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AquaMEND: Reconciling multiple impacts of salinization on soil carbon biogeochemistry

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Coastal soil salinization, exacerbated by climate change, poses a global threat to ecosystem function and soil quality. Of particular concern are the consequences of soil salinization for below ground carbon cycling, as mounting evidence suggests that increased salinity drives changes in the quantity or quality of soil organic matter and carbon mineralization rates. Despite extensive research, consensus on the impact of salinity on belowground carbon cycling remains elusive. Salinity influences carbon cycling through direct effects on microbial activity and indirect alterations to soil physicochemical properties. The interplay of saltwater intrusion, cation exchange, pH, and soil organic carbon availability complicate our understanding of the impact of salinity on carbon cycling. Current models inadequately represent these complexities, relying on linear reduction functions that overlook specific physicochemical changes induced by salinity. To address this gap, we developed an integrated model framework, AquaMEND, that couples microbially explicit biogeochemical transformations with aqueous-phase biogeochemical processes. The model explicitly captures salinity-induced cation exchange and surface complexation, important processes governing solute chemistry and nutrient availability in soils. Together with salinity response functions that capture salinity impacts on both salt-sensitive and salt-resistant microbial processes, this model testbed allowed us to compare different process-based assumptions and understand how abiotic and biotic mechanisms respond individually and collectively to salinity and ultimately regulate organic and inorganic pools and fluxes. Leveraging soil characterizations across two contrasting upland-to-wetland transects, we further demonstrated how this new modeling capability can be used to capture divergent soil carbon responses to salinization mediated by soil physicochemistry.