# Assessing groundwater vulnerability for nitrate pollution in the Brussels Capital Region (Belgium) using statistical modelling approaches

M. Vanclooster[1], S. Petit[1], P. Bogaert[1] and A. Lietar[2]

1. Earth and Life Institute, Université catholique de Louvain, Louvain-la-Neuve, Belgium.
2. Institut Bruxellois de la Gestion de l'Environnement, Brussels, Belgium.



## Objectives of the study

To implement a statistical data based modelling approach to predict nitrate pollution vulnerability of groundwater in an urban environment.

⇨ Application to the Brussels Capital Region in Belgium



## Outline of presentation

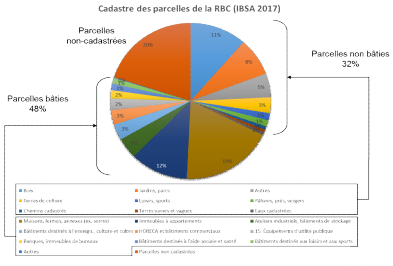
- Background of the case study
- The statistical data based vulnerability models
- Results
- Conclusions and outlook



## Background of the case study

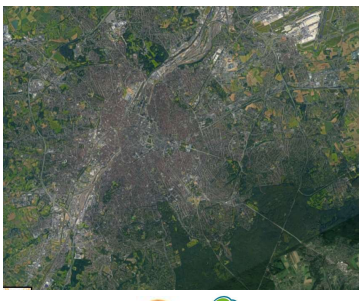



## Background of the case study



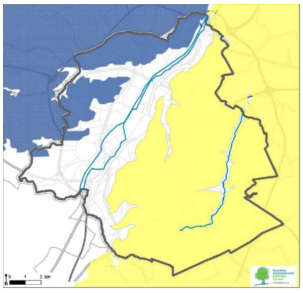



## Background of the case study



Source: Google Earth™

## Hydrogeology of the system





## Hydrogeology of the system

Géologie

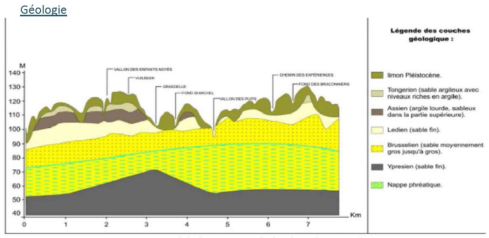
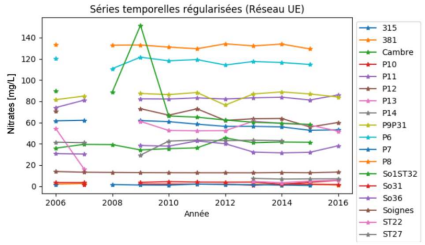



**Figure 3** : Coupe géologique N-S en Forêt de Soignes (IBGE, 2003)
**Figuur 3** : Geologische snede N-S in het Zoniënwoud (BIM, 2003)

