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Chapter 9

THE ROLE OF MANAGEMENT AND LANDSCAPE ON AGGREGATE CHARACTERISTICS WITHIN THE SOIL ACTIVE LAYER

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ABSTRACT

Within agricultural soils, the active layer is by far the most dynamic in response to management. Tillage fragments the structure of the soil, breaking down aggregate size fractions and weakening soil aggregates and

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reducing their resilience to mechanical and hydrological forces. This can also dampen biological activity through alterations of the soil microclimate. With precipitation patterns changing to more extreme rainfall events, agricultural soils will be expected to handle larger volumes of incoming rainfall in a shorter amount of time. Certain management practices may encourage infiltration and remove landscape effects by increasing residue cover or cover crops, which can absorb raindrop impact and disrupt flowpath connectivity. Quantifying the soil aggregate characteristics (size distribution and stability) within the active layer may provide key information into tillage disturbance and unveil landscape processes. In this chapter we discuss some methods of determining these characteristics.

Keywords: aggregate stability, management, landscape processes, soil active layer, raindrop impact, biological activity

INTRODUCTION

The structure of the soil relates to the distribution of aggregates size fractions and ability to maintain pore spacing under applied forcing (Diaz-Zorita et al., 2002). Within the cracks and confines of the soil lives a vast population of microorganisms, critical in the decomposing of organic material and nutrient cycling (Gougoulias et al., 2014). Soil microbes also produce a mixture of gummy substances (e.g., polysaccharides) that cement aggregates and aid in formation (Lehmann and Rillig, 2015). Soil fertility and production rates have been positively associated with soil with higher microbial biomass, organic matter and aggregate stability (Hatfield et al., 2018).

In agricultural landscapes the soil active layer (top 5-10 cm) is at the interface of dynamic exchanges of water, gas and nutrient fluxes. The bulk of soil CO_2 respiration as an indicator for microbial activity originates from these top soil layers (Hicks Pries et al., 2017; Xiao et al., 2015). During a rainfall event, aggregates within the soil active layer are subjected to hydrologic forces. In addition to the rainfall-induced breakdown of surface aggregates, rainwater can also penetrate void spaces within the aggregate structure causing the aggregate to rupture due to building excess internal pore pressure (Wacha et al., 2018). The finer grained encapsulated material within the aggregates can accumulate and clog pore spaces. As more pore space becomes clogged, the soil active layer begins to restrict water movement into the soil column, dampening infiltration and causing ponding (Hatfield et al., 2017). Due to a collapsing structure and unstable microclimatic conditions for soil microbes, biological activity decreases which further degrades soil conditions (Figure 1).

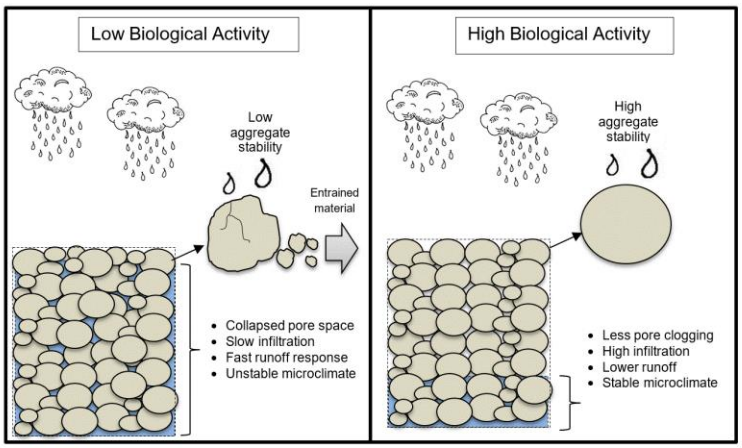

Figure 1. Schematic comparing the impact of soil biological activity on stability and soil-water interactions.

