farmdoc DAILY

Agricultural, Consumer & Environmental Sciences | University of Illinois Urbana-Champaign

When It Rains, It Pours: Extreme Precipitation & Nutrient Loss, Part 1

Marin Skidmore and Jonathan Coppess

Department of Agricultural and Consumer Economics
University of Illinois

December 7, 2023

***farmdoc daily* (13): 222**

Gardner Policy Series

Recommended citation format: Skidmore, M. and J. Coppess. "When It Rains, It Pours: Extreme Precipitation & Nutrient Loss, Part 1." *farmdoc daily* (13): 222, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, December 7, 2023.

Permalink: https://farmdocdaily.illinois.edu/2023/12/when-it-rains-it-pours-extreme-precipitation-nutrient-loss-part-1.html

In 1914, the Morton Salt Company cleverly converted an 18th century English proverb ("it never rains but it pours") into a successful marketing slogan ("when it rains, it pours") (see e.g., Means, May 23, 2022; Meider, 2018; Barbour, 1963). Clever marketing aside, we generally understand the phrase to mean that when something bad happens, other bad things tend to happen at the same time. Among the many increased risks for farming from climate change is an increase in extreme precipitation, especially in the spring—2019 serves a recent reminder (Lee and Abatzoglou, 2023; US EPA, November 16, 2023; Time, August 11, 2023; Haverback and Curry, August 3, 2023; Gustin, May 2, 2021; NOAA, May 7, 2020; Schwartz, November 21, 2019; USDA, 2019; Yale, E360 Digest, May 2, 2019; Motha, 2011; Trenberth, 2011). With the proverbial "when it rains, it pours" in mind, we begin a series exploring recent research about the impacts of extreme participation on nutrient loss (Skidmore et al., 2023). The key takeaway is intuitive and critical: when something bad happens (extreme precipitation) the key to minimizing other bad from happening (nutrient loss) at the same time is to avoid excess nutrients being available to be lost. The farmer cannot control extreme events, but farmers do have some degree of control over whether excess nutrients are present on bare or frozen soils to be washed away. In other words, control what you can so that when it rains, it *doesn't* pour. The following serves as background to the series of articles.

Background: Nutrient Loss 101

To begin this series, we briefly discuss the background on the process by which nutrients are lost from farming and fields. Nutrients include the basic elements such as nitrogen and phosphorus necessary for plant growth, many of which are supplied in modern farming by synthetic fertilizers applied to the fields. Excess nutrients can be exported from farm fields and remain a major natural resource concern for farmers, policymakers, and all of us who depend on clean water. For the farmer, lost nutrients are lost profits, and most farmers have little interest in polluting public waters. The cost of nitrogen, for example, can range from $193 per ton (anhydrous ammonia) to as much as $760 per ton and this cost can vary significantly as farmers have experienced in the last 15 years (see e.g., *farmdoc daily*, September 19, 2023; September 12, 2023; August 29, 2023; August 15, 2023; August 1, 2023; June 13, 2023; February 28, 2023). A farmer's management of input cost such as fertilizer is a key driver of farm income, and

USDA's recent farm income forecasts are notable for the decline in fertilizer costs, helping overall farm income remain above average (USDA ERS, November 30, 2023).

Farmers face significant pressure to reduce nutrient losses for water quality reasons. High loads of nitrogen and phosphorus can lead to algae blooms in lakes and rivers (*Chicago Tribune*, November 18, 2021; *The Gazette*, October 2, 2022) or unsafe nitrate levels in private wells (*PBS Wisconsin*, December 1, 2022). For states in the Mississippi River watershed, runoff can reach the Gulf and contribute to the Gulf Hypoxic (or dead) Zone (NOAA). As one indication of the pressure to reduce nutrient losses, the States along the Mississippi have signed on to the Hypoxia Task Force and created state-level Nutrient Reduction Strategies (EPA). Illinois, for example, has operated a Nutrient Loss Reduction Strategy since 2015 (Illinois EPA, INLRS).

Arguably, the key finding for nutrient loss in research is consistent and has the added benefit of aligning with intuition and common sense: Nutrient losses nearly all occur during heavy rainfall and snow melt, particularly in non-irrigated production systems (Skidmore et al., 2023; Xia et al., 2020; Zopp et al., 2019). In Midwestern systems like Wisconsin, for example, half of all runoff comes from precipitation (either rain or snowmelt) when the ground was frozen (February and March), despite these only accounting for 11% of annual precipitation (USGS, 2011). On non-frozen ground, the highest runoff occurs in May and June, which is a period of "high-intensity and (or) repetitive rainfall events" leading to high soil moisture. Moreover, crop cover is minimal at the time.