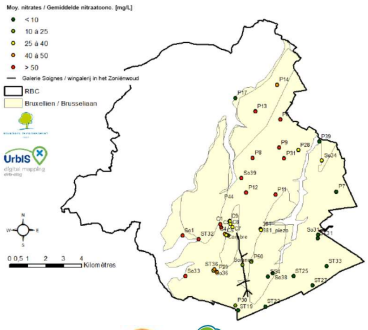


## Nitrate pollution



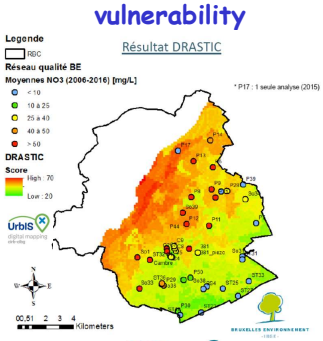



## Nitrate pollution



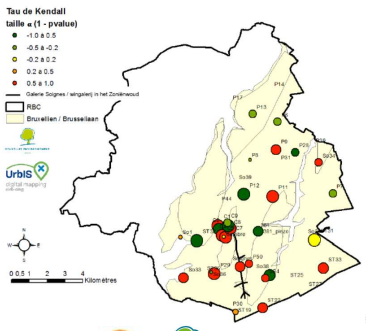



## Nitrate pollution versus DRASTIC vulnerability

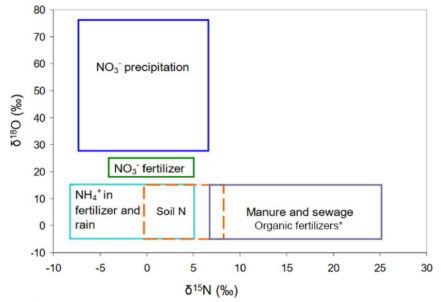





## Nitrate pollution trend



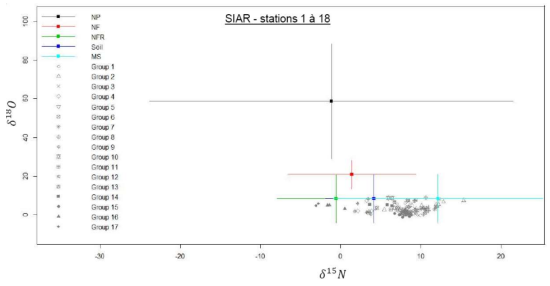
## Nitrate isotope analysis




UCLouvain AGRO LOUVAIN



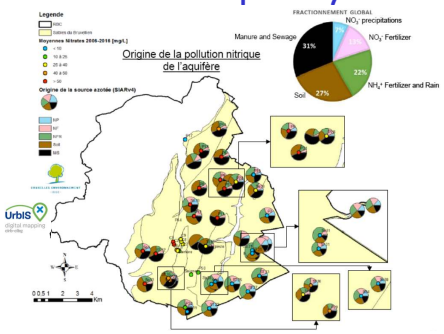
## Nitrate isotope analysis




UCLouvain AGRO LOUVAIN



## Nitrate isotope analysis




UCLouvain AGRO LOUVAIN

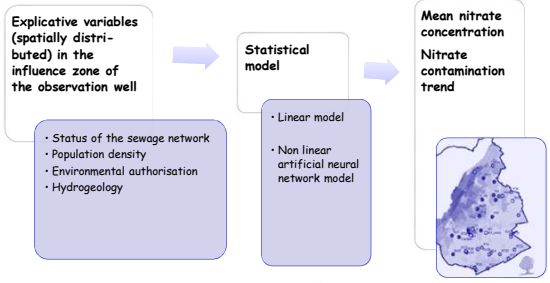


## The statistical data based vulnerabilty models

UCLouvain AGRO LOUVAIN



## The statistical data based vulnerabilty model




UCLouvain AGRO LOUVAIN



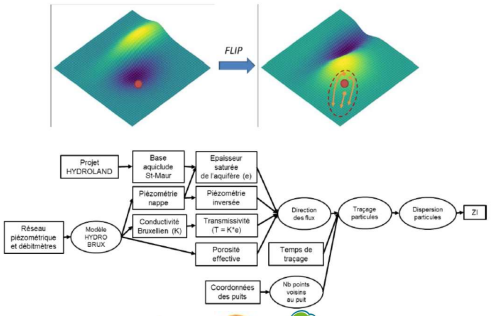
## Some methodological details

UCLouvain AGRO LOUVAIN

## Some methodological details

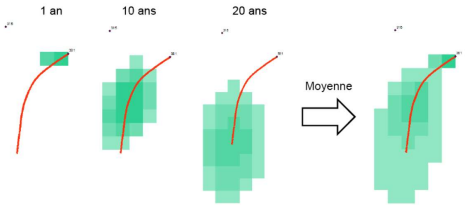


## Some methodological details





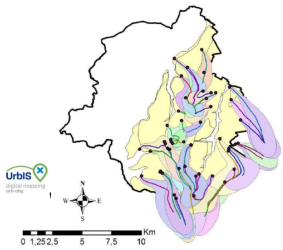

## Some methodological details




Injected masse : 3,2*10^8
Dispersivity ratio (longitudinal to transvers) : 3
No retardation factor
No decay coefficient

