Food, Fodder and Phosphorus: A Quantification of Long-Term Nutrient Legacies in Human-Impacted Watersheds

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Phosphorus (P) inputs to human-impacted watersheds have more than doubled over the last century in response to the use of fertilizers, detergents, and P additives in a range of products, from animal feed to motor oil. Although mass balance studies consistently show inputs of P exceeding outputs in human-impacted areas, particularly those under intensive agriculture, the forms and relative magnitudes of legacy P accumulation across the land-water continuum as well as their respective residence times within the landscape are still not well understood. In the present work, we have developed a parsimonious, process-based model, ELEMeNT-P, that pairs soil P dynamics with both erosion processes for simulation of surface P transport and a travel time-based approach for simulation of transport and retention along subsurface pathways. Using a more than 100-year trajectory of watershed P inputs to five Great Lakes watersheds, we have not only reconstructed total phosphorus yields at the outlets of these highly impacted catchments, but also estimate the magnitudes of P accumulation in reservoirs and surface soils as well as along subsurface pathways. As Lake Erie and other inland lakes continue to be impacted from eutrophication events and the occurrence of harmful algal blooms, even after significant implementation of improved nutrient management practices, such estimates of legacy P accumulation will be crucial to setting realistic targets for reducing P loading and for better understanding the contribution of P legacies to current and future lake nutrient dynamics.