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Monitoring and Modelling of the Long-term Effect of Changing Agriculture on Nitrate Concentrations in Groundwater and Streams in Small Experimental subsurface dominant watersheds

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Management and prediction of water quality in watersheds is critical especially in agricultural regions. Water quality in watersheds varies in a very broad range of temporal scales, from storm events or diurnal cycles, seasonal cycles, to pluriannual trends. It varies also spatially, with contrasted dynamics of solutes in the soil, the recharge, the groundwater and the streams. This is challenging both in term of monitoring and of modelling. Agricultural watershed are interesting to discriminate short term from long term mechanisms, as most of them experienced drastic changes in agricultural inputs in the past 50 years. Recently, the analysis of long-term stream water quality data sets has allowed improving significantly our understanding of solute residence time in watersheds [1]. However, as historical agricultural practices are usually poorly documented, large assumptions are needed to achieve such exercises. Despite the large amount of research in the past 30 years dedicated to understand and model the dynamics of agricultural-borne diffuse pollution at the watershed level, there is no accepted perceptual model explaining the observed dynamics of water quality simultaneously at all the relevant spatial and temporal scales and a very little number of sites sufficiently documented to test it.
We present results from a long-term comprehensive monitoring of agricultural inputs and chemistry of surface water (20 years) and groundwater (10 years) in small experimental watersheds (ORE AgrHys, http://www.inra.fr/ore_agrhys/). Results showed (i) a strong stability in the stream chemistry whereas agricultural inputs in these small watersheds were highly variable from year to year, (ii) a high spatial heterogeneity of the groundwater chemistry, both laterally along the hillslope and vertically and (iii) contrasted behavior of long-term trends in agricultural inputs and nitrate concentration in groundwater. A simple model was developed, based on linear reservoirs, and run with observed weather data and agricultural practices as forcing variables. The model was calibrated using both stream and groundwater data. It accounted well for the observed seasonal variations and long-term trends of nitrate concentrations in streams, and for the long term trends in groundwater, as well as for the hysteretic behavior of the storage/discharge relationship.
Inversion of the model using weather data from 1950 to 2011 allowed us estimating the changes in agricultural inputs since the beginning of agriculture intensification in the region. It shows that considering the two linear reservoirs, it is possible to start in the 60ies from nitrate-free watersheds and to reach the measured concentrations since 1991 while reproducing the contrasted seasonal cycles in both watersheds. We will discuss the implications of these results in term of solute pathways and residence times, and on the potential of this approach as a diagnostic tool to assess the watershed status with respect to nitrate contamination when only few years of monitoring are available.

1. Howden, N.J.K, et al., WRR, 47, 2011