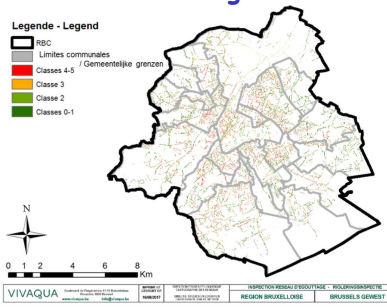


## Some methodological details






## Some methodological details




VIVAQUA



## Some methodological details

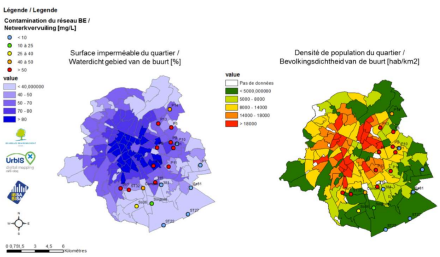
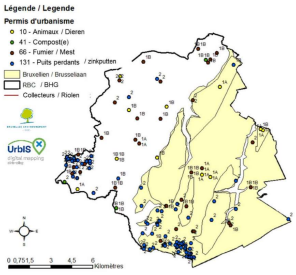



*Figure 17 - Statistiques de densité urbaine (IBSA) / Statistieken voor de stedelijke verdichting (IBSA).*

