



National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Changes over the past 25 years in rainwater and groundwater quality in forests in The Netherlands as a result of emission reduction policy

1989-2014

Esther Wattel

Leo Boumans

Eric Van der Swaluw

Changes in rainwater and groundwater quality as a
result of emission reduction policy - ICP Forests 2015



Acidification & eutrophication: awareness and policy measures

- Awareness 'acid rain'



- Policy measures and autonomous developments:
 - the transition from coal to natural gas (S)
 - desulfurization of flue gas in industry (S)
 - introduction of the three-way catalytic converter in cars (N)
 - applying filters at air outlets of stables (N)

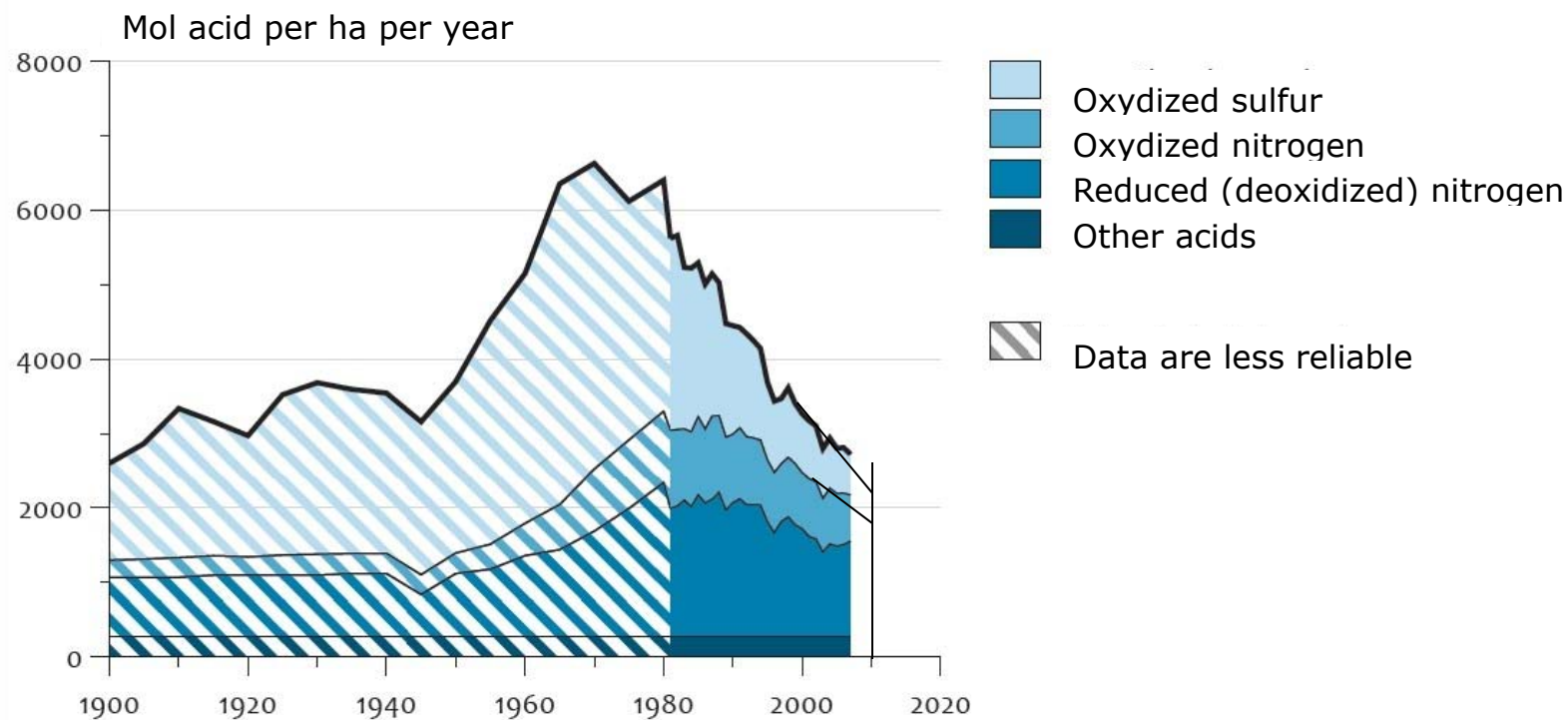


Emission of acidifying substances in the Netherlands

	million kg					
	year 1990	1995	2000	2005	2009	2010
Sulphur dioxide (SO ₂)	192	130	73	65	38	33
Nitrogen oxide (NO _x)	566	472	398	344	279	280
Ammonia (NH ₃)	355	208	161	140	126	124



