Phosphorus mobilisation and risk assessments in a small agricultural catchment with heavy clay soil

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A refined version of a conditional phosphorus risk index (PRI) for P losses to waters was tested a small (7.3 km^2) agricultural catchment in south-eastern Sweden. The catchment has a hummocky landscape of heavy glacial till overlying moraine and an overall balanced soil P level. Background estimation of stream water total phosphorus (TP) concentrations in the period 1988-2007 revealed a stable concentration, with mean 0.26 mg L^{-1}. Average TP concentrations in flow-proportional water samples were nearly twice as high (0.44 mg L^{-1}) as those estimated from flow-weighted manual samples (0.23 mg L^{-1}) at the catchment endpoint in 2008-2009 and more than three times higher than TP values based on flow-weighted manual samples in an underlying culvert in the upper part of the catchment (0.15 mg L^{-1}). High concentrations of TP (up to 0.63 mg L^{-1}), mainly in particulate-bound form (PP), were recorded along the open reach of the stream in the rising limb of high flow pulses. A clear anticlockwise hysteresis effect was demonstrated for NO_3-N concentration in every autumn event. In contrast, the peak of suspended material (analysed as turbidity) appeared 4-7 hours before the NO_3-N peak and hysteresis was clockwise.
Water-extractable soil P (P_w) and P sorption index (PSI) in the topsoil were used for risk assessment of P source together with the degree of P saturation (DPS) in the three layers of the soil profile down to tile drain depth (90 cm). An empirical relationship was established (Pear-son correlation coefficient 0.861, $p<0.001$) between PSI, measured in a weak calcium chloride solution, and iron (Fe-AL) aluminium (Al-AL) and phosphorus (P-AL) in soil extract with acid ammonium lactate. Differing relationships were found for a field that had not received any manure in the last 15 years and a field that had received chicken litter very recently. In addition, a general relationship (Pearson correlation coefficient 0.839, $p<0.001$) was found between the ratio of phosphorus extracted from fresh soil in water (Pw) to PSI and DPS. One exception was a single field, representing 7% of agricultural land in the catchment, that had been treated with glyphosate shortly before soil sampling. Saturated hydraulic conductivity (SHC) in clay in contact with the moraine base (at 1 m depth) was on average 0.06 m day^{-1}. In clay not in contact with moraine, SHC was significantly lower (mean 0.007 m day^{-1}). A reduction in the present tile drain spacing (from 14-16 m to 11 m) is theoretically required to maintain satisfactory water discharge and groundwater level. Up to 10% of the arable land was estimated to be a potential source area for P, based on different indices. Parts of a few fields close to farm buildings (1% of total arable land) were identified as essential P source areas, with high DPS values and low PSI values throughout the soil profile. A further 3% of arable land was identified as potential important transport areas, based on visible surface water rills or frequent water-ponded conditions. Fields comprising 10% of the total arable land in the catchment should be re-drained in the near future to improve water infiltration and avoid unnecessary channelised water flow. Precision fertilisation and manure application to some fields, soil structure improvement and restoration of the technical function of the tile drain system and open stream are recommended measures to counteract P losses.