## Some methodological details






| Catégories | Variables | n | Moy. | Mediane | Ecart-type | Min | 25% | 50% | 75% | Max | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Concentrations & Tendance | Moyenne[2006-2016] | 48 | 38,38 | 34,10 | 35,19 | 0,00 | 6,70 | 34,10 | 57,00 | 132,20 | Concentration moyenne en NO3 sur la période 2006-2016 [m |
| | Kendall | 43 | 0,08 | 0,00 | 0,63 | -1,00 | -0,40 | 0,00 | 0,62 | 1,00 | Tendance des concentrations e n NO3 2006-2016 [-] |
| | pvalue | 43 | 0,35 | 0,32 | 0,33 | 0,00 | 0,04 | 0,32 | 0,61 | 1,00 | Significativité de la tendance |
| Origine de la source azotée | NP | 35 | 0,07 | 0,06 | 0,05 | 0,01 | 0,02 | 0,06 | 0,11 | 0,16 | Proba. d'appartenance isotopique au groupe 'NO3 Fré cipitat |
| | NF | 35 | 0,13 | 0,14 | 0,06 | 0,03 | 0,08 | 0,14 | 0,19 | 0,21 | Proba. d'appartenance isotopique au groupe 'NO3 Fertilisati |
| | NFR | 35 | 0,22 | 0,20 | 0,08 | 0,10 | 0,15 | 0,20 | 0,26 | 0,50 | Proba. d'appartenance isotopique au groupe 'NH4 Fertl. et P |
| | Sol | 35 | 0,27 | 0,25 | 0,06 | 0,21 | 0,23 | 0,25 | 0,30 | 0,47 | Proba. d'appartenance isotopique au groupe 'Sol' |
| | MS | 35 | 0,31 | 0,30 | 0,13 | 0,13 | 0,19 | 0,30 | 0,41 | 0,59 | Proba. d'appartenance isotopique au groupe 'Egouttage et fu |
| Etat du réseau d'égouttage | lg_col | 50 | 49,30 | 2,75 | 291,41 | 0,08 | 0,37 | 2,75 | 8,87 | 2063,77 | Longueur totale des collecteurs rapportée à la surface de la Z |
| | lg_col_1 | 50 | 13,98 | 0,37 | 89,65 | 0,00 | 0,02 | 0,37 | 1,58 | 634,71 | En bon état |
| | lg_col_2 | 50 | 25,72 | 0,59 | 170,36 | 0,00 | 0,03 | 0,59 | 2,23 | 1205,95 | En état correct |
| | lg_col_3 | 50 | 1,44 | 0,52 | 3,14 | 0,02 | 0,07 | 0,52 | 1,60 | 21,16 | En état dégradation |
| | lg_col_4 | 50 | 8,37 | 1,25 | 31,33 | 0,01 | 0,23 | 1,25 | 3,50 | 201,85 | En état médiocre |
| | lg_col_12 | 50 | 39,30 | 0,89 | 260,01 | 0,01 | 0,06 | 0,89 | 3,87 | 1840,66 | Somme des densités des meilleures classes |
| | lg_col_34 | 50 | 9,80 | 1,78 | 34,02 | 0,05 | 0,30 | 1,78 | 4,71 | 223,11 | Somme des densités des pires classes |
| Permis envi. à risques | nb_permis | 50 | 9,80 | 6,00 | 10,29 | 0,00 | 1,00 | 6,00 | 16,00 | 42,00 | Nombre total de demande de permis à risque [-] |
| | nb_permis_10 | 50 | 2,52 | 1,00 | 3,49 | 0,00 | 1,00 | 1,00 | 2,00 | 11,00 | Hébergements d'animaux |
| | nb_permis_131 | 50 | 5,42 | 1,00 | 9,79 | 0,00 | 1,00 | 1,00 | 7,00 | 40,00 | Puits perdants |
| | nb_permis_66 | 50 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | Centre de compostage |
| | nb_permis_66 | 50 | 1,86 | 1,00 | 1,29 | 0,00 | 1,00 | 1,00 | 3,00 | 4,00 | Stockage de fumier |
| Densité urbaine | perc_surf_imperm | 49 | 32,49 | 24,23 | 25,33 | 2,67 | 13,33 | 24,23 | 52,11 | 80,84 | Pourcentage de surface urbaine impe méable du quartier [% |
| | perc_imperm_ZI | 50 | 30,60 | 19,64 | 26,10 | 2,67 | 4,25 | 19,64 | 56,16 | 80,33 | Pourcentage de surface urbaine impe méable de la ZI [%] |
| | popu_density | 49 | 4601 | 2584 | 5810 | 0 | 5 | 2584 | 8630 | 21512 | Densité de population moyenne du quartier [hab/km2] |
| | popu_density_ZI | 50 | 4326 | 1423 | 4750 | 5 | 126 | 1423 | 7912 | 16944 | Densité de population moyenne de la ZI [hab/km2] |
| | popu_sum_ZI | 50 | 10313 | 4279 | 15489 | 0 | 68 | 4279 | 11068 | 63935 | Somme de la population de la ZI [-] |
| | surf_cimetiere_ZI | 50 | 0,29 | 0,95 | 0,00 | 0,00 | 0,00 | 0,00 | 0,02 | 6,32 | Surface de la ZI surplombée par un cimetière [km2] |
| | surface_ZI | 50 | 4,66 | 5,07 | 2,73 | 0,03 | 2,31 | 5,07 | 6,41 | 9,66 | Surface totale de la ZI [km2] |
| | surf_argile_ZI | 50 | 1,21 | 0,99 | 0,96 | 0,00 | 0,44 | 0,99 | 1,92 | 3,73 | Surface de la ZI surplombée par un horizon argileux [km2] |
| Hydrogéologie | prof_aquif | 42 | 53,81 | 54,51 | 19,03 | 14,49 | 40,15 | 54,51 | 67,67 | 87,07 | Profondeur de l'aquifère à l'implantation du piézomètre [m] |
| | prof_rel_m | 49 | 28,79 | 33,20 | 21,68 | 0,00 | 1,15 | 33,20 | 47,00 | 71,00 | Profondeur de la crépine par rapport au niveau du sol [m] |
| | perc_surf_ZIsnRBC | 50 | 0,66 | 0,92 | 0,39 | 0,00 | 0,28 | 0,92 | 1,00 | 1,00 | Part de la surface de la ZI sur le territoire de la RBC [%] |

