50 mg nitrate per liter, a realistic value in all surface waters? a case study in Limburg (Flanders)

Understanding the influence of farming practices on nitrate leaching through the development of a simple mechanistic model for soil moisture and mineral nitrogen dynamics.

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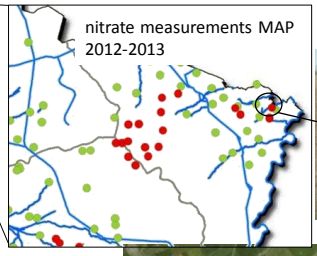
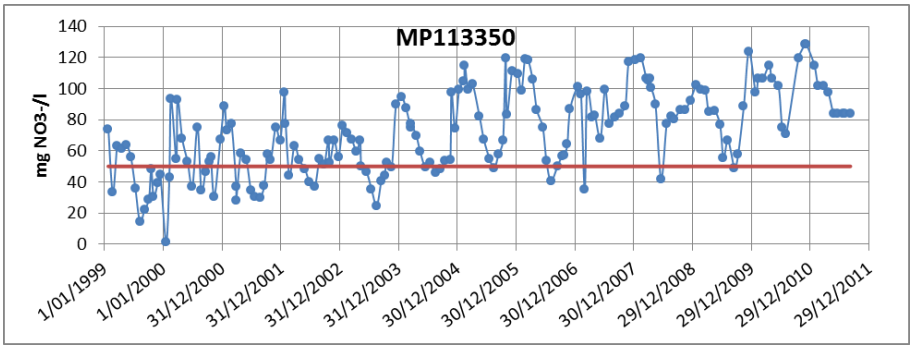
The case study site



- Catchment area Horstgaterbeek, north Limburg, Flanders, ± 130 ha
- Important agricultural activity: livestock farms, grassland, arable crops
- Flat area with sandy to sandy loam soils
- Shallow groundwater table

The case study site – background, problem



Causes?

Solutions?

Approach

Monitoring of

surface and groundwater quality → water measuring network

agricultural activities → crops, cropping systems, fertilisation, yields

soils → pH, C-content, nitrate content

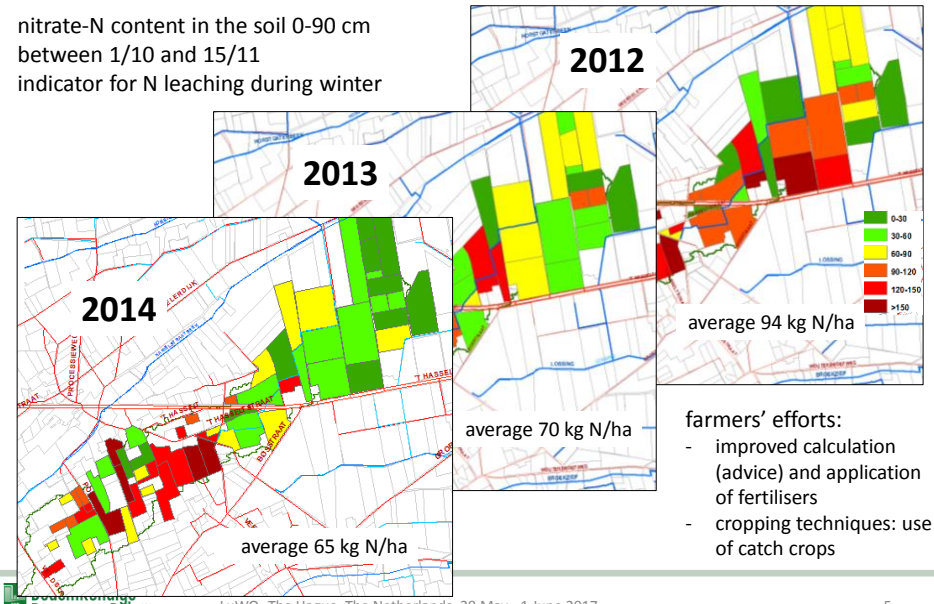
local **climatic conditions**: temperature, rainfall, evapotranspiration