Extreme precipitation events have been increasing over the past decades worldwide and throughout the United States, especially in the Midwest (Pryor et al., 2014; Prein et al., 2017). When these episodic, high magnitude storm events hit, agricultural soils will be expected to handle large volumes of incoming rainfall in a shorter amount of time (Rosenzweig et al., 2001). The soil active layer may act as a regulator or restrictor of water moving vertically (down) into the soil column based on the ability to maintain pore spacing under hydrological forcing (Six et al., 2000). A regulating layer allows water to infiltrate into the soil while a restricted layer instigates runoff. During heavy rainfall, these effects can become more pronounced as runoff fluxes from a collection of fields (hillslopes) may overload drainage networks, triggering flooding events, amplify fluvial erosion and mass failure of the stream banks (Papanicolaou et al., 2017). The adoption of certain conservation management practices and their response to the structure of the soil active layer may be critical in managing these fluxes during intense storm events.

In this chapter we will demonstrate on the example of Midwestern US agriculture how soil and crop management in the agricultural landscape impact the resilience of soil aggregates during rain events, and which amelioration methods exist for growers.

ROLE OF MANAGEMENT

Crop production in the US Midwest is constrained within a 5-6 month growing season window, with the majority of these cropping systems being rain fed with the bulk of precipitation being delivered during late spring to early summer months. During the early parts of the growing season, the crop canopy is negligible, which along with surface residue can act as a shield for the soil surface against raindrop impact (Martinez-Mena et al., 2000). Without the presence of cover, the kinetic energy of the falling raindrops can be transferred directly into the soil surface, which can dislodge soil fractions that can be swept away when overland flow conditions develop (Nearing et al., 2017). The rainfall-induced breakdown of surface aggregates can also promote crusting and influence the size selectivity or enrichment of material available for transport (Neave and Rayburg, 2007; Shi et al., 2017). Soil surfaces without an established cover may also be directly exposed to intense sunlight which can rapidly elevate surface temperatures (Mitchell et al., 2012). Bare soil surface temperatures in the US Midwest have been reported to exceed 120°F during the middle of the day (Hatfield et al., 2018a). Such amplified temperatures are not conducive for soil biology and may stress or even terminate crop production.

Management that increases surface residue may help protect the soil surface from direct raindrop impact and provide larger inputs of organic material and a stable microclimate for soil biology (Shaver et al., 2002; Trivedi et al., 2015). An important aspect of increasing the biological capacity within the soil is to provide more stable soil aggregates and enhance nutrient cycling (Hatfield and Walthall, 2015). To provide additional protection of the soil surface against raindrop impact during the bookends of the growing season, management practices have used cover crops, resulting in decreased runoff and soil loss (Kaspar et al., 2001; Zuazo and Pleguezuelo, 2009). The residue layer behaves as a passive blanket to the soil surface while the cover crops acts as an active blanket, promoting fresh supplies of organic material and microbial communities in addition to physical protection. Neglecting surface cover can result in enhanced rainsplash effects, which breaks down surface aggregates and dislodges soil particles making them vulnerable to flow entrainment (Papanicolaou et al., 2015).

Any tillage disturbance that removes cover increases the potential for surface sealing and crusting during a storm event. Tillage physically disrupts the soil active layer, fragmenting soil aggregates, causing the distribution of size fractions to become more pronounced in finer fractions to varying degree based on intensity (Wacha et al., 2018). In addition, sub-surface soil can be inverted and exposed to wetting and drying and raindrop impact (Six et al., 2000). Tillage incorporates surface residues in the soil, which sparks microbial decomposition and fluxes (losses) of carbon dioxide from the soil due to increased aeration and a fresh supply of labile material released from exposed soil aggregates (Roberts and Chan, 1990; Reicosky, 1997; Six et al., 2000). Tillage has a further down spiraling effect on soil aggregation due to a diminished organic matter supplies and providing unstable microclimatic conditions for the soil biology (Wardle and Parkinson, 1990; Hatfield et al., 2017).

ROLE OF LANDSCAPE

During high storm events the negative influences of management on the soil active layer may become pronounced when moving to the landscape scale. Agricultural landscapes consist of both eroding and depositional areas (Papanicolaou et al., 2015). When runoff is generated, organic material and aggregate fractions displaced with rainsplash is transported from interrill areas to various flowpathways called rills that in turn convey material to downslope positions (Figure 2; Govers and Poesen, 1988; Schiettecatte et al., 2008). The flow within the rill applies a shear stress to the bed to varying degree as a function of flow depth and gradient, and when this stress exceeds the critical erosional strength of the soil, the rill bed begins to erode, mobilizing and transporting various size fractions of material along the downslope (Wacha et al., 2018). Aggregate fractions entrained in the flow can be further subjected to hydraulic forces and breakdown during transport (Wang et al., 2017). Once the carrying capacity of the flow is exceeded, larger size fractions of material may begin to fall out of suspension and deposit. The redistribution (transport and deposition) of material across agricultural landscapes is highly regulated by slope, aspect, topographic curvature (convex vs concave) and roughness (Abban et al., 2017; Papanicolaou et al., 2018).

