Stratification of Soil Organic Matter and its Potential Impact on Water Runoff Quality

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Rationale

Soil organic matter is a key component of soil quality that sustains many vital soil functions by providing the energy, substrates, and biological diversity to support biological activity, which affects:

(1) aggregation; important for habitat space, O_2 supply, and preventing soil erosion
(2) infiltration; important for leaching, runoff, and water uptake
(3) decomposition; important for nutrient cycling and detoxification of amendments

Lack of residue cover and exposure of soil to high-intensity rainfall can result in poor aggregation, reduced plant water availability, erosion, and off-site impacts of sedimentation and poor water quality.

It is hypothesized that the degree of soil organic matter stratification could indicate soil quality or ecosystem functioning.

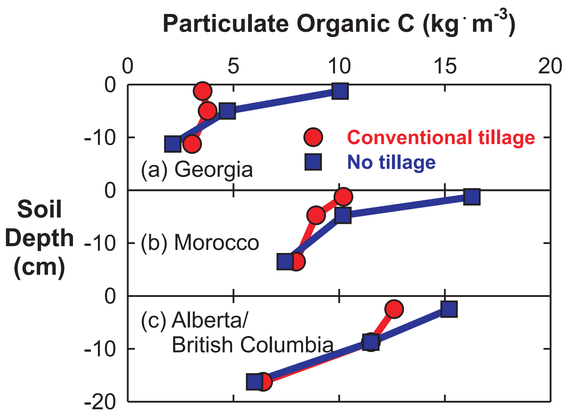
However, there is growing concern that continual fertilizer or manure application to pasture or conservation-tilled soils might lead to deterioration of surface water quality from the accumulation of P at the soil surface (Sharpley, 2003; Pote et al., 2006).

Objective

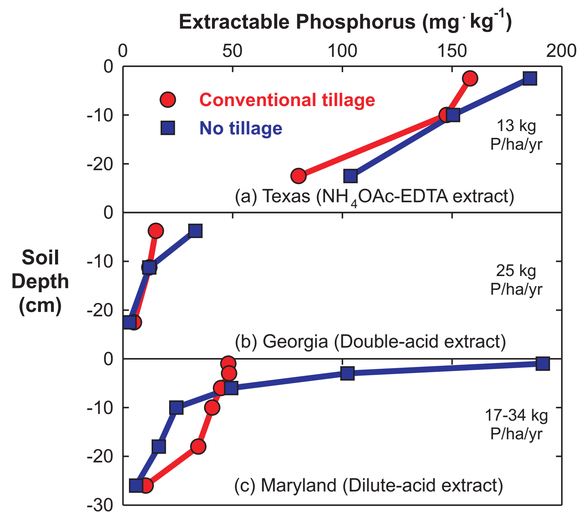
Review available literature on how adoption of conservation tillage, which often leads to stratification of soil organic matter, might affect water runoff volume and quality.

CT is conventional tillage
NT is no tillage

----- Stratification -----



Many soil organic matter fractions can become stratified with depth, including total, particulate, microbial biomass, and mineralizable C and N (Franzluebbers, 2002). The degree of stratification appears to depend upon the soil organic matter fraction, soil type, climatic conditions, management, and time. Data in Georgia from Franzluebbers et al. (1999), in Morocco from Mrabet et al. (2001), and in Alberta from Franzluebbers and Arshad (1997).



With the continuous application of P fertilizer, stratification of soil P can occur in the soil profile, especially under conservation tillage. At present, the accumulation of total and labile soil P at the surface under conservation tillage is viewed as a threat to water quality from runoff (Sharpley, 2003). Data in Texas from Franzluebbers and Hons (1996), in Georgia from Hargrove et al. (1982), and in Maryland from Weil et al. (1988).

------- Water Runoff Characteristics ------

Tillage	Soil Organic C	Extractable Soil P	Phosphorus Loss in Runoff: Total	Dissolved	Bioavailable
	Mg/ha	mg/kg	kg/ha/event		
Conventional	**32.5**	**39**	**1.31**	**0.02**	**0.21**
No tillage	**38.3**	**62**	**0.18**	**0.01**	**0.03**

On small (1.4 m^2) runoff plots in Wisconsin under maize, extractable soil P was greater under NT than CT at the soil surface, yet runoff loss of P fractions was mitigated by the presence of surface residue and high surface organic C. Data from Andraski et al. (1985).

Tillage	Runoff	Sediment	Nitrogen	Phosphorus
	mm	kg/ha		
Conventional	**46**	**3558**	**10.3**	**4.1**
No tillage	**10**	**18**	**0.5**	**0.3**

On runoff plots (112 m^2) in Virginia under wheat/soybean-maize, sediment and nutrient loss in runoff were greatly reduced with NT compared to CT. Dissolved N in runoff from NT was 50% of that from CT, but dissolved P in runoff from NT was 4 times greater than from CT. P loss with CT was 95% associated with sediment, while that with NT was 77% associated with the dissolved fraction. Data from Ross et al. (2001).

