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Environmental implications of redox dynamics in agricultural soils with subsurface drainage infrastructure

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Many agricultural soils are naturally poorly drained and require engineered subsurface drainage infrastructure, known as tiles, for successful row crop production. Many tile-drained soils still experience episodically high moisture, potentially driving temporal oscillations in redox reactions. Our previous laboratory experiments showed that oxic/anoxic fluctuations can release mineral-bound carbon and sustain the emissions of carbon dioxide and methane from these soils, yet the actual frequency and extent of in-situ redox dynamics remain difficult to evaluate. I will synthesize several unpublished datasets of iron (Fe) measured in soil extractions and water samples collected within and among Iowa agricultural fields over several years, where soils differed in inherent drainage properties as well as tile drainage intensity. All soils (0-10 cm depth) and sites sampled had detectable variation in 0.5 M HCl-extractable Fe(II) over time during periods of average precipitation, consistent with net Fe reduction and oxidation. The Fe(II) concentration measured within a given plot varied by up to three orders of magnitude over time and was generally greatest in topographic depressions, but elevated Fe(II) was also observed in hillslope soils following prolonged rainfall. Rates of potential Fe reduction measured in the lab under anoxic conditions were greatest in surface soils and declined several-fold with depth, likely due to carbon limitation, as illustrated by a >10-fold increase following glucose addition. A site with intensive modern tile drainage had the lowest in-situ soil Fe(II), but these soils readily produced Fe(II) in the lab, and rates were greatest in soils planted with diverse perennials as opposed to annual grain crops. Leaching of Fe(II) might have depleted soil-extractable Fe(II) in some cases, as indicated by sporadically high Fe(II) (0 – 132, median 3 uM) observed in water collected from subsoil lysimeters at one site. Overall, we conclude that surface-soil Fe redox cycling is a widespread phenomenon in these tile-drained agricultural soils. Consequently, mechanisms of Fe-mediated decomposition documented in controlled lab experiments can enhance our understanding of the distribution and dynamics of soil carbon across these agricultural landscapes and their response to management change, with key implications for “climate-smart” agricultural practices.