Impact of Management Practices on Water Extractable Organic Carbon and Nitrogen in Poultry Litter-Amended Soil

Mingchu Zhang,[1] Zhongqi He,[2] Heidi Waldrip,[3] Paulo Pagliari[4], and Daren Harmel[5]

[1]University of Alaska-Fairbanks, Fairbanks, AK; [2]USDA-ARS Southern Regional Research Center, New Orleans, LA; [3]USDA-ARS Conservation and Production Research Laboratory, Bushland, TX; [4]University of Minnesota, Lamberton, MN; [5]USDA-ARS Grassland Soil and Water Research Laboratory, Temple, TX

Introduction

Modern poultry production systems generate large quantities of poultry litter (PL) that generally is either disposed via land application or used as a source of organic matter (OM) and nutrients for crop and pasturelands. If properly managed, PL can enhance soil fertility and reduce dependence on chemical fertilizers; however, over-application can result in runoff losses of nitrogen (N) and phosphorus (P) that may promote surface water eutrophication. To date, most studies on nutrient fate and transport from manure-amended soils have focused on nitrate (NO_3^-) and P in runoff. Considerably less attention has been given to fate of soluble OM, which can contain significant amounts of water-extractable organic carbon (WEOC) and N (WEON) that also contribute to surface water enrichment (Wilson and Xenopoulos, 2009; Zhao et al., 2013).

Objectives: (***1***) Determine impact of PL application rate on concentrations of WEOC and WEON, (***2***) Identify how management practices influence soil WEOC and WEON, and (***3***) characterize Ultraviolet-Visible (UV-Vis) spectral properties of water-extractable OM (WEOM) as affected by long-term (12-year) PL application and management/land-use practices in cropped and pastureland soils.

Materials and Methods

- A long-term (2000-2012) watershed-scale study was conducted where PL (turkey litter) at different rates or inorganic fertilizer were applied annually to cropped (fallow-corn-wheat rotation) and pasture (hayed or grazed) Texas Blackland Vertisol plots (***Table 1***). Further management information can be found in Harmel et al. (2009, 2011).
- Soil samples were collected in winter. Water extractable organic matter (WEOM) was obtained by extraction with deionized water [1:10 (wt:vol) soil:H_2O] on a reciprocal shaker for 30 min at 22°C. The WEOM was analyzed for WEOC, Total N, and inorganic N (NH_4-N, and NO_3-N). The WEON concentration was calculated as difference between Total N and inorganic N.
- The UV-Vis spectral characteristics of WEOM were determined by measuring absorbance (*A*) from 200 to 800 nm with a UV-Vis-NIR spectrometer. Specific absorptivity at 254 ($SUVA_{254}$, aromaticity) and 280 nm ($SUVA_{280}$, aromaticity and molecular weight) were calculated according to Zhang et al. (2011). Ratios of absorbance at specific wavelengths [E2/E3 (A_{254}/A_{365}; molecular weight), E4/E6-1 and E4/E6-2 (A_{400}/A_{600} and A_{465}/A_{665}, respectively; molecular weight, humification, aromaticity)] were calculated to further characterize the effects of PL application and management on spectral properties of WEOM.

Results and Discussion

In cultivated fields, soil NO_3^- concentration increased with PL application; however, this increase was not proportional to rate of application (***Table 2***). In a previous study at the same research site, Harmel et al. (2009) found lower levels of NO_3^--N in runoff from PL-amended plots than those that received chemical fertilizer, which was attributed to the slow mineralization of organic N in PL. The results of the current study substantiate these findings, as demonstrated by higher concentrations of WEON, but not NO_3^-, as PL application rate increased from 9 to 13.4 Mg ha^{-1}.

Soil WEOC and WEON concentrations were dynamic and varied over time, reflecting instability of WEOM (***Figs. 1a and b***). Even with this variation over years, on average, WEOC and WEON were higher in grassland than cultivated plots, indicating that cropping practices promoted decomposition of soil WEOM. Despite variation, the accumulation of WEON can be clearly seen when PL application rate exceeded 9 Mg ha^{-1}. In addition, continuous application of PL at rates < 9 Mg ha^{-1} also increased WEON in both cultivated and pasture soils (***Fig. 1***).

Table 1. Annual fertilization and management properties of soils from the long-term study by Harmel et al. (2009, 2011).

