62	2.85	3.76	1.78
Biosolid–manure							
GMD	−2.05	2.43*	1.12	1.04	−0.39	0.10	0.37
WEF	2.85**	−0.95	−1.36	−0.58	0.07	−0.52	−0.67
Biosolid– control							
DMWD	6.90	−2.86	3.35	0.49	1.03	4.66*	2.26
WEF	−0.47	−0.04	−0.55	−1.1	−0.42	−2.12*	−0.78

Note. ENREC, Eastern Nebraska Research and Extension Center.

[a]Contrast results are reported for the differences of all amendments–control; biosolid–manure; and biosolid–control.

*Significant at $P < .05$.

**Significant at $P < .01$.

TABLE 4 Sand-free mean weight diameter of water stable soil aggregates (WMWD) under different organic amendments and soil textural classes. The sites means for sand-free soil in water stable aggregates (WSA, g kg^{-1}) of > 2 mm, 0.25–2 mm, 0.053–0.25 mm, and < 0.053 mm are also reported

Treatment	ENREC	Saunders		Colfax		Antelope	Mean
	Rain	Rain	Irrigation	Rain	Irrigation	Irrigation	
	WMWD, mm						
No amendment	2.77	5.11	2.11	3.28	3.85	3.68	3.47
Stockpiled feedlot manure	2.16	4.83	2.81	3.18	3.72	2.75	3.29
Dry feedlot scrapings	2.28	5.51	3.07	3.7	3.47	3.47	3.58
Raw poultry manure	2.21	5.57	2.23	2.91	3.84	4.24	3.50
Dairy manure compost	2.52	5.09	2.15	3.07	3.29	3.63	3.40
Novozyme by-product	2.25	5.23	1.88	2.7	3.96	3.37	3.29
Lincoln municipal biosolid	2.00	5.19	1.97	3.48	3.23	3.87	3.23
Fremont composted biosolid	2.27	4.82	2.66	2.68	4.33	4.23	3.50
Fremont dewatered biosolid	2.50	5.21	2.26	3.12	4.32	3.01	3.24
Site means							
WMWD, mm	2.33	5.17	2.35	3.12	3.78	3.58	3.38
WSA > 2 mm	536	929	532	612	768	706	680
WSA 0.25–2 mm	312	54	294	229	169	182	207
WSA 0.053–0.25 mm	154	18	180	154	64	112	114
WSA < 0.053 mm	−2	0	−5	5	0	0	0
Significant contrast differences[a]							
All– control							
WSA > 2 mm	−5.94	0.18	10.16*	−5.45	−3.35	−2.54	−1.15
WSA 0.25–2 mm	7.31*	−0.21	−4.73	2.69	1.49	2.59	1.52
Biosolid–manure	−0.04	−0.18	−0.27	−0.12	0.38	0.18	−0.01
WSA 0.25–2 mm	0.82	1.70*	5.34	−0.48	−3.18	−2.87	−0.07
Biosolid–control							
WSA 0.25–2 mm	7.92*	0.90	−1.79	2.02	−0.15	0.47	1.56
WSA 0.053–0.25 mm	−2.56	0.11	−6.36*	2.43	0.39	1.90	0.45

Note. ENREC, Eastern Nebraska Research and Extension Center.

[a]Cases with significant contrast results are reported for the differences of all amendments–control; biosolid–manure; and biosolid–control.

*Significant at $P < .05$.

Soil texture and SOM can affect soil aggregation (Kara & Baykara, 2014) and the high sand content and relatively low SOM likely contributed to the dry soil fragility and low GMD and DMWD for the loamy fine sand.

The effects of organic amendments on WEF have been inconsistent but with most studies reporting no decrease in WEF (Blanco-Canqui & Wortmann, 2017). The effect of applied organic amendments on soil aggregation is expected to be greater with SOM of <10 g kg^{-1}, such as with much eroded soil (Kara & Baykara, 2014). The SOM was ≥21 g kg^{-1} with a mean of 42 g kg^{-1} and the CEC was ≥12 cmol$_c$ kg^{-1} with a mean of 22 cmol$_c$ kg^{-1} for the 0- to 0.2-m soil depth for the current study (Table 1). However, application of sufficient organic amendment did increase resistance to erosion and reduced runoff for a silt loam with >30 g kg^{-1} SOM in eastern Nebraska (Wortmann & Walters, 2007).