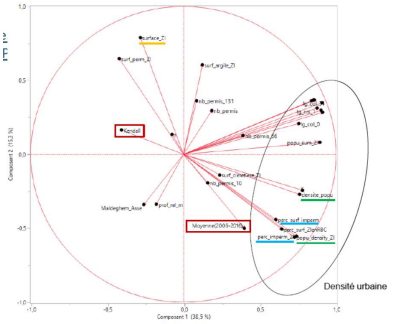
* Moyenne des séries régulières



## Results



## Results

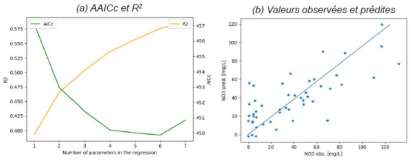





## Results

(a) AAICc et $R^2$

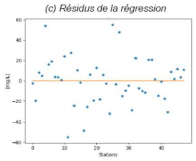
(b) Valeurs observées et prédites



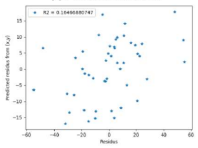




(c) Résidus de la régression

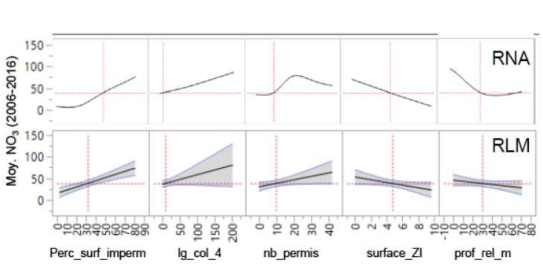



(d) Prédiction des résidus






## Results



## Results

- Performance linear model (R2 = 0.56)
- Performance ANN model (R2 = 0.60)



## Conclusions

- Data based modelling approaches allow explaining upto 60 % of observed nitrate contamination of urban groundwater in terms of easy available spatially distributed environmental attributes.
- Principle driver of nitrate vulnerability is related to urban infrastructure (sewage network, …), which is consistent with results of isotopic tracer analysis.
- Proposed vulnerability allows focussing groundwater management and protection in the studied urban environment.

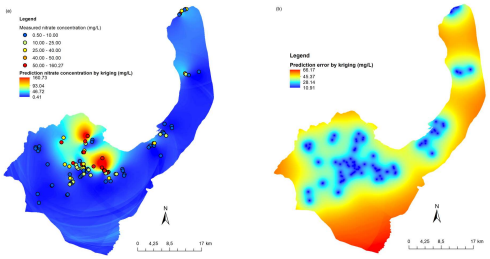


## Outlook

- Application for other substances.
- Integration in BDF (data assimilation oriented approaches for groundwater vulnerability assessments).
- Testing on other case studies.

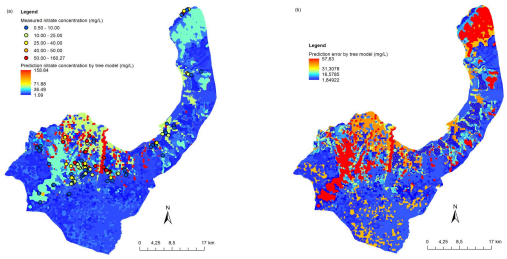


## Exemple BDF (Mfumu et al., 2018) Kinshasa (RDC): Kriging results





## Exemple BDF (Mfumu et al., 2018), Kinshasa (RDC): Regression tree results





## Exemple BDF (Mfumu et al., 2018) Kinshasa (RDC): Baysian Data Fusion