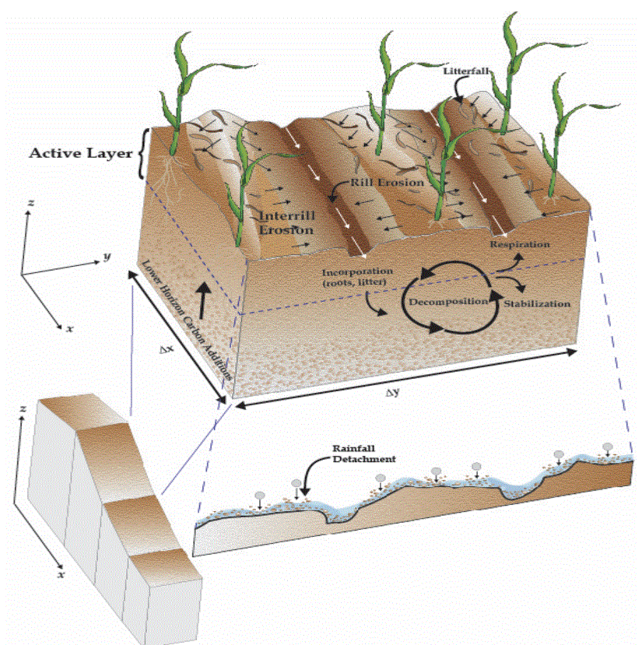

Figure 2. Conceptual sketch highlighting the landscape and biogeochemical processes impacting the soil active layer of an intensely managed agricultural hillslope.

As a result of the aggregate size fractions and organic material being redistributed during storm events, agricultural landscapes can have high spatial and temporal variability in soil texture, organic matter content, and structure (Huang et al., 2016). Variations in soil composition can heavily influence soil-water interactions and nutrient cycling. Several studies have observed higher microbial activity in depositional portions of the landscape compared to upslope, eroding sections (Wickings et al., 2016; Sekaran et al., 2018). These dynamics can also prompt yield gaps (difference between potential and actual yield) throughout the field which impacts available biomass and potential stocks of surface residue to varying degrees of residue management (Hatfield et al., 2018b).

SOIL AGGREGATE CHARACTERISTICS: WHAT DO THEY TELL US?

To better understand how management and landscape impact the regulative/restrictive tendencies of the soil active layer, it is important to focus on the aggregate characteristics (size distribution and stability) dictating soil structure. There are a collection of well-documented methods used to quantify aggregate characteristics by applying disruptive forces to the soil aggregates that mimic processes aggregates could be exposed to within the landscape (Kemper and Rosenau, 1986; Bronick and Lal, 2005). These methods include the use of dry sieving to assess relative degree of abrasion triggered through tillage events (Yang et al., 1998; Larney, 2008; Ciric et al., 2012) or exposure to hydrologic forcing through wet sieving or rainfall simulator to assess aggregate breakdown via raindrop impact (Eynard et al., 2004; Wang et al., 2015a; Wacha et al., 2018). A brief synopsis of these methods follows and what information they can provide.

To determine the dry aggregate size distribution (DASD), air dried samples are run through a stack of sieves on a flat or rotary shaker (Perfect et al., 1993), using sieve sizes corresponding to significant breaks in aggregate classification (Tisdall and Oades, 1982). The mass of aggregates recorded from each sieve are used to determine the DASD, and a dry mean weight diameter (DMWD), a characteristic diameter weighted proportionally to aggregate size (Ciric et al., 2012). Studies have looked the resistance of aggregates to abrasion by repeated dry sieving of the sample to determine changes in the DASD (Kemper and Rosenau, 1986).