At the two sites with organic amendment effects, the decrease in WEF corresponded with an increase in DMWD and an increase in GMD at ENREC-Rain. Increased soil sand content was associated with reduced dry aggregate size but not with WSA properties. As stated earlier, the study soils had >28 g kg^{-1} SOM content, except for Antelope irrigation (ANT-Irr), with 100% crop residue retention which contributes to soil aggregation (Blanco-Canqui & Wortmann, 2017). As a result, the soils were well-aggregated with little opportunity for improving aggregation through organic amendment application. Future similar studies may be better done on soils with <20 g kg^{-1} SOM, such as eroded soils, and sampling should be at least several months after harvest, such as in the spring when rhizosphere effects on aggregation are reduced and when both wind and water erosive forces tend to be greatest in eastern Nebraska.

The results did not fully support the three stated hypotheses. A single application of organic amendment cannot be expected to generally increase dry aggregate size and WSA for soils similar to those of this study. The hypothesis that amendment effects for reduced WEF and increased WSA aggregation with increased cellulose plus lignin content of the amendment was generally rejected for these soils as the effect occurred at ENREC only. Soil sand content was associated with WEF but not with WSA. Soil pH was not associated with soil aggregation. Dry aggregate size and WMWD were greater with >60 than with <60 g kg^{-1} SOM.

5 | CONCLUSION

Application of organic amendments had little effect on near-surface dry and wet soil aggregate properties. Dry aggregate properties including WEF are much affected by soil sand content. The WSA > 0.25 mm tend to be more with SOM > 60 g kg^{-1} compared with less SOM. It cannot be concluded that soil aggregation will be affected by soil pH and by organic amendment application when the soil is already well aggregated. Also, it cannot be concluded that the amendment levels of cellulose plus lignin are important to amendment effects on soil aggregate properties. Future amendment research should focus on soils with <20 g kg^{-1} SOM for a greater probability of amendment effects on soil aggregation. Moreover, sample collection for such analysis should be carried out when soil is most susceptible to erosion such as in the spring in eastern Nebraska.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Maman Garba https://orcid.org/0000-0002-3377-3064
Charles Wortmann https://orcid.org/0000-0001-9715-8469
Humberto Blanco-Canqui https://orcid.org/0000-0002-9286-8194

REFERENCES

Blanco-Canqui, H., Ferguson, R. B., Jin, V. I., Schmer, M. R., Wienhold, B. J., & Tatarko, J. (2014). Can cover crop and manure maintain soil properties after stover removal from irrigated no-till corn? *Soil Science Society of America Journal*, *78*, 1368–1377. https//doi.org/10.2136/sssaj2013.12.0550

Blanco-Canqui, H., & Lal, R. (2010). Critical reviews in plant sciences mechanisms of carbon sequestration in soil aggregates. *Critical Reviews in Plant Sciences*, *26*, 481–504. https//doi.org/10.1080/07352680490886842

Blanco-Canqui, H., Shapiro, C. A., Wortmann, C. S., Drijber, R. A., Mamo, M., Shaver, T. M., & Ferguson, R. B. (2013). Soil organic carbon: The value to soil properties. *Journal of Soil and Water Conservation*, *68*, 129A–134A. https//doi.org/10.2489/jswc.68.5.129

Blanco-Canqui, H., Sindelar, M., Wortmann, C. S., & Kreikemeier, G. (2017). Aerial interseeded cover crop and corn residue harvest: Soil and crop impacts. *Agronomy Journal*, *109*, 1344–1351. https//doi.org/10.2134/agronj2017.02.0098

Blanco-Canqui, H., & Wortmann, C. (2017). Crop residual removal and erosion by wind. *Journal of Soil and Water Conservation*, *72*, 97A–104A. https//doi.org/10.2489/jswc.72.5

Garcia-Montealegre, J. P., Wortmann, C., Schepers, J., & Little, R. (2019). Applied organic nitrogen: Pre-plant and in-season estimation of corn nitrogen uptake. *Field Crops Research*, *241*, 1–8. https//doi.org/10.1016/j.fcr.2019.107577

Hernandez, T., Hernandez, M. C., & Garcia, C. (2017). The effects on soil aggregation and carbon fixation of different organic amendments for restoring degraded soil in semiarid areas. *European Journal of Soil Science*, *68*, 941–950. https//doi.org/10.1111/ejss.12474