Not all runoff creates the same nutrient losses. Runoff from frozen ground has the lowest concentration of suspended sediments, likely because there is less soil loss when the soil is frozen. This means the snowmelt losses are primarily of dissolved nutrients—these are nutrients sitting at the soil's surface, waiting to run off. In contrast, rainfall in May and June delivers more suspended sediment to surface water systems. These sediments include "legacy nutrients" that may have been applied decades ago and are still bound to soil today (Motew et al., 2017, Gentry et al., 2007). Furthermore, rain on frozen or bare ground leads to runoff, particularly when nutrients were spread since the last harvest. These conditions are perfect for overland flow, or transport of nutrients and soils along the surface to nearby streams.

Extreme precipitation events are also a big factor for nutrient and soil losses. Rain events categorized as ten-year-or-less (i.e., those we expect to occur at least once in every ten years) generate runoff 66% of the time. Twenty-five-or-more-year events generate runoff 82% of the time. Moreover, extreme events are more likely to generate soil loss, even compared to their impact on nutrient loss (*Wisconsin Discovery Farms*, 2021). Soil loss has a magnifying effect for nutrient loss, creating a feedback loop. For one, soil erosion is costly to farmers, and one study found that US corn growers spend half a billion dollars per year on fertilizer to make up for soil erosion (Jang et al., 2020). Moreover, researchers at North Dakota State estimate that 1 inch of lost topsoil costs $688 per acre in lost nutrients. These nutrients likely end up in surface water, further exacerbating water quality problems (Franzen, July 21, 2021).

The overarching findings of these and other studies is the importance of the soil conditions and practices at the time of precipitation. Precipitation on bare ground is a recipe for higher runoff, higher soil losses, and more sediment transport. In contrast, healthy soils—and especially those soils protected by crop cover—are less vulnerable to the heavy losses we observe around extreme precipitation events (*Farm Progress*, September 27, 2017). The bottom line also aligns with intuition and common sense: the weather is not in the farmer's control, nor can they do much about extreme precipitation and weather events that may only get worse with climate change. But some things are in the farmer's control: the farmer can take steps to decrease the amount of nutrients sitting on bare and frozen soils for snow melt, spring rains, and extreme events.

For nutrient losses, the key is controlling what can be controlled. Keep soils healthy and prevent erosion, as well as avoid excess nutrients on bare and frozen ground. Practices like cover cropping, conservation tillage, and buffer strips all have been shown to reduce nutrient loss. These practices, of course, come with costs. Conservation practices may also increase managerial challenges and production risk. Importantly, such practices are also investments in the soils, the fields, and the farm, in addition to reducing losses.

The gap between the costs and the benefits, including those due to different time horizons and off-farm benefits, are arguably the point of public policies. Policies can provide public investments in assisting farmers with successfully adopting and maintaining conservation practices. As discussed in previous articles, the conservation title of the Farm Bill makes significant investments in these practices and the Inflation Reduction Act of 2022 made additional investments specifically for soil health, nutrient loss reduction, and greenhouse gas emission reductions (see e.g., *farmdoc daily*, April 13, 2023; May 11, 2023; September 21, 2023; October 19, 2023). Those policies also face challenges such as insufficient funding for the demand and political challenges over priorities for funding (see e.g., *farmdoc daily*, September 28, 2023; November 16, 2023).

In conclusion, farmers can't control the weather, but they can take steps to prepare their land for ordinary and extreme precipitation. In future articles, we will explore further the findings of recent research that uses over a decade of data on land use and water quality across Wisconsin to retrospectively observe concentrations of nitrogen and phosphorus in surface water following precipitation events (Skidmore et al., 2023). We will differentiate by land use in the surrounding watershed as well as time of year to shed light on practices that reduce nutrient and soil losses during extreme precipitation events. We'll further review how soil health and soil cover are only going to get more important as variable and extreme precipitation become the norm.

References

Barbour, Frances M. "Some Uncommon Sources of Proverbs." *Midwest Folklore* 13, no. 2 (1963): 97-100.

Coppess, J. "A Question of Priorities: Additional Context for Inflation Reduction Act Conservation Funding." *farmdoc daily* (13):210, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, November 16, 2023.

Coppess, J. "Farm Bill 2023: NRCS Backlogs and the Conservation Bardo." *farmdoc daily* (13):177, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, September 28, 2023.

Coppess, J. "A View of the Farm Bill Through Policy Design, Part 7: ACEP and RCPP." *farmdoc daily* (13):192, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, October 19, 2023.

Coppess, J. "A View of the Farm Bill Through Policy Design, Part 6: Conservation Reserve Program." *farmdoc daily* (13):172, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, September 21, 2023.

Coppess, J. and A. Knepp. "A View of the Farm Bill Through Policy Design, Part 2: CSP." *farmdoc daily* (13):86, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, May 11, 2023.

Coppess, J. and A. Knepp. "A View of the Farm Bill Through Policy Design, Part 1: EQIP." *farmdoc daily* (13):69, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, April 13, 2023.