To measure the disruption and breakdown of aggregates under the presence of water, studies have utilized wet sieving apparatus (Kemper and Rosenau, 1986; Catania et al., 2018). Similar to dry sieving methods, samples are placed atop a stack of sieves with the sieve stack being agitated (raising and lowering of sample in the water) for several minutes under a constant rate (Karlen et al., 2013). During the test, water fills the voids of the aggregates casing them to disintegrate completely or remain intact based on internal bond and cohesive strength (Amézketa, 1999). The proportion of water stable aggregates (WSA) of each size fraction is estimated from dry masses retained on sieves, which allows for a wet mean weight diameter (WMWD) of the stable fractions to be quantified.

Additional studies have used rainfall simulators to better reflect the influence of raindrop impact on the breakdown of surface aggregates (Almajmaie et al., 2017; Shi et al., 2017). A calibrated simulator applies kinetic energy through a fixed rainfall intensity to the samples placed atop a sieve to assess resilience (Moebius et al., 2007; Wacha et al., 2018). Aggregate fractions can be broken down directly by raindrop impact or by the building of internal pressure as water fills void spaces (Farres, 1980). These methods can also provide insight into erosion potential by looking the manner in which aggregates break down and what size fractions are available for transport during a rainfall event (Hu et al., 2013; Papanicolaou et al., 2015).

Each of the above-mentioned methods used to quantify aggregate characteristics provides some level of insight into the impact of management and landscape processes (Bronick and Lal, 2005). The DASD and DMWD have been used extensively in studies evaluating differences in tillage intensity, seedbed structure and susceptibility to erosion processes (Yang et al., 1998; Eynard et al., 2004; Larney, 2008). Based on a given intensity, tillage events can reshape the size distribution of aggregates within the soil, thereby altering supplies of organic matter and disrupting pore continuity (Arsahd et al., 1990; Wang et al., 2015b). Elliot and Efetha (1999) reported a 37% increase in DMWD, 42% higher infiltration, and 31% more soil organic carbon after a decade of no-till management. In a similar finding, Eynard (2004) seen a 32% increase in DMWD in the top 5 cm after 10 years of no-till conversion. The DASD has also been used to describe the heterogeneity of microbial community profiles (Schutter and Dick, 2002) and nutrient composition (Whalen and Change, 2002) amongst various aggregate size fractions. Microbial communities differ with respect to aggregate size fractions, which creates a complex environment for microbes within the active layer (Li et al., 2015). Bacteria, fungal and total biomass were reported to be 32% greater in aggregates under no-till compared to conventional tillage (Helgason et al., 2010). Tillage influences microbial biomass and activity, with variations most pronounced in macroaggregate fractions (Gupta and Germida, 1988; Yang and Wander, 1998).

The proportion of water stable aggregates (WSA) have also been widely used to distinguish between management (Shaver et al., 2002; Cantón et al., 2009; Pulido Moncada et al., 2013; Li et al., 2015). Tillage negatively impacts aggregation processes directly by altering the size distribution of aggregate fractions, supply of organic matter, and biological activity through changes in soil microclimate (Hatfield et al., 2017). In a study comparing conventional and no-till systems, Franzluebbers and Arshad (1996) observed significantly lower WSA and MWD in the top soil of the tilled system. These trends resound in other agricultural study sites assessing the impact of tillage intensity on stable aggregates (Amezketa, 1999; Pikul et al., 2009; Karlen et al., 2013). Additionally, when assessing the stability of soil aggregates under hydrologic forcing (rainfall), stability was found to decrease with increasing tillage intensity (Moebius et al., 2007; Wacha et al., 2018).

In terms of landscape, significant relationships have been observed between stability and profile curvature, as more stable aggregates have been reported in convex areas where flow and erosion potential are lower (Cantón et al., 2009). Stability and DMWD values were shown to decrease along the downslope, due in part to additional fluvial forces applied to the soil aggregate fractions during transport (Wacha et al., 2018). The orientation of tillage-induced roughness elements (contour ridge till) against downslope flowpaths was found to significantly disrupt hydraulic conductivity of the flow, thereby homogenizing aggregate characteristics. Other studies have reported positive correlation between DASD and WSA (Yang and Wander, 1998; Eynard, 2004; Ciric et al., 2012), and observed similar trends in WSA along cultivated landscapes (Martz, 1992; Changere and Lal, 1997).