Calculated total acid anion deposition in the Netherlands



1900-1980: Eerens & van Dam (2001);

1980-2007: Buijsman et al. (2010)



Goal

to show the effect of
emission-reducing measures
on
rainwater & groundwater quality



National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Content

1. Emissions-Depositions
- 2. Rainwater quality or wet deposition**
3. Groundwater quality at 1 m depth
(leaching water)
4. Groundwater quality at 10 m depth
5. Comparing rainwater and groundwater
trends

Changes in rainwater and groundwater quality as a
result of emission reduction policy - ICP Forests 2015

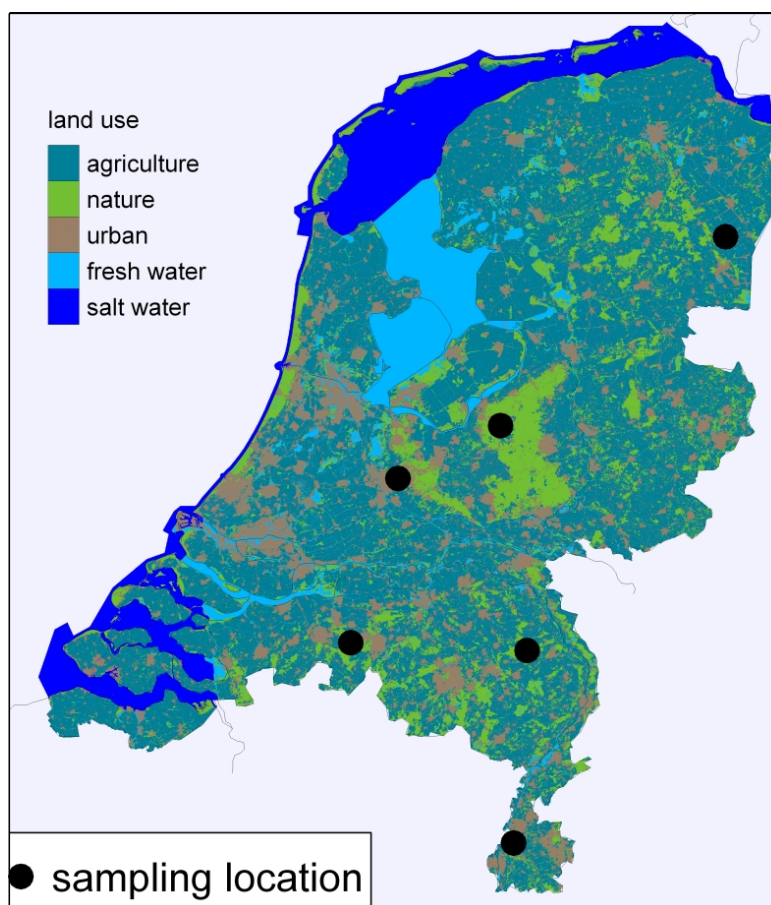


Sampling rainwater



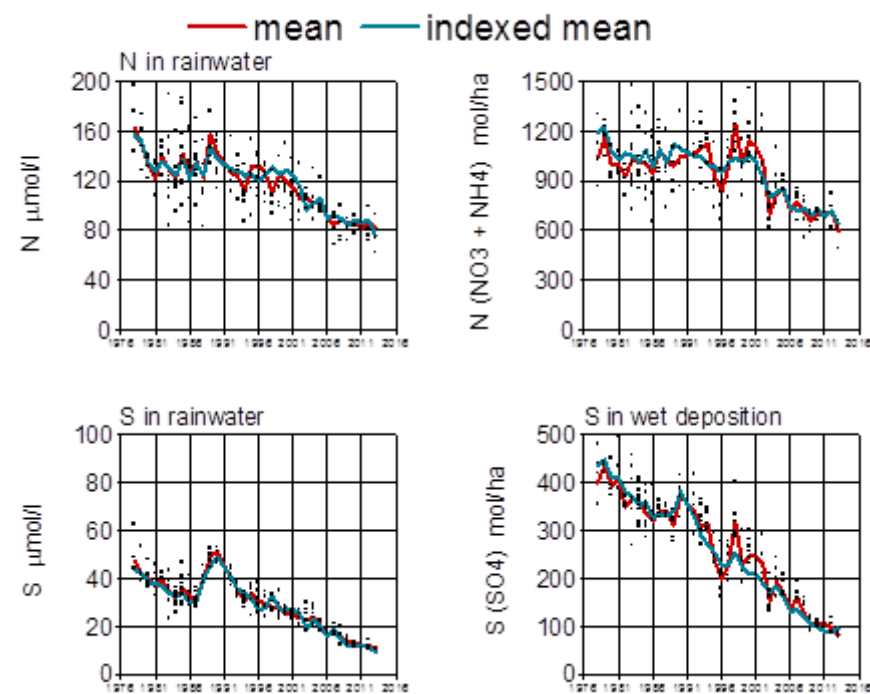


Locations where rainwater is sampled





Results – Rainwater concentrations





National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Content

1. Emissions-Depositions
2. Rainwater quality or wet deposition
3. **Groundwater quality at 1 m depth (leaching water)**
4. Groundwater quality at 10 m depth
5. Comparing rainwater and groundwater trends



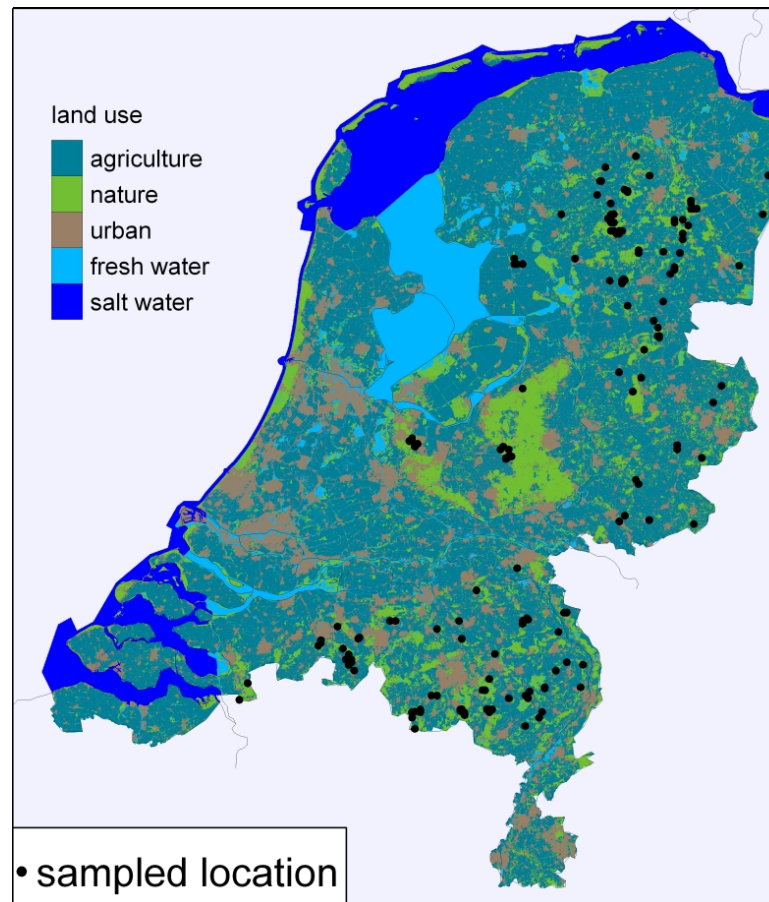
Groundwater quality – upper meter: concentrations of leaching water by the Acidification Trend Monitoring Network (TMV)