Watershed	Annual PL rate (Mg ha^{-1})	Average annual N rate (kg ha^{-1})	Land use type
Y6 (Con)	-	146	Cultivated
Y13	4.5	196	Cultivated
Y10	6.7	231	Cultivated
W12	9.0	245	Cultivated
W13	11.2	289	Cultivated
Y8	13.4	338	Cultivated
SW12	-	-	Native pasture, hayed
SW17	-	-	Pasture, grazed
Y14	13.4	335	Pasture, hayed
W10	6.7	158	Pasture, hayed and grazed

Table 2. Average concentrations of inorganic N, WEOC, and WEON in soils under different fertilization and management strategies. Standard deviation in parentheses.

Watershed	NH_4-N	NO_3-N	WEOC	WEON	C:N
	mg kg^{-1}				ratio
Y6 (Con)	7.5 (2.8)	9.8 (6.6)	346 (83)	18.9 (6.5)	21
Y13	7.7 (3.8)	11.8 (9.1)	431 (109)	21.6 (4.8)	21
Y10	6.8 (3.0)	19.0 (10.9)	426 (77)	21.8 (4.7)	20
W12	6.7 (2.6)	19.5 (13.8)	443 (130)	22.1 (17.8)	21
W13	8.3 (3.1)	22.1 (17.9)	488 (140)	35.6 (16.6)	16
Y8	9.0 (3.5)	22.2 (13.4)	555 (229)	42.8 (26.5)	17
SW12	7.3 (3.0)	5.4 (3.2)	613 (108)	32.9 (12.5)	20
SW17	7.3 (3.5)	6.1 (5.5)	574 (141)	24.6 (6.5)	23
Y14	10.0 (7.1)	11.1 (7.4)	604 (120)	33.3 (8.8)	19
W10	7.4 (3.7)	8.1 (5.9)	610 (164)	27.6 (7.9)	23
Probability	0.75	0.0095	0.0004	0.0130	
LSD (0.05)	NA	5.4	61	6.6	