CONCLUSION

An enhanced understanding of management impact on soil aggregates within the soil active layer can help identify effective conservation practices for producers, especially to protect against rainfall and storm events. As we better understand the dynamics of aggregate characteristics within the soil active layer, we can better understand how to improve and implement management practices that will lead to less runoff, erosion and enhance the environment.

Soil biological activity is essential to the development of a productive, healthy soil. This begins by providing and maintaining a stable microclimate that reduces temperature variability and regulates soil water, maintains an attractive food source to supply nutrients for microbial activity. Soil aggregates can become more resilient when microbial activity is enhanced and we begin to treat the soil as an ecological system that protects soil biology from physical and hydrologic forces (Hatfield et al., 2017). Our understanding of these processes is evolving through various metrics used to quantify changes in soil aggregate characteristics within the soil active layer. Increased stability of surface aggregates can decrease rainsplash effects, thereby limiting the amount material available for transported during an event.

Complimenting improved residue management is the selection of reduced or no-till practices as well as the use of cover crops that decrease disturbance to the active layer, allowing time-sensitive aggregation processes occur.

REFERENCES

Abban, B. K., Papanicolaou, A. T., Giannopoulos, C. P., Dermisis, D. C., Wacha, K. M., Wilson, C. G., & Elhakeem, M. (2017). *Quantifying the changes of soil surface microroughness due to rainfall impact on a smooth surface*, *24*(3), 569.

Almajmaie, A., Hardie, M., Acuna, T., & Birch, C. (2017). Evaluation of methods for determining soil aggregate stability. *Soil and Tillage Research*, *167*, 39-45.

Amezketa, E. (1999). Soil aggregate stability: a review. *Journal of sustainable agriculture*, *14*(2-3), 83-151.

Arshad, M. A., Schnitzer, M., Angers, D. A., & Ripmeester, J. A. (1990). Effects of till vs no-till on the quality of soil organic matter. *Soil Biology and Biochemistry*, *22*(5), 595-599.

Bronick, C. J., & Lal, R. (2005). Soil structure and management: a review. *Geoderma*, *124*(1-2), 3-22.

Cantón, Y., Solé-Benet, A., Asensio, C., Chamizo, S., & Puigdefábregas, J. (2009). Aggregate stability in range sandy loam soils relationships with runoff and erosion. *Catena*, *77*(3), 192-199.

Carter, M. R. (1992). Influence of reduced tillage systems on organic matter, microbial biomass, macro-aggregate distribution and structural stability of the surface soil in a humid climate. *Soil and Tillage Research*, *23*(4), 361-372.

Catania, P., Badalucco, L., Laudicina, V. A., & Vallone, M. (2018). Effects of tilling methods on soil penetration resistance, organic carbon and water stable aggregates in a vineyard of semiarid Mediterranean environment. *Environmental earth sciences*, *77*(9), 348.

Changere, A., & Lal, R. (1997). Slope position and erosional effects on soil properties and corn production on a Miamian soil in central Ohio. *Journal of Sustainable Agriculture*, *11*(1), 5-21.

Ciric, V., Manojlovic, M., Nesic, L., & Belic, M. (2012). Soil dry aggregate size distribution: effects of soil type and land use. *Journal of soil science and plant nutrition*, *12*(4), 689-703.

Dıaz-Zorita, M., Perfect, E., & Grove, J. H. (2002). Disruptive methods for assessing soil structure. *Soil and Tillage Research*, *64*(1-2), 3-22.

Elliott, J. A., & Efetha, A. A. (1999). Influence of tillage and cropping system on soil organic matter, structure and infiltration in a rolling landscape. *Canadian Journal of Soil Science*, *79*(3), 457-463.

Eynard, A., Schumacher, T. E., Lindstrom, M. J., & Malo, D. D. (2004). Aggregate sizes and stability in cultivated South Dakota prairie Ustolls and Usterts. *Soil Science Society of America Journal*, *68*(4), 1360-1365.

Farres, P. J. (1980). Some observations on the stability of soil aggregates to raindrop impact. *Catena*, *7*(2-3), 223-231.

Food and Agriculture Organization of the United Nations (2019). *FAOSTAT Statistics Database.* Rome: FAO, data acquired: 3/8/2019.

Franzluebbers, A. J., & Arshad, M. A. (1996). Water-stable aggregation and organic matter in four soils under conventional and zero tillage. *Canadian Journal of Soil Science*, *76*(3), 387-393.

