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Obtaining Agro-Hydrological Sustainable Nitrogen Application Rates via Deep Vadose Zone Observation, Model-Calibration, and Simulation

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Nitrate contamination of groundwater under intensive-agriculture land use is probably the most concerning agro-hydrological sustainability problem, worldwide. Whereas many studies confronting this problem focused on the root zone or on nitrate in groundwater, this work is based on models that were calibrated to relatively deep vadose-zone field data. The nitrogen-root-uptake function that was deduced from the calibration to deep vadose zone data was validated by results of a controlled lysimeter experiment.
In the last decade many wells producing water from the Israeli Coastal Aquifer were disqualified for drinking-water supply due to exceeding the Israeli standard for nitrate (70 mg L-1 NO_3-). The significant nitrate-plumes in the aquifer appeared under the loamy-sand red Mediterranean (Hamra) soils where citruses and vegetables are the dominant crops. Samples from 0 to 9 m depth of vadose zones under citrus orchards overlaying the aquifer were analyzed for variables controlling water flow and fate and transport of nitrogen fertilizers. Steady state estimates of water and NO_3-N fluxes to groundwater were found spatially variable with ranges of 90 – 330 mm yr-1 and 50 – 220 kg ha-1 yr-1, respectively. Calibration of 1-D transient models to two selected vadose-zone profiles required limiting of the concentration of NO_3-N in the solution that is taken up by the roots to 30 mg L-1. Results of an independent three-year lysimeter experiment showed similar nitrogen uptake regime. Simulations of past conditions revealed a significant correlation between NO_3-N flux to groundwater and previous year precipitation. Fifty-years simulations of different nitrogen application rates showed that using half of the nitrogen fertilizer added to the irrigation water by the farmers today will reduce average NO_3-N flux to groundwater by 70% while decreasing nitrogen root uptake by 20%. When considering the relatively high masses of nitrogen in the irrigation water (local wells or treated wastewater) together with this reduced rate of N-fertilizer application the total N applied is similar to previously-recommended nitrogen application rate for intensive citrus growing (200 kg ha-1 yr-1). Furthermore the simulations show that after sufficient time using this rate of application the average pore-water nitrate concentration in the deep vadose zone will be reduced to below the Israeli drinking water standard, hence this rate of nitrogen application was found agro-hydrologically sustainable. Beyond the investigation of nitrate fluxes to groundwater under citrus orchards and the interesting case-study aspects, this work demonstrates a methodology that enables skillful decisions concerning joint sustainability of both the water resource and agricultural production in a common environmental setting.