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Phosphorus delivery via groundwater in agricultural river catchments

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Mitigating diffuse phosphorus (P) delivery to rivers, lakes and estuaries in the agricultural landscape is important for ecological quality management. In order to plan this management, it is useful to identify and quantify dominating P transfer pathways and their potential variation over time and space. Phosphorus is anticipated to mainly be transferred to rivers episodically via pathways on the surface and is not usually considered as a major concern in groundwater-fed waters. However, in this paper we report considerable proportions of P delivery via groundwater in two agricultural river catchments with permeable soils. We investigated the P transfer pathways and links between groundwater and surface water, as well as the implication of spatio-temporally variable P concentrations in groundwater at the hillslope scale. We present four years of P concentrations in stream water (sub-hourly) and in groundwater (monthly) of different strata in four hillslopes, as well as estimated P transfer pathways for winter periods (Oct-Jan) in two ca. 10 km2 catchments in Ireland. One catchment was dominated by arable land overlying slate bedrock and the other by grassland overlying sandstone. High temporal resolution monitoring of river discharge and P concentration allowed an estimation of total P (TP) and total reactive P (TRP) transfer pathways as well as flow pathways. In the groundwater of both catchments the 4-year average dissolved reactive P was up to 0.021 mg/l (Arable) and 0.050 mg/l (Grassland) in shallow near-stream groundwater. During the winter periods in the Arable catchment 20% of the runoff, 59% of stream TP load and 35% of stream TRP load was transferred by quick aboveground pathways while 77% of runoff, 36% of TP and 58% of TRP was transferred via delayed groundwater pathways. In the Grassland catchment 10% of the runoff, 48% of TP and 38% of TRP was transferred above ground while 86% of runoff, 46% of TP and 55% of TRP transferred via groundwater. In both catchments only a small percentage of the discharge and P transfer occurred as interflow. The percentages of P loads were similarly distributed over the years in respect to transfer pathways. However, the total loads appeared to be more influenced by the amount of runoff. In one wet year the TP loss exceeded 0.35 kg/ha from the Arable catchment and 1.10 kg/ha from the Grassland catchment (more than double the loss from a dry year). Spatiotemporal variability in groundwater P concentration highlighted the importance of distinguishing between P concentration events and trends in groundwater. Catchment P transfers via groundwater pathways need to be considered in certain agricultural settings when reviewing mitigating strategies.