Gougoulias, C., Clark, J. M., & Shaw, L. J. (2014). The role of soil microbes in the global carbon cycle: tracking the below-ground microbial processing of plant-derived carbon for manipulating carbon dynamics in agricultural systems. *Journal of the Science of Food and Agriculture*, *94*(12), 2362-2371.

Govers, G., & Poesen, J. (1988). Assessment of the interrill and rill contributions to total soil loss from an upland field plot. *Geomorphology*, *1*(4), 343-354.

Gupta, V. V. S. R., & Germida, J. J. (1988). Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. *Soil Biology and Biochemistry*, *20*(6), 777-786.

Hatfield, J. L., Allmaras, R. R., Rehm, G. W., & Lowery, B. (1998). Ridge tillage for corn and soybean production: environmental quality impacts. *Soil and tillage research*, *48*(3), 145-154.

Hatfield, J. L., & Walthall, C. L. (2015). Soil biological fertility: Foundation for the next revolution in agriculture? *Communications in soil science and plant analysis*, *46*(6), 753-762.

Hatfield, J. L., & Dold, C. (2017). Climate Variability Effects on Agriculture Land Use and Soil Services. In *Soil Health and Intensification of Agroecosytems*, pp. 25-50. Academic Press.

Hatfield, J. L., K. Wacha, and C. Dold. (2018a). Why is soil organic matter so important? *Crops Soils* 51:4-55. doi:10.2134/cs2018.51.0205.

Hatfield, J. L., Wright-Morton, L., & Hall, B. (2018b). Vulnerability of grain crops and croplands in the Midwest to climatic variability and adaptation strategies. *Climatic Change*, *146*(1-2), 263-275.

Helgason, B. L., Walley, F. L., & Germida, J. J. (2010). No-till soil management increases microbial biomass and alters community profiles in soil aggregates. *Applied Soil Ecology*, *46*(3), 390-397.

Hu, Y., Fister, W., & Kuhn, N. (2013). Temporal variation of SOC enrichment from interrill erosion over prolonged rainfall simulations. *Agriculture*, *3*(4), 726-740.

Hicks Pries, C. E., Castanha, C., Porras, R. C., & Torn, M. S. (2017). The whole-soil carbon flux in response to warming. Science, 355(6332), 1420-1423. http://science.sciencemag.org/content/sci/355/6332/1420.full.pdf

Huang, X., Shi, Z. H., Zhu, H. D., Zhang, H. Y., Ai, L., & Yin, W. (2016). Soil moisture dynamics within soil profiles and associated environmental controls. *Catena*, *136*, 189-196.

Karlen, D. L., Cambardella, C. A., Kovar, J. L., & Colvin, T. S. (2013). Soil quality response to long-term tillage and crop rotation practices. *Soil and Tillage Research*, *133*, 54-64.

Kaspar, T. C., Radke, J. K., & Laflen, J. M. (2001). Small grain cover crops and wheel traffic effects on infiltration, runoff, and erosion. *Journal of Soil and Water Conservation, 56*(2), 160-164.

Kemper, W. D., & Rosenau, R. C. (1986). *Aggregate stability and size distribution*.

Larney, F. J. (2008). Dry-aggregate size distribution. *Soil sampling and methods of analysis*, 821-31.

Lehmann, A., & Rillig, M. C. (2015). Understanding mechanisms of soil biota involvement in soil aggregation: A way forward with saprobic fungi? *Soil Biology and Biochemistry, 88*, 298-302.

Li, N., Yao, S. H., Qiao, Y. F., Zou, W. X., You, M. Y., Han, X. Z., & Zhang, B. (2015). Separation of soil microbial community structure by aggregate size to a large extent under agricultural practices during early pedogenesis of a Mollisol. *Applied Soil Ecology*, *88*, 9-20.

Martz, L. W. (1992). The variation of soil erodibility with slope position in a cultivated Canadian prairie landscape. *Earth Surface Processes and Landforms*, *17*(6), 543-556.

Mitchell, J., Singh, P., Wallender, W., Munk, D., Wroble, J., Horwath, W., ... & Hanson, B. (2012). No-tillage and high-residue practices reduce soil water evaporation. *California Agriculture*, *66*(2), 55-61.