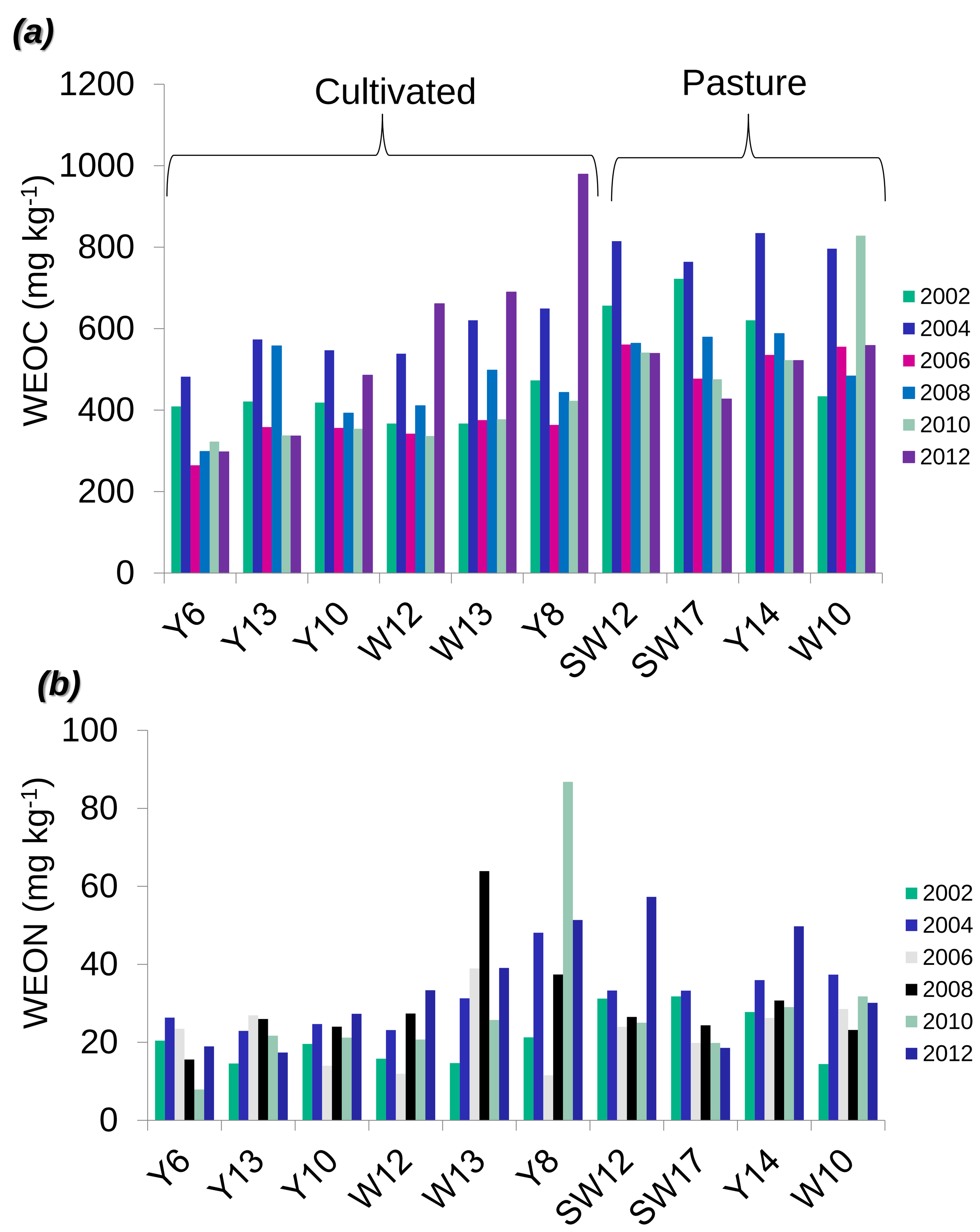

Fig. 1. Change from 2002 to 2012 in soil (***a***) **WEOC** and (***b***) **WEON** in cultivated fields and grassland amended with PL or chemical fertilizer.

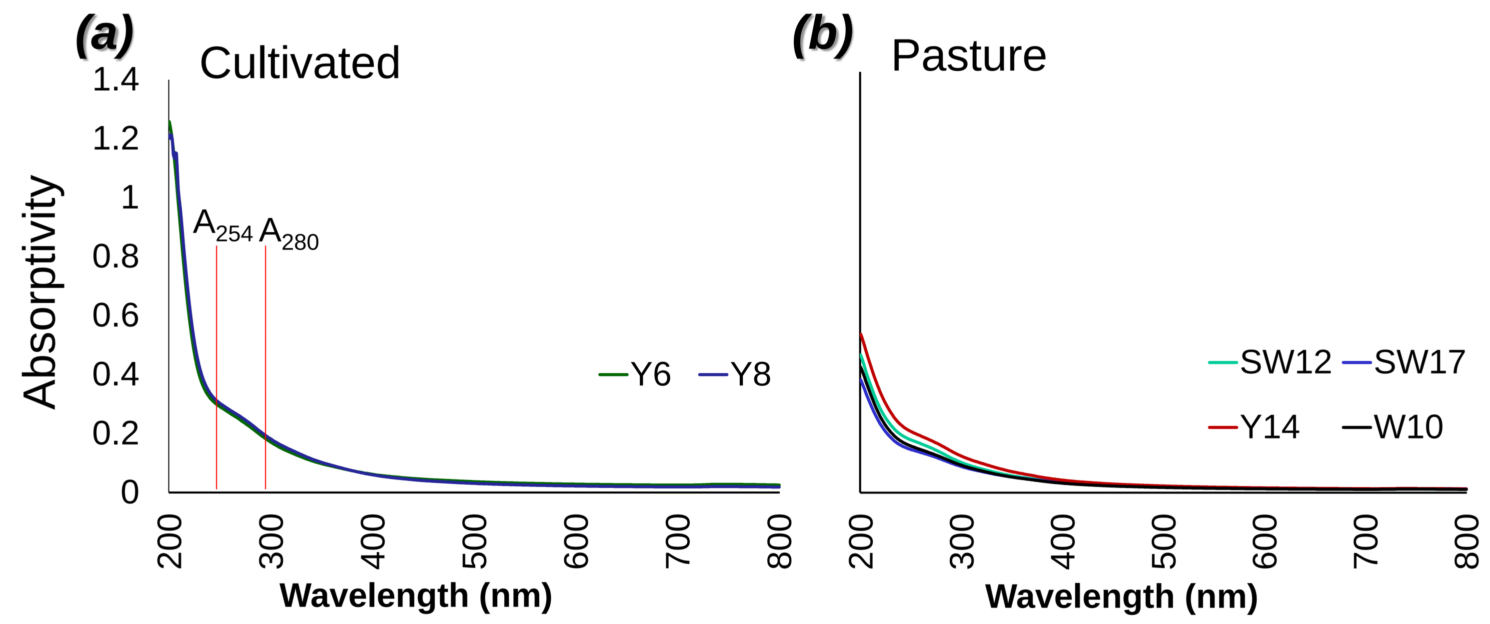

Fig. 3. Specific absorptivity of WEOM from (***a***) cropland soils that received inorganic fertilizer (Y6) or 13.4 Mg ha^{-1} poultry litter (Y8), and (***b***) native ungrazed pasture (SW12), grazed pasture (SW17), hayed pasture (Y14), and grazed hay field (W10).