Gentry, L.E., David, M.B., Royer, T.V., Mitchell, C.A. and Starks, K.M. (2007), "Phosphorus Transport Pathways to Streams in Tile-Drained Agricultural Watersheds." J. Environ. Qual., 36: 408-415. https://doi.org/10.2134/jeq2006.0098

Jang, W. S., Neff, J. C., Im, Y., Doro, L., & Herrick, J. E. (2021). "The hidden costs of land degradation in US maize agriculture." *Earth's Future*, 9, e2020EF001641. https://doi.org/10.1029/2020EF001641

Lee, Seunghyun and John T Abatzoglou 2023 *Environ. Research Communications*. https://iopscience.iop.org/article/10.1088/2515-7620/acf919/meta.

Mieder, Wolfgang, "American Proverbs and Related Sayings," in Simon J. Bronner (ed.), *The Oxford Handbook of American Folklore and Folklife Studies*, Oxford Handbooks (2019; online edn, Oxford Academic, 7 Mar. 2018), https://doi.org/10.1093/oxfordhb/9780190840617.013.7.

Motew, M., Chen, X., Booth, E.G. *et al.* The Influence of Legacy P on Lake Water Quality in a Midwestern Agricultural Watershed. *Ecosystems* **20**, 1468–1482 (2017). https://doi.org/10.1007/s10021-017-0125-0

Motha, Raymond P. “Chapter 30: The Impact of Extreme Weather Events on Agriculture in the United States” (2011). Publications from USDA-ARS / UNL Faculty. 1311. https://digitalcommons.unl.edu/usdaarsfacpub/1311

Paulson, N., C. Zulauf, G. Schnitkey and J. Baltz. "Fertilizer Prices Continue Year-Long Decline from 2022 Peak." *farmdoc daily* (13):142, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, August 1, 2023.

Paulson, N., C. Zulauf, G. Schnitkey, J. Colussi and J. Baltz. "How Historic Were Fertilizer Prices in 2022?" *farmdoc daily* (13):165, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, September 12, 2023.

Paulson, N., C. Zulauf, G. Schnitkey, J. Colussi and J. Baltz. "Variability in Nitrogen Fertilizer Prices in Illinois Over the Last 15 Years." *farmdoc daily* (13):170, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, September 19, 2023.

Paulson, N., G. Schnitkey, C. Zulauf, J. Colussi and J. Baltz. "Fertilizer Prices Continue Decline and May Impact Farmers’ Nitrogen Decisions." *farmdoc daily* (13):150, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, August 15, 2023.

Schnitkey, G., N. Paulson, C. Zulauf and J. Baltz. "2024 Crop Budgets." *farmdoc daily* (13):157, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, August 29, 2023.

Schnitkey, G., N. Paulson, C. Zulauf and J. Baltz. "Fertilizer Prices and Company Profits Going into Spring 2023." *farmdoc daily* (13):36, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 28, 2023.

Schnitkey, G., N. Paulson, C. Zulauf and J. Baltz. "Nitrogen Fertilizer Prices Stabilize at High Levels in Spring 2023." *farmdoc daily* (13):108, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, June 13, 2023.

Schwartz, John. “A Wet Year Causes Farm Woes Far Beyond the Floodplains.” *The New York Times*. November 21, 2019. https://www.nytimes.com/2019/11/21/climate/farms-climate-change-crops.html.

Skidmore, M., Foltz, J., and Andarge, T. "The impact of extreme precipitation on nutrient runoff." *Journal of the Agricultural and Applied Economics Association.* 2023. https://onlinelibrary.wiley.com/doi/full/10.1002/jaa2.90?campaign=wolearlyview

Trenberth, Kevin E. “Changes in Precipitation with Climate Change.” *Climate Research* 47, no. 1-2 (2011): 123-138.

U.S. Department of Agriculture, Economic Research Service. *Farm Sector Income & Finances: Farm Sector Income Forecast*, November 30, 2023. https://www.ers.usda.gov/topics/farm-economy/farm-sector-income-finances/farm-sector-income-forecast/.

Xia, Yinfeng, Ming Zhang, Daniel C. W. Tsang, Nan Geng, Debao Lu, Lifang Zhu, Avanthi Deshani Igalavithana, et al. 2020. “Recent Advances in Control Technologies for Non-Point Source Pollution With Nitrogen and Phosphorous From Agricultural Runoff: Current Practices and Future Prospects.” *Applied Biological Chemistry* 63(1): 8. https://doi.org/10.1186/s13765-020-0493-6

Zopp, Zachariah P., Matthew D. Ruark, Anita M. Thompson, Todd D. Stuntebeck, Eric Cooley, Amber Radatz, and Timothy Radatz. 2019. “Effects of Manure and Tillage on Edge-of-Field Phosphorus Loss in Seasonally Frozen Landscapes.” *Journal of Environmental Quality* 48(4): 966–977. https://doi.org/10.2134/jeq2019.01.0011