Estimating the basin extent and persistence of legacy nutrient sources with dynamic SPARROW

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Abstract
Nutrients that have accumulated in storage repositories, such as soils, groundwaters, and riparian areas, in previous years or decades are lagged in their delivery to today's flowing rivers. We have reconceptualized the U.S. Geological Survey's SPARROW (SPAtially Referenced Regression On Watershed attributes) model into a dynamic mean seasonal configuration (dynamicSPARROW-MS) to provide a first-order approximation of load delivered to rivers from new within-season sources, such as crop fertilizers, versus nutrients that have accumulated in storage repositories during previous seasons. The standard long-term equilibrium SPARROW model was updated into a dynamic model by tracking the seasonal inputs and adding a seasonally varying storage term (additional input source) for each catchment (see figure 1 below). The storage term (*S*) operates seasonally by looking back one period, and the output of S from the last season is used as input to the first season for efficient prediction at basin scales. The actual mass of *S* in each season and catchment is unknown and was, therefore, empirically estimated during the dynamic calibration of SPARROW using seasonal load estimates measured at stream sites throughout the study area.

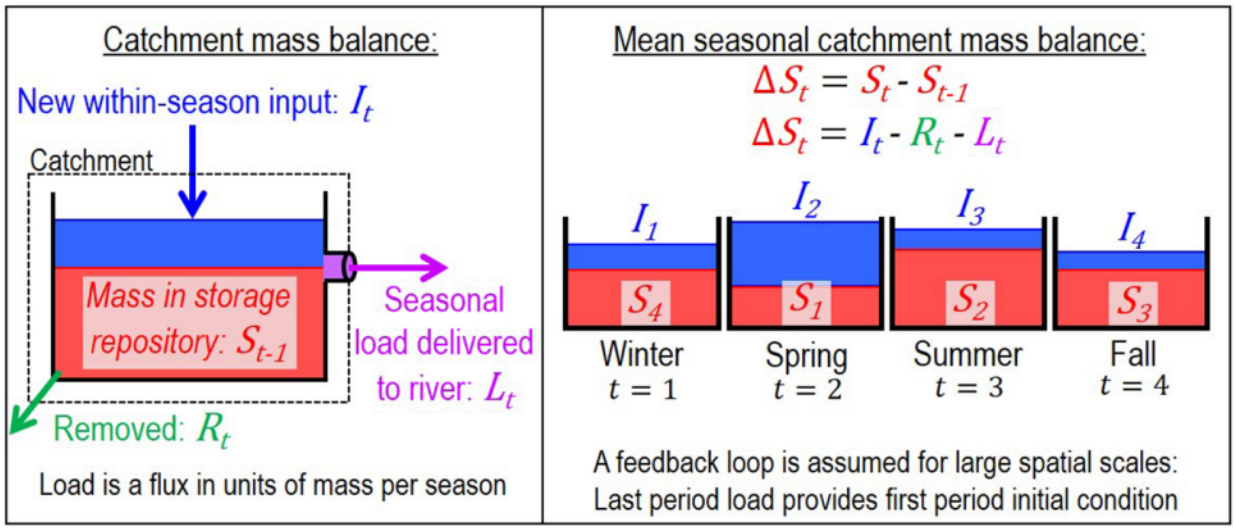

Figure 1. Diagram of conceptual model of the mean seasonal catchment mass balance used in the dynamicSPARROW-MS model (Schmadel et al., 2021; *Environmental Research Letters*).

Progress with the dynamic SPARROW model is documented with the northeastern United States as a test case where we found that nearly 30% and 20% of the current season phosphorus and nitrogen load delivered to rivers comes from older mass in storage repositories, respectively, with watershed transit times to rivers generally being longer for nitrogen (5 years) compared to phosphorus (2 years). Our results confirm that a delay in the downstream response to management practices should be expected and this modeling approach could be updated to forecast and quantify those management effects if appropriate datasets existed.