Table 3. The UV-Vis spectral properties of WEOM from soils under different long-term fertilization and management strategies.

Watershed	$SUVA_{254}$	$SUVA_{280}$	E2/E3	E4/E6-1	E4/E6-2
Y6	0.20 (0.04)	0.16 (0.03)	3.43 (0.23)	2.22 (0.24)	1.64 (0.14)
Y13	0.19 (0.02)	0.15 (0.01)	3.48 (0.16)	2.44 (0.11)	1.74 (0.08)
Y10	0.21 (0.01)	0.17 (0.01)	3.53 (0.08)	2.62 (0.25)	1.82 (0.10)
W12	0.17 (0.02)	0.14 (0.02)	3.51 (0.10)	2.52 (0.19)	1.69 (0.09)
W13	0.18 (0.03)	0.14 (0.02)	3.48 (0.11)	2.70 (0.43)	1.80 (0.20)
Y8	0.22 (0.03)	0.18 (0.02)	3.45 (0.09)	2.77 (0.32)	1.92 (0.16)
SW12	0.17 (0.05)	0.13 (0.04)	3.57 (0.23)	2.47 (0.25)	1.81 (0.14)
SW17	0.14 (0.03)	0.11 (0.02)	3.15 (0.24)	2.17 (0.17)	1.67 (0.15)
Y14	0.20 (0.04)	0.16 (0.04)	3.37 (0.21)	2.60 (0.28)	1.90 (0.14)
W10	0.15 (0.02)	0.12 (0.01)	3.45 (0.21)	2.50 (0.23)	1.79 (0.08)
Probability	0.0005	0.0004	0.018	0.0001	0.0016
LSD (0.05)	0.017	0.014	0.10	0.07	0.12

Cultivated plots that received high rates of PL (Y8) or fertilizer (Y6) had higher $SUVA_{254}$ and $SUVA_{280}$ than hayed pasture (SW12, SW17, W10), indicating greater aromaticity and a lower degree of decomposition (***Fig.3, Table 3***). The spectral ratio of E2/E3 tended to be slightly higher for PL-amended soil than soil that received chemical fertilizer (***Table 3***). The E4/E6 ratio was higher following PL-amendment than application of chemical fertilizer and in manure-amended pasture. These ratios (E2/E3 and E4/E6) indicate that as PL application increases, concentrations of decomposable organic compounds in soil (Zhang et al., 2011).

The WEOM from grazed pasture had lower $SUVA_{254}$ and $SUVA_{280}$ than did native and hayed pasture (***Fig.3, Table 3***). In addition, WEOM from grazed pasture (SW17) had lower E2/E3 and E4/E6 ratios, indicating that OM in grazed pasture is well-decomposed and condensed, and that grazing promotes cycling of soluble OM in soil (***Table 3***).

Conclusions

There was a positive relationship between PL application rate and soil NO_3-N, WEOC, and WEON concentrations. A sharp increase was observed in concentrations of WEON when the PL application rate was > 9 Mg ha^{-1}, and lower C:N ratios indicated accumulation of organic N in soil. Grazing reduced soil WEON concentrations. The UV-Vis spectral properties of soil WEOM indicated that PL application resulted in the presence of more readily decomposable OM than that in soil fertilized with chemical fertilizer.

Acknowledgements

Laboratory analysis for this study was provided by Mr. Robert Van Veldhuizen and Ms. Darleen Masiak, Department of High Latitude Agriculture, University of Alaska Fairbanks.

References

Harmel, R.D., D.R. Smith, R.L. Haney, and M. Dozier. 2009. J. Soil Water Conserv. 64:400-412.
Harmel, R.D., R.L. Haney, and D.R. Smith. 2011. Soil Sci. 176(5):227-236.
Wilson, H.F. and M.A. Xenopoulos. 2009. Nat. Geosci. 2:37-41.
Zhang, M. Z. He, and A. Zhao. 2011. pp 61-82. *In*: Z. He (ed) Environmental Chemistry of Animal Manure. NOVA, Publishers, New York.
Zhao, M. Zhang, and Z. He. 2013. Commun. Soil Sci. Plant Anal. http://dx.doi.org/10.1080/00103624.2013.829086