Cooperation and consultation with the **farmers**

Simulations with **soil mineral N balance model**

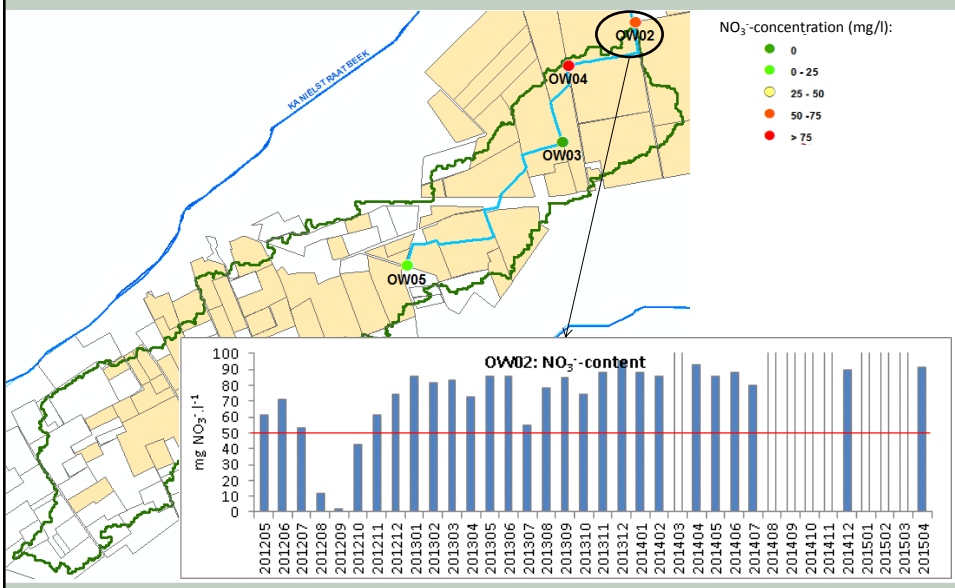
Monitoring of the agricultural fields: residual nitrate

nitrate-N content in the soil 0-90 cm
between 1/10 and 15/11
indicator for N leaching during winter



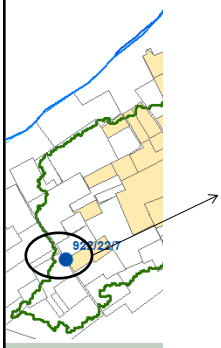
farmers' efforts:
- improved calculation (advice) and application of fertilisers
- cropping techniques: use of catch crops

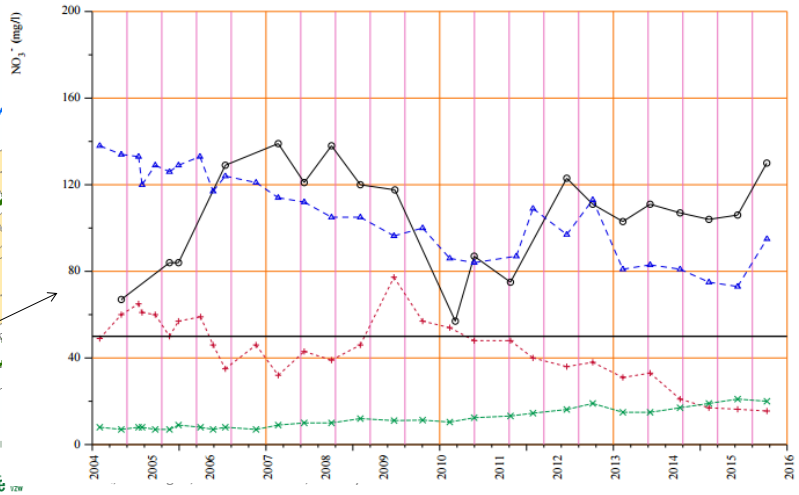
Monitoring of the surface water quality



Monitoring of the groundwater quality

Filternummer	Type	Onderkant (m-MV)	Lengte (m)	Diameter (mm)	Aquifer
1	peilfilter	4.80	1.00	58	0151
2	peilfilter	14.60	1.00	58	0170
3	peilfilter	28.80	1.00	58	0211
4	peilfilter	33.80	1.00	58	0211