Martinez-Mena, M., Rogel, J. A., Albaladejo, J., & Castillo, V. M. (2000). Influence of vegetal cover on sediment particle size distribution in natural rainfall conditions in a semiarid environment. *Catena*, *38*(3), 175-190.

Moebius, B. N., van Es, H. M., Schindelbeck, R. R., Idowu, O. J., Clune, D. J., & Thies, J. E. (2007). Evaluation of laboratory-measured soil properties as indicators of soil physical quality. *Soil science*, *172*(11), 895-912.

Nearing, M. A., Yin, S. Q., Borrelli, P., & Polyakov, V. O. (2017). Rainfall erosivity: An historical review. *Catena*, *157*, 357-362.

Neave, M., & Rayburg, S. (2007). A field investigation into the effects of progressive rainfall-induced soil seal and crust development on runoff and erosion rates: The impact of surface cover. *Geomorphology*, *87*(4), 378-390.

Papanicolaou, A. T., Wacha, K. M., Abban, B. K., Wilson, C. G., Hatfield, J. L., Stanier, C. O., & Filley, T. R. (2015). From soilscapes to landscapes: A landscape-oriented approach to simulate soil organic carbon dynamics in intensively managed landscapes. *Journal of Geophysical Research: Biogeosciences*, *120*(11), 2375-2401.

Papanicolaou, A. T., Wilson, C. G., Tsakiris, A. G., Sutarto, T. E., Bertrand, F., Rinaldi, M., ... & Langendoen, E. (2017). Understanding mass fluvial erosion along a bank profile: using PEEP technology for quantifying retreat lengths and identifying event timing. *Earth Surface Processes and Landforms*, *42*(11), 1717-1732.

Papanicolaou, A. N., Abban, B. K., Dermisis, D. C., Giannopoulos, C. P., Flanagan, D. C., Frankenberger, J. R., & Wacha, K. M. (2018). Flow resistance interactions on hillslopes with heterogeneous attributes: Effects on runoff hydrograph characteristics. *Water Resources Research*, *54*(1), 359-380.

Perfect, E., Kay, B. D., Ferguson, J. A., Da Silva, A. P., & Denholm, K. A. (1993). Comparison of functions for characterizing the dry aggregate size distribution of tilled soil. *Soil and tillage research*, *28*(2), 123-139.

Pikul, J. L., Chilom, G., Rice, J., Eynard, A., Schumacher, T. E., Nichols, K., ... & Ellsbury, M. (2009). Organic matter and water stability of field aggregates affected by tillage in South Dakota. *Soil Science Society of America Journal*, *73*(1), 197-206.

Prein, A. F., Rasmussen, R. M., Ikeda, K., Liu, C., Clark, M. P., & Holland, G. J. (2017). The future intensification of hourly precipitation extremes. *Nature Climate Change*, *7*(1), 48.

Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson, (2014): Ch. 18: Midwest. *Climate Change Impacts in the United States: The Third National Climate Assessment,* J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N.

Pulido Moncada, M., Gabriels, D., Cornelis, W., & Lobo, D. (2015). Comparing aggregate stability tests for soil physical quality indicators. *Land degradation & development*, *26*(8), 843-852.

Reicosky, D. C. (1997). Tillage-induced CO 2 emission from soil. *Nutrient cycling in agroecosystems*, *49*(1-3), 273-285.

Roberts, W. P., & Chan, K. Y. (1990). Tillage-induced increases in carbon dioxide loss from soil. *Soil and Tillage Research*, *17*(1-2), 143-151.

Rosenzweig, C., Iglesias, A., Yang, X. B., Epstein, P. R., & Chivian, E. (2001). Climate change and extreme weather events; implications for food production, plant diseases, and pests. *Global change & human health*, *2*(2), 90-104.

Schiettecatte, W., Gabriels, D., Cornelis, W. M., & Hofman, G. (2008). Enrichment of organic carbon in sediment transport by interrill and rill erosion processes. *Soil Science Society of America Journal*, *72*(1), 50-55.

Schutter, M. E., & Dick, R. P. (2002). Microbial community profiles and activities among aggregates of winter fallow and cover-cropped soil. *Soil Science Society of America Journal*, *66*(1), 142-153.