- 150 nature locations
- mainly forest, some heather
- sandy soils
- initial sampling in 1989
- 2-year cycle with 75 locations per year
- locations prone to deposition
- sampling of upper metre of groundwater (=leaching water)

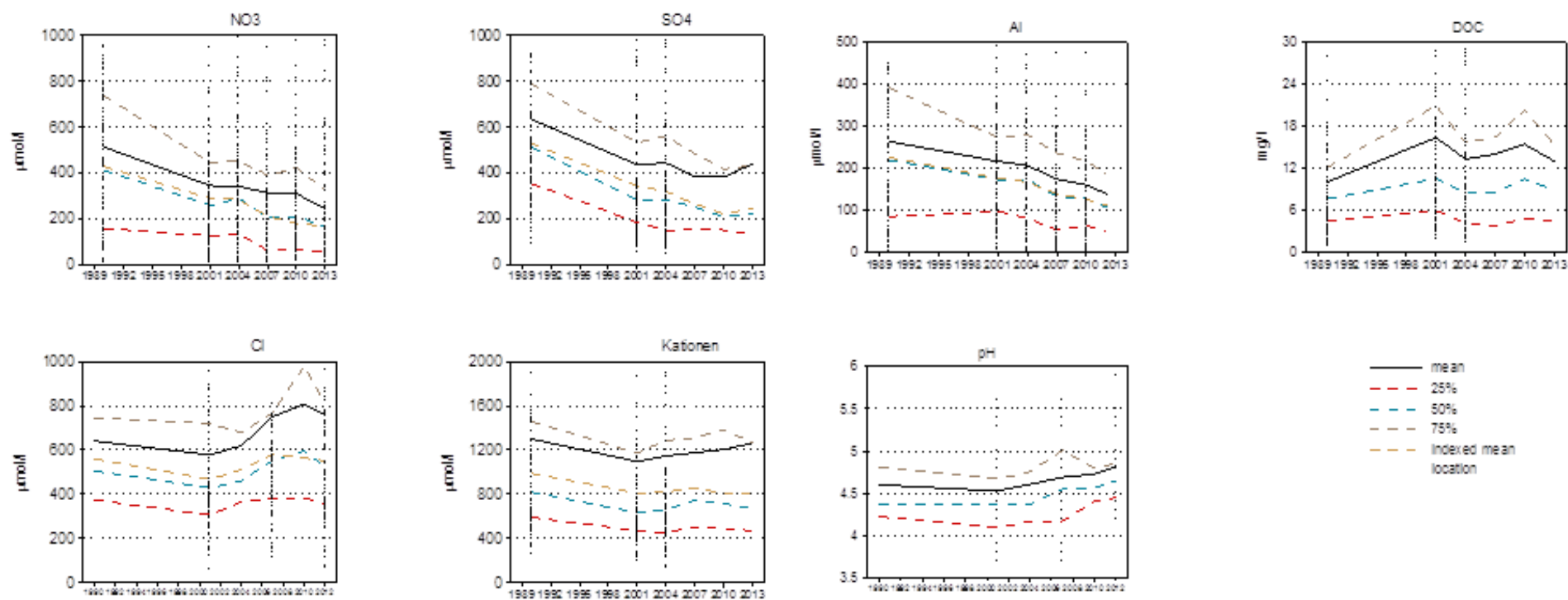


Locations where upper meter groundwater is sampled





Results - Upper groundwater concentrations





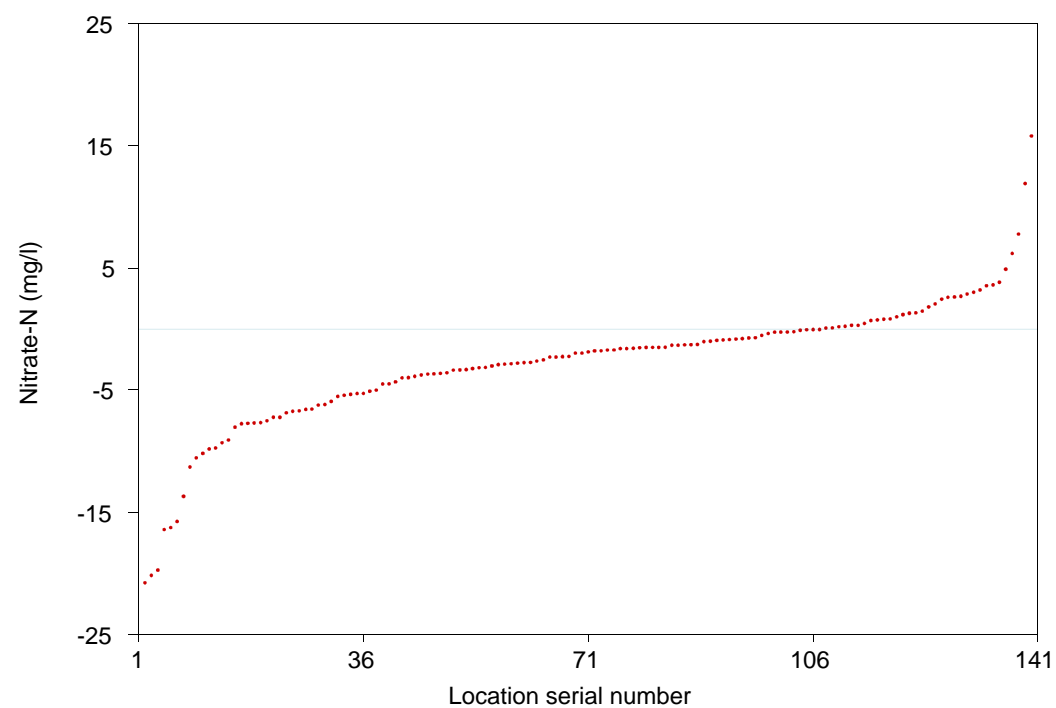