Bodemkundige Dienst van België vzw

Travel time of shallow groundwater

When will the measured nutrient charge in the shallow groundwater reach the surface water?

Direction of groundwater flow: north-east → seepage area

Flow rate of shallow groundwater ?

Estimation of order of magnitude:

- Average phreatic surface gradient: 1,7 **‰**
- Average hydraulic conductivity: 10 – 100 m/day
- Distance to surface water: ± 2 km

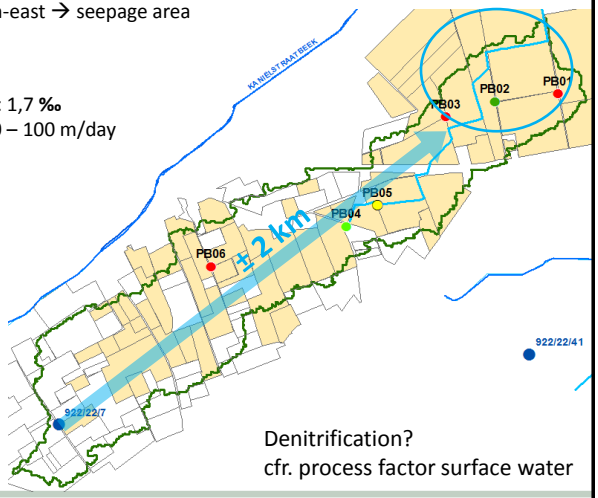
→ Flow rate: 12 – 89 m/year

Travel time to surface water ?

→ 24 – 178 years

Assumptions:

- Concerned fields are not drained;
- No groundwater extraction
- Hydraulically homogeneous subsoil

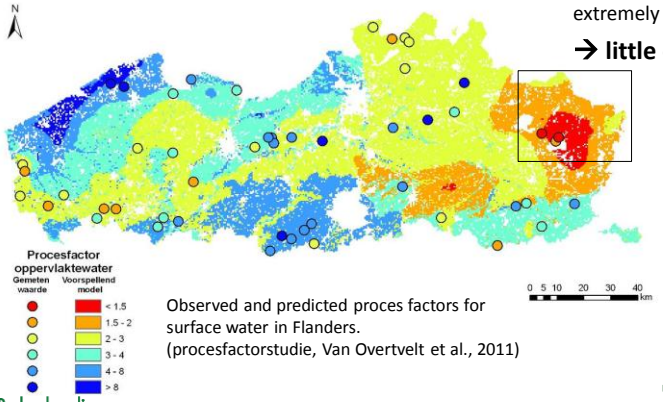


Denitrification?
cfr. process factor surface water

Nitrate processes in shallow groundwater

Process factor:
- empirical "black box" factor
- includes all processes that occur between the leaching of nitrate from the soil profile and the measured nitrate concentrations in surface water.

Process factor for surface water = ratio leached N / N in surface water



Observed and predicted proces factors for surface water in Flanders.
(procesfactorstudie, Van Overtvelt et al., 2011)

extremely low in Limburg: 1 - 2

→ **little or no denitrification**

Case study site: conclusions of monitoring

improved farmers' practices: fertilisation and cropping techniques

↓

lower residual nitrate

↕

no improvement of water quality

why?

1. historical N charge in groundwater

2. actual N charge from agricultural sources?

