Numerical modelling and isotopes underline climate impacts on groundwater nitrate in temperate agricultural settings

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Abstract

The nitrogen (N) cycle is highly modified by human activities in agricultural settings, with significant impacts on water quality, particularly groundwater. We sought to investigate possible interactions between climate change and agricultural practices on nitrate concentrations. To address this question, we have developed a research project to evaluate (1) how climate change and adaptation of agricultural practices could impact groundwater (GW) nitrate concentrations in a temperate region; and (2) the sources and proportions of nitrate transferred from agricultural soils to aquifers on a seasonal basis in a selected agricultural watershed.

To examine interactions of present-day nitrate loading (2002) on PEI, the average GW nitrate concentrations in nitrate-predicted for 2050 increase by about 11%. When simulating climate change impacts, the concentrations increase by another 6%, but combined CC and adaptation of agricultural practices (APC) would create an increase of 3%. The forecast increase in concentrations imply that, in 2050, the percentage of domestic wells with nitrate in excess of the health guideline would be higher than the current proportion.

Nitrate isotopic ratios indicate that nitrate occurs at all levels, with agriculture taking place where recharge is occurring, and nitrate retention plays an important role. The main sources of nitrate in the chemical elements during summer (16±0% of total load) and across crop material (27±0% total organic nitrogen) during winter (10±0% total organic nitrogen). A portion of nitrate in groundwater is expected to modify the isotopic signature of the nitrate. Enhanced or reduced nitrate measurements on PEI. Enhanced growing season has the potential to highly influence the rate of nitrate recycling, and increased frequency of winter storms could enhance the winter transfer of nitrate from agricultural field organic matter biological.

Study Area and Methodology

Average Groundwater N-NO₃ & N-NO₃-<sup>-B</sup> in 3 Watersheds and 2 Fields

Unconfined, mixed-porosity sandstone aquifer covered by permeable till

Hydrogeological conceptual model

Modelling & Analyses

A 2D model was built to reproduce groundwater nitrate and nitrate concentrations over PEI for present-day and for the GCM2 AD scenario of Canadian Institute General Model of climate change. GW nitrate is estimated with a one-dimensional flow model coupled with 2D nitrate transport model. The amount of flow available in the estuary is estimated on a watershed scale with the agricultural indicator (Fluvial Soil Nitrate (FSN)).

Results & Interpretation

Simulations of Nitrate Concentration per Watershed

Seasonal Nitrate Loads

Snow cover (insulator) allows bacterial activity to take place

Nitrification in a farm field does not affect the sampled loads of nitrate

Detection of nitrification (when soil warming and drying occurs with high temperature) is important in the characterization of nitrate present on the soil surface as a risk for groundwater nitrate concentrations in agricultural fields. Nitrification in the seasonal period soil and field occurs because of soil inorganic matter (average 98%), soil organic matter (20%), and surface water (15%).

Wet periods of the growing season are dominated by the NO₃, from soil organic matter (16%).

Over 184 tonnes of KNO₃ were transformed by the winter period.

Inorganic matter, organic matter, and the atmosphere contributed an average total of 181, 21, 23 and 189 tonnes, respectively.

On a seasonal basis, 65 tonnes (11.2%) were transformed during the warm period, and 70 tonnes (11.7%) during the cold period.

Conclusions

- The simulated class distribution for 2050 of watersheds as based on modelled average concentrations of nitrate due to combined CC and APC reveals an important increase in contamination levels.
- The numbers of watersheds belonging to the medium and high classes are now 21 and 11.
- These numbers translate into an increase of over 120 and 275% when compared to the simulated current situation.
- This research underlines the major role of winter transfer in the agricultural N dynamics of temperate regions.
- Significant changes in agricultural practices are required urgently to see future improvements in water quality.
- Truly effective strategies aiming at a reduction of N leaching will need to focus not only on reducing the application rates of inorganic fertilizers, but also on carefully considering the management of residual crop material, the main source of nitrate during winter.

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