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Application of generalized linear regression (GLR) models to study spatially varying nitrates concentration in groundwater in a large paddy area of Northern Italy

Petra Baják[1], Paolo Bricchi[1], Marco Masetti[1], Daniele Pedretti[1], Giulio Gilardi[2], Arianna Facchi[2], and Alessandro Sorichetta[1]
[1]Università degli Studi di Milano, Department of Earth Sciences "Ardito Desio" (DiSTAD), Via Mangiagalli 34, Milan 20133, Italy
[2]Università degli Studi di Milano, Department of Agricultural and Environmental Sciences (DiSAA), Via Celoria 2, Milan 20133, Italy

Italy is the leading rice producer in Europe, with 92% of its production concentrated in the Piedmont–Lombardy rice basin in Northern Italy. To increase yields, farmers use fertilizers, which can potentially lead to nitrate contamination of groundwater. However, there is limited research in Italy on the extent to which rice production contributes to nitrate pollution. Assessing the environmental impact of rice production is therefore crucial, as water pollution is a major issue for the sustainability of rice-growing regions. This is particularly important as the protection of water from nitrate pollution caused by agricultural activities is a key aspect of European Union legislation, specifically the Nitrates Directive 91/676/EEC.

This study focuses on the Lomellina area, a sub-region of the Piedmont–Lombardy rice basin, located on the left bank of the Po River and along the Ticino River. This area has 90.000 ha of irrigated crops out of a total agricultural area of 125,000 ha, of which 70% is devoted to rice cropping.

Our objectives were to identify the factors controlling nitrate concentrations and to assess groundwater vulnerability based on the relationship between observed concentrations and statistically significant explanatory variables. Nitrate concentrations were measured in 17 groundwater samples collected from shallow monitoring wells in June 2024 across the Lomellina area. The factors initially considered for deriving the associated explanatory variables to be used in the analysis were: topography, groundwater recharge and table depth, presence of irrigation canals, vertical hydraulic conductivity, and land use. Generalized linear regression (GLR) models were used to assess the relationships between nitrate concentrations and twelve explanatory variables.

Covariate selection was done based on Akaike's Information Criterion corrected (AICc) and adjusted R2 values. The best GLR model fit (AICc=140.7 and adjusted R2= 0.73) showed that the most important covariates are: topography, slope, groundwater table depth, vertical hydraulic

conductivity, and distance to rice fields. These covariates were statistically significant (at a 0.05 level) except for vertical hydraulic conductivity. Nitrate concentration and slope were negatively correlated, while the other covariates showed positive correlation. Next steps will include investigating and addressing spatial autocorrelation, and build a predictive model and explore the use of machine learning techniques.

An improved understanding of the spatially varying relation between nitrate concentrations and influencing factors could be used to produce reliable groundwater vulnerability maps and help to assess the environmental impact of rice cultivation. Our approach highlights the importance of local variability and contributes to discussion on the regional-scale impacts.

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