↓

soil mineral N balance model → better understanding of different factors

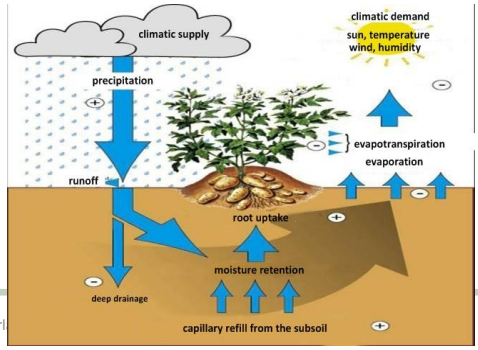
Soil mineral N balance model

N input	N output
atmospheric deposition	
mineralisation from SOM, based on: - C-content - soil texture - soil temperature - soil moisture content	losses through: - denitrification - leaching
mineralisation of crop residues	uptake by crops and catch crops
fertilisation: mineral & organic	

Soil moisture balance model:

- soil water characteristics,
- changes of the groundwater table,
- local precipitation,
- parcel-specific evapotranspiration,
- crop rotation,
- soil cover.

- time step: 1 day

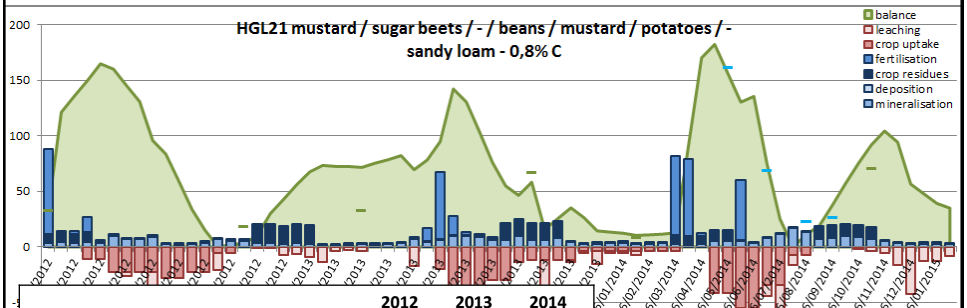


Soil mineral N balance model

Calculation of the balance model for 8 representative parcels:

parcel	texture	%C	Rotation
HGL48	sand	1,8	grass / maize / grass / maize / grass / maize / grass
HGL03	sand	1,6	grass / maize / grass / maize / grass / maize / grass
HGL18	sandy loam	1,9	- / potatoes / mustard / spring barley / grass / maize / -
HGL21	sandy loam	0,8	mustard / sugar beets / - / beans / mustard / potatoes / -
HGL22	sand	1,6	mustard / peas / mustard / potatoes / winter wheat / radish
HGL41	sandy loam	1,6	salsify / peas-beans / grass / carrots / grassland
HGL49	sandy loam	2,0	grassland /fodder beets / grass / maize / grassland
HGL08	sand	1,6	grass / beans / grass / maize / winterwheat / grass

Soil mineral N balance model



	2012	2013	2014
deposition (kg N/ha)	30	30	30
mineralisation (kg N/ha)	190	177	239
fertilisation (kg N/ha)	157	141	221
crop residues (kg N/ha)	87	50	21
crop uptake (kg N/ha)	-341	-318	-402
leaching (kg N/ha)	-137	-94	-128
precipitation surplus (mm)	**234**	**207**	**231**
average leachate concentration (mg N/l)	59	38	55
average leachate concentration (mg NO_3^-/l)	259	201	246

→ process factor: 1 - 2

Conclusions

improved farmers' practices: fertilisation and cropping techniques

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lower residual nitrate

↕

no improvement of water quality

why?

1. historical N charge in groundwater
2. actual N charge from agricultural sources

Based on N model outputs and simplified groundwater calculations,
it seems very hard if not impossible, in this study site,
to meet the nitrate limit value of 50 mg/l in surface water
under the current nutrient management
and, more importantly, in the given hydrogeological situation.