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Evaluating vulnerability to nitrate pollution of groundwater in Andosol area in the Kasumigaura basin by LEACHM model

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Groundwater pollution by nitrate discharged from agricultural fields continues to be a threat to water resources. Here, we define the environmental vulnerability to nitrate pollution as the likelihood of nitrate pollution at a specific site as determined by the meteorological, geomorphological and soil characteristics at the site, and show an example of its evaluation on Andosol fields in the Kasumigaura basin, Ibaraki Prefecture.

Model predictions were made on nitrate transport and discharge to groundwater at 104 Andosol field sites in the Kasumigaura basin subject to the standard agricultural practice. In the prediction, meteorological data obtained at AMeDAS Tsukuba in 1978-2008 were used as input data, which enabled the influence of variations in the annual precipitation on the nitrate concentration in the discharging water and the annual nitrate discharge to groundwater to be investigated. The LEACHM Ver. 4.1 (Hutson, 2003) was used as the simulation model for water and nitrogen dynamics in soil for its flexibility in describing nitrogen transformation and plant uptake. The model has the ability to properly describe the differences in the water and nitrogen dynamics between an Andosol and a Sand-dune Regosol as dictated by the hydraulic properties of soils (Urakawa et al., 2009).

In the simulation, we used site-specific values compiled in the soil survey data for soil properties at 0-80 cm depth, including profile description, textural composition, total carbon, C/N ratio, and bulk density. For the Tachikawa loam (80-200 cm depth) and the Musashino loam (>200 cm depth), site-independent values were assigned to these properties. As the lower boundary condition, a fixed-depth groundwater table was assumed for each site. Groundwater table depths were collected from the boring survey data in this region. Parameters for soil hydraulic properties were determined from the measured water retention and unsaturated hydraulic conductivities, using the data obtained by Hasegawa et al. (1994) for the 0-80 cm depth soil and the Tachikawa loam, and by Maeda et al. (1986) on the Musashino loam. Distribution coefficients for NH_4^+ and NO_3^- were taken as 1.0 L kg^{-1} and 0.6 L kg^{-1}, respectively. In the simulation, the fields were cropped with corn from April to July, and with Chinese cabbage from September to December every year. The amounts of fertilizer application were based on the recommendation by the Ibaraki Prefecture.

For the 104 sites with the groundwater table depth ranging from 1.8 m to 7.4 m, between-site variations in the simulated annual water and NO_3-N discharge to groundwater and discharging NO_3-N concentration were insignificant. In contrast, large interannual variations were observed in the simulated annual water and NO_3-N discharge. Interannual variations in the discharging NO_3-N concentration were negligible. Consequently, there was a strong positive correlation between the annual rainfall and the simulated annual NO_3-N discharge to groundwater. The medians of yearly-averaged discharging NO_3-N concentration and annual NO_3-N discharge for each site were in the range of 15-20 mg-N $L^{-1}$and 70-90 kg-N $ha^{-1}y^{-1}$, respectively. The simulated discharging NO_3-N

concentrations were in reasonable agreements with those measured in Yuki City in the basin where cropping systems similar to that assumed in the simulation are practiced. Minor interannual variations in the discharging NO_3-N concentrations are indicative of the attenuation of NO_3-N concentration peaks as they move downward in the soil profiles. These results show that between-site variations in the environmental vulnerability to nitrate pollution are of minor importance in the Andosol fields in the Kasumigaura basin.

Keywords: Andosol, groundwater pollution, LEACHM, meteorological conditions, model prediction, nitrate discharge