Tillage	Runoff	Soil Loss	Phosphorus in Runoff: Particulate	Bioavailable	Total
	%	Mg/ha	kg/ha/yr		
Bushland, Texas (54 cm rainfall)					
Stubble mulch	**5**	**0.9**	**0.5**	**0.1**	**0.5**
No tillage	**8**	**0.5**	**0.3**	**0.2**	**0.4**
Woodward, Oklahoma (60 cm rainfall)					
Disk tillage	**17**	**39.6**	**14.4**	**0.9**	**14.9**
No tillage	**23**	**1.9**	**1.8**	**1.5**	**2.9**
El Reno, Oklahoma (74 cm rainfall)					
Plow tillage	**20**	**12.8**	**5.7**	**1.2**	**5.9**
No tillage	**24**	**0.4**	**0.5**	**1.4**	**1.7**

On paired watersheds (2.8 ± 0.8 ha), mean soil loss and total P in runoff were lower under NT than under CT. Runoff loss of bioavailable P tended to be greater under NT than under CT, suggesting that overland flow of water without sediment transport was still carrying dissolved nutrients. Data from Sharpley et al. (1992).

Tillage	Soil Loss (Mg/ha/yr): Mississippi	Georgia
Conventional	**18**	**23**
No tillage	**3**	**<0.1**

Data from McGregor et al. (1975) in Mississippi and from Endale et al. (2000) in Georgia.

References

Andraski BJ, Mueller DH, Daniel TC. 1985. Phosphorus losses in runoff as affected by tillage. *Soil Science Society of America Journal* 49, 1523-1527.
Endale DM, Schomberg HH, Steiner JL. 2000. Long term sediment yield and mitigation in a small Southern Piedmont watershed. *International Journal of Sediment Research* 14, 60-68.
Franzluebbers AJ. 2002. Soil organic matter stratification ratio as an indicator of soil quality. *Soil and Tillage Research* 66, 95-106.
Franzluebbers AJ, Arshad MA. 1997. Particulate organic carbon content and potential mineralization as affected by tillage and texture. *Soil Science Society of America Journal* 61, 1382-1386.
Franzluebbers AJ, Hons FM. 1996. Soil-profile distribution of primary and secondary plant-available nutrients under conventional and no tillage. *Soil and Tillage Research* 39, 229-239.
Franzluebbers AJ, Langdale GW, Schomberg HH. 1999. Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. *Soil Science Society of America Journal* 63, 349-355.
Hargrove WL, Reid JT, Touchton JT, Gallaher RN. 1982. Influence of tillage practices on the fertility status of an acid soil double-cropped to wheat and soybeans. *Agronomy Journal* 74, 684-687.
McGregor KC, Greer JD, Gurley GE. 1975. Erosion control with no-tillage cropping practice. *Transactions of the ASAE* 18, 918-920.
Mrabet R, Saber N, El-Brahli A, Lahlou S, Bessam F. 2001. Total, particulate organic matter and structural stability of a Calcixeroll soil under different wheat rotations and tillage systems in a semiarid area of Morocco. *Soil and Tillage Research* 57, 225-235.
Pote DH, Kingery WL, Aiken GE, Han FX, Moore PA Jr. 2006. Incorporating granular inorganic fertilizer into perennial gassland soils to improve water quality. *Journal of Soil and Water Conservation* 61, 1-7.
Ross PH, Davis PH, Heath VL. 2001. Water quality improvement resulting from continuous no-tillage practices: Final report. Virginia Polytechnic Institute and State University, Blacksburg VA.
Sharpley AN. 2003. Soil mixing to decrease surface stratification of phosphorus in manured soils. *Journal of Environmental Quality* 32, 1375-1384.
Sharpley AN, Smith SJ, Jones OR, Berg WA, Coleman GA. 1992. The transport of bioavailable P in agricultural runoff. *Journal of Environmental Quality* 21, 30-35.
Weil RR, Benedetto PW, Sikora LJ, Bandel VA. 1988. Influence of tillage practices on phosphorus distribution and forms in three Ultisols. *Agronomy Journal* 80, 503-509.

Summary and Conclusions

Conservation tillage generally reduces water runoff volume and sediment transport. Unfortunately, few water quality studies have data reporting soil organic matter and its stratification with depth, which could be a key indicator linking soil and water quality.

Total loss of nutrients is often reduced with conservation tillage, because of a reduction in sediment-borne nutrients.

Bioavailable P in water runoff may be a threat to water quality, although multi-season and multi-year data describing field-scale management impacts on water runoff characteristics are needed.

Interactions of nutrients with surface residue and soil organic matter may be complex, but could be the key to developing sustainable soil management systems.

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