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title: **Stochastic modeling of space-time variability of nitrate pollution in the Campina de Faro upper aquifer using indicator geostatistics and transition probability**

author(s): **Luis Ribeiro**
CVRM — Instituto Superior Tecnico, Portugal, luis.ribeiro@ist.utl.pt

Tibor Stigter
CVRM — Instituto Superior Tecnico, Portugal, tstigter@ualg.pt

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The Campina de Faro aquifer system, bordering the Ria Formosa lagoon in the south of Portugal, has been largely affected by agricultural practices that have caused nitrate contamination and groundwater salinisation (Stigter et al., 1998, 2006, 2008). Groundwater in the upper aquifer, which consists of Miocene sand and Plio-Quaternary sand and gravel, reveals the highest nitrate concentrations, exceeding 300 mg/l in a diffuse, well-defined contaminant plume. In 1997 the area was designated a nitrate vulnerable zone in compliance with the Nitrates Directive (91/676/EEC), but the monitoring program shows that so far the measures that were implemented to reduce the nitrogen load have not led to an overall lowering of the nitrate levels.

The study of the space-time variability of nitrate diffuse pollution was carried out using advanced geostatistical techniques. The study encompassed the following steps:

1. Several thresholds and indicators of the nitrate were built, and a structural analysis was performed.
2. The indicator structural analysis has shown a phenomenon with gradual variations, i.e. a transition through neighboring values. The fact suggests the use of a diffusion-type model for kriging purposes.
3. Iso-probability contour maps of the nitrate content exceeding a specific threshold value were determined.
4. Transition probabilities in function of the distance, i.e. the probabilities to exceed a specific threshold when entering the domain of a lower threshold, were calculated on the basis of the ratios between the cross-variograms of two indicators and their simple variograms. These transition curves represent the probabilities with which, getting into the domain of the values ≥ Z, one meets a value ≥ Z' (upwards) and the probabilities with which, getting into the domain of the values < Z', one meets a value < Z (downwards).

This methodological approach provides a good image of the spatial correlation patterns where the diffuse phenomenon is well characterized by continuity/non continuity models. The probability maps and transition curves can be particularly useful for water managers and policy-makers, allowing the incorporation of uncertainty into the monitoring data.

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