Results - Groundwater concentrations at 1 meter depth

Parameter	% decrease median concentration in 2014 compared to level in 1989
N (NO ₃)	61
S (SO ₄)	54
Al	40
H ⁺	40
Sum cations - anions	-80% (= 80% increase)

Paired t-test, $\alpha < 0.05$ indicates N, S, Al are significantly lower in 2014 compared to 1989, and pH is significantly higher.

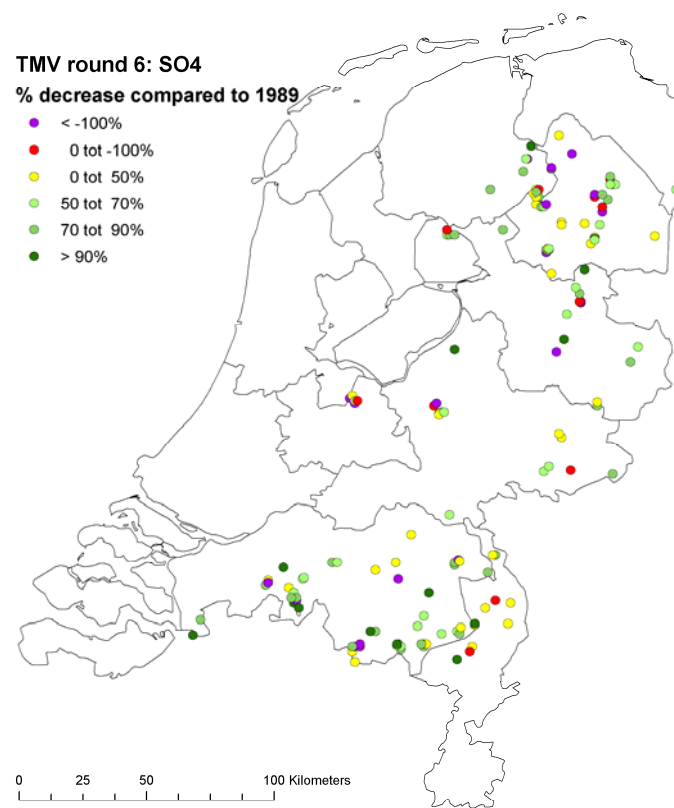