Sekaran, U., McCoy, C., Kumar, S., & Subramanian, S. (2018). Soil microbial community structure and enzymatic activity responses to nitrogen management and landscape positions in switchgrass (Panicum virgatum L.). *GCB Bioenergy*.

Shaver, T. M., Peterson, G. A., Ahuja, L. R., Westfall, D. G., Sherrod, L. A., & Dunn, G. (2002). Surface soil physical properties after twelve years of dryland no-till management. *Soil Science Society of America Journal*, *66*(4), 1296-1303.

Shi, P., Arter, C., Liu, X., Keller, M., & Schulin, R. (2017a). Soil aggregate stability and size-selective sediment transport with surface runoff as affected by organic residue amendment. *Science of the Total Environment*, *607,* 95-102.

Shi, P., Thorlacius, S., Keller, T., Keller, M., & Schulin, R. (2017b). Soil aggregate breakdown in a field experiment with different rainfall intensities and initial soil water contents. *European Journal of Soil Science*, *68*(6), 853-863.

Six, J., Elliott, E. T., & Paustian, K. (2000). Soil structure and soil organic matter II. A normalized stability index and the effect of mineralogy. *Soil Science Society of America Journal*, *64*(3), 1042-1049.

Tisdall, J. M., & Oades, J. (1982). Organic matter and water-stable aggregates in soils. *Journal of soil science*, *33*(2), 141-163.

Trivedi, P., Rochester, I. J., Trivedi, C., Van Nostrand, J. D., Zhou, J., Karunaratne, S., ... & Singh, B. K. (2015). Soil aggregate size mediates the impacts of cropping regimes on soil carbon and microbial communities. *Soil Biology and Biochemistry*, *91*, 169-181.

Wacha, K., Papanicolaou, A., Giannopoulos, C., Abban, B., Wilson, C., Zhou, S., & Hou, T. (2018). The Role of Hydraulic Connectivity and Management on Soil Aggregate Size and Stability in the Clear Creek Watershed, Iowa. *Geosciences*, *8*(12), 470.

Wang, Z., S. Doetterl, M. Vanclooster, B. van Wesemael, and K. Van Oost (2015a), Constraining a coupled erosion and soil organic carbon model using hillslope-scale patterns of carbon stocks and pool composition. *J. Geophys. Res. Biogeosci.*, 120, 452–465. doi: 10.1002/2014JG002768.

Wang, Y., Zhang, J. H., & Zhang, Z. H. (2015b). Influences of intensive tillage on water-stable aggregate distribution on a steep hillslope. *Soil and Tillage Research*, *151*, 82-92.

Wang, J. G., Yu, B., Yang, W., Cheng, J. N., Song, Y. R., & Cai, C. F. (2017). The abrasion of soil aggregate under different artificial rough beds in overland flow. *Catena*, *155*, 183-190.

Wardle, D. A., & Parkinson, D. (1990). Interactions between microclimatic variables and the soil microbial biomass. *Biology and Fertility of Soils*, *9*(3), 273-280.

Whalen, J. K., & Chang, C. (2002). Macroaggregate characteristics in cultivated soils after 25 annual manure applications. *Soil Science Society of America Journal*, *66*(5), 1637-1647.

Wickings, K., Grandy, A. S., & Kravchenko, A. N. (2016). Going with the flow: Landscape position drives differences in microbial biomass and activity in conventional, low input, and organic agricultural systems in the Midwestern US. *Agriculture, Ecosystems & Environment*, *218*, 1-10.

Xiao, X., Kuang, X., Sauer, T. J., Heitman, J. L., & Horton, R. (2015). Bare Soil Carbon Dioxide Fluxes with Time and Depth Determined by High-Resolution Gradient-Based Measurements and Surface Chambers. *Soil Science Society of America Journal*, 79(4), 1073-1083. http://dx.doi.org/10.2136/sssaj2015.02.0079.

Yang, X. M., & Wander, M. M. (1998). *Temporal changes in dry aggregate size and stability: tillage and crop effects on a silty loam Mollisol in Illinois*.

Zuazo, V. H. D., & Pleguezuelo, C. R. R. (2009). Soil-erosion and runoff prevention by plant covers: a review. In *Sustainable agriculture*, pp. 785-811. Springer, Dordrecht.