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Modeling nutrient in-stream processes at the watershed scale using Nutrient Spiralling metrics

R. Marcé[1,2] and J. Armengol[2]

[1]Catalan Institute for Water Research (ICRA), Edifici H2O, Parc Científic i Tecnològic de la Universitat de Girona, 17003 Girona, Spain

[2]Fluvial Dynamics and Hydrological Engineering (FLUMEN), Department of Ecology, University of Barcelona, Diagonal 645, 08028 Barcelona, Spain

Abstract. One of the fundamental problems of using large-scale biogeochemical models is the uncertainty involved in aggregating the components of fine-scale deterministic models in watershed applications, and in extrapolating the results of field-scale measurements to larger spatial scales. Although spatial or temporal lumping may reduce the problem, information obtained during fine-scale research may not apply to lumped categories. Thus, the use of knowledge gained through fine-scale studies to predict coarse-scale phenomena is not straightforward. In this study, we used the nutrient uptake metrics defined in the Nutrient Spiralling concept to formulate the equations governing total phosphorus in-stream fate in a deterministic, watershed-scale biogeochemical model. Once the model was calibrated, fitted phosphorus retention metrics where put in context of global patterns of phosphorus retention variability. For this purpose, we calculated power regressions between phosphorus retention metrics, streamflow, and phosphorus concentration in water using published data from 66 streams worldwide, including both pristine and nutrient enriched streams.

Performance of the calibrated model confirmed that the Nutrient Spiralling formulation is a convenient simplification of the biogeochemical transformations involved in total phosphorus in-stream fate. Thus, this approach may be helpful even for customary deterministic applications working at short time steps. The calibrated phosphorus retention metrics were comparable to field estimates from the study watershed, and showed high coherence with global patterns of retention metrics from streams of the world. In this sense, the fitted phosphorus retention metrics were similar to field values measured in other nutrient enriched streams. Analysis of the bibliographical data supports the view that nutrient enriched streams have lower phosphorus retention efficiency than pristine streams, and that this efficiency loss is maintained in a wide discharge range. This implies that both small and larger streams may be impacted by human activities in terms of nutrient retention capacity, suggesting that larger rivers located in human populated areas can exert considerable influence on phosphorus exports from watersheds. The role of biological activity in this efficiency loss showed by nutrient enriched streams remained uncertain, because the phosphorus mass transfer coefficient did not show consistent relationships with streamflow and phosphorus concentration in water. The heterogeneity of the compiled data and the possible role of additional inorganic processes on phosphorus in-stream dynamics may explain this. We suggest that more research on phosphorus dynamics at the reach scale is needed, specially in large, human impacted watercourses.

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