Kara, O., & Baykara, M. (2014). Changes in soil microbial biomass and aggregate stability under different land uses in the northeastern Turkey. *Environmental Monitoring and Assessment*, *186*, 3801–3808. https//doi.org/10.1007/s10661-014-3658-0

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, *7*, 5875–5895. https//doi.org/10.3390/su7055875

Le Bissonnais, Y., Prieto, I., Roumet, C., Nespoulous, J., Metayer, J., Huon, S., … Stokes, A. (2017). Soil aggregate stability in Mediterranean and tropical agro-ecosystems: Effect of plant roots and soil characteristics. *Plant and Soil*, *424*, 303–317. https//doi.org/10.1007/s11104-017-3423-6

López, M. V., de Dios Herrero, J. M., Hevia, G. G., Gracia, R., & Buschiazzo, D. E. (2007). Determination of the wind-erodible fraction of soils using different methodologies. *Geoderma*, *139*, 407–411. https://doi.org/10.1016/j.geoderma.2007.03.006

Mikha, M. A., Hergert, G. A., Benjamin, J. G., Jabro, J. B., & Nielsen, R. A. (2015). Long-term manure impacts on soil aggregates and aggregate-associated carbon and nitrogen. *Soil Science Society of America Journal*, *79*, 626–636. https//doi.org/10.2136/sssaj2014.09.0348

Nimmo, J. R., & Perkins, K. I. M. S. (2002). Aggregate stability and size distribution. In G. C. Topp & J. H. Dane (Eds.), *Methods of soil analysis. Part 4. Physical methods* (pp. 317–328). Madison, WI: SSSA.

Quincke, J. A., Wortmann, C. S., Mamo, M., Franti, T. G., Drijber, R. A., & Garcia, J. P. (2007). One-time tillage of no-till systems: Soil physical properties, phosphorus runoff, and crop yield. *Agronomy Journal*, *99*, 1104–1110. https//doi.org/10.2134/agronj2006.0321

Palm, C. A., & Sanchez, P. A. (1991). Nitrogen release from the leaves of some tropical legumes as affected by their lignin and polyphenolic contents. *Soil Biology and Biochemistry*, *23*, 83–88.

Rabot, E., Wiesmeier, M., Schlüter, S., & Vogel, H. J. (2018). Soil structure as an indicator of soil functions: A review. *Geoderma*, *314*, 122–137. https//doi.org/10.1016/j.geoderma.2017.11.009

Sarker, T. C., Incerti, G., Spaccini, R., Piccolo, A., & Mazzoleni, S. (2018). Linking organic matter chemistry with soil aggregate stability : Insight from C NMR spectroscopy. *Soil Biology & Biochemistry*, *117*, 175–184.

Scanlan, C. A., & Davies, S. L. (2019). Soil mixing and redistribution by strategic deep tillage in a sandy soil. *Soil Tillage Research*, *185*, 139–145.

Six, J., Elliot, E. T., Paustian, K., & Doran, J. W. (1998). Aggregation and soil organic matter accumulation in cultivated and native grassland soils. *Soil Science Society of America Journal*, *62*, 1367–1377.

Wang, J., Yang, W., Yu, B., Li, Z., Cai, C., & Ma, R. (2016). Estimating the influence of related soil properties on macro- and micro-aggregate stability in ultisols of south-central China. *Catena*, *137*, 545–553. https//doi.org/10.1016/j.catena.2015.11.001

Wortmann, C. S., Drijber, R., & Franti, T. G. (2010). One-time tillage of no-till crop land five years post-tillage. *Agronomy Journal*, *102*, 1302–1307. https//doi.org/10.2134/agronj2010.0051

Wortmann, C. S., & Shapiro, C. A. (2008). The effects of manure application on soil aggregation. *Nutrient Cycling in Agroecosystems*, *80*, 173–180. https//doi.org/10.1007/s10705-007-9130-6

Wortmann, C. S., & Walters, D. T. (2007). Residual effects of compost and plowing on phosphorus and sediment in runoff. *Journal of Environmental Quality*, *36*, 1521–1527. https//doi.org/10.2134/jeq2006.0404

How to cite this article: Garba M, Wortmann C, Blanco-Canqui H. Soil aggregation as affected by application of diverse organic materials. *Agrosyst Geosci Environ*. 2020;3:e20097. https://doi.org/10.1002/agg2.20097