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Factors Controlling Content and Transformations of Dissolved Organic Matter Components in Agricultural Soils at Field and Global Scales

Abstract (English)

Dissolved organic matter (DOM)—operationally comprising dissolved organic carbon (DOC), nitrogen (DON), and phosphorus (DOP)—is the most mobile and bioactive fraction of soil organic matter (SOM). Yet its controls and responses across climates, managements, and depths remain insufficiently resolved. This thesis evaluates how nitrogen (N) addition, climate warming, and agricultural practices regulate DOM quantity and quality, and how cropping system and soil depth modify these effects. Analyses span global syntheses and a long-term field experiment to better capture SOM/DOM dynamics.

A global database (>6,799 observations) supported three meta-analyses: (i) 1,132 paired DOC observations from 103 studies on N addition; (ii) 321 DOC and 187 DON observations from 50 studies on warming; and (iii) 3,539 DOC, 196 CO_2, and 1,424 yield observations from 286, 15, and 92 studies on cropland management. The field component compared crop rotation versus monoculture, sampling 0–30, 30–60, and 60–90 cm, quantifying DOC, DON, DOP, optical indices (SUVA, E4/E6), and their drivers.

N addition increased SOC by 8.16% (humid) and 2.05% (non-humid). DOC and microbial biomass C (MBC) declined in humid regions (−2.49%, −2.60%) but increased in non-humid regions (+7.30%, +8.74%). Precipitation seasonality emerged as a universal driver; baseline SOC predicted DOC in humid regions, while N rate did so in non-humid regions. Soil pH reversed DOC associations between humidity regimes, underscoring the need for region-specific parameterization.

Warming decoupled C–N dynamics: mean DOC and MBC were unchanged, whereas SOC (−3.36%) and DOC:DON (−10.79%) decreased while DON (+8.84%) and NO_3^- (+13.12%) increased. Soil moisture governed DOC responses; nitrate availability predicted DON responses, indicating moisture–N interactions as the central mechanism of warming-induced C loss and nitrate accumulation.

Across croplands, all evaluated practices increased DOC, with the largest gains under mineral N + manure (NM, +78%) > manure (M, +50%) > N + straw (NS, +41%). The Abstract (English)

DOC/SOC ratio generally rose under NM, NS, M, straw (S), and mineral N; it was unchanged under conservation tillage and declined under biochar (−25%), consistent with biochar's stabilization bias. A new "DOC-efficiency" metric showed that DOC associated with mineral N, straw, and NM more effectively increased yields and lowered CO_2 intensity than DOC under conservation tillage or biochar, emphasizing management rate and duration as key design factors.
In the long-term field study, depth strongly structured DOM: DOC, DON, and DOP decreased with depth, while SUVA increased and E4/E6 decreased, indicating more aromatic, humified, high-molecular-weight DOM in subsoils. Cropping effects were modest and depth-limited: monoculture retained higher DOC at 60–90 cm; DON and DOP did not differ between systems. Random-forest analyses identified element-specific drivers (DOC: total N, total C, DOP; DON: DOC, depth, available P; DOP: humus, total P, available P), reflecting C–N–P coupling with distinct constraints.
Collectively, the findings establish a regime-specific, moisture-sensitive, and quality-aware framework for DOM dynamics: (i) N effects on DOC invert across humidity regimes; (ii) warming mobilizes reactive N while promoting net C loss via moisture-mediated DOC turnover; (iii) synchronizing C supply with N maximizes DOC's agronomic benefits while minimizing CO_2 intensity; and (iv) subsoils harbor more humified DOM shaped by depth and mineral interactions. The work delivers actionable parameters and diagnostics (soil pH, initial SOC, N rate, soil moisture, DOC-efficiency, E4/E6) to improve ecosystem models and guide climate-smart, depth-aware soil management.
Keywords: dissolved organic matter components, nitrogen addition, global climate warming, agricultural management, crop rotation vs. monoculture, spectroscopy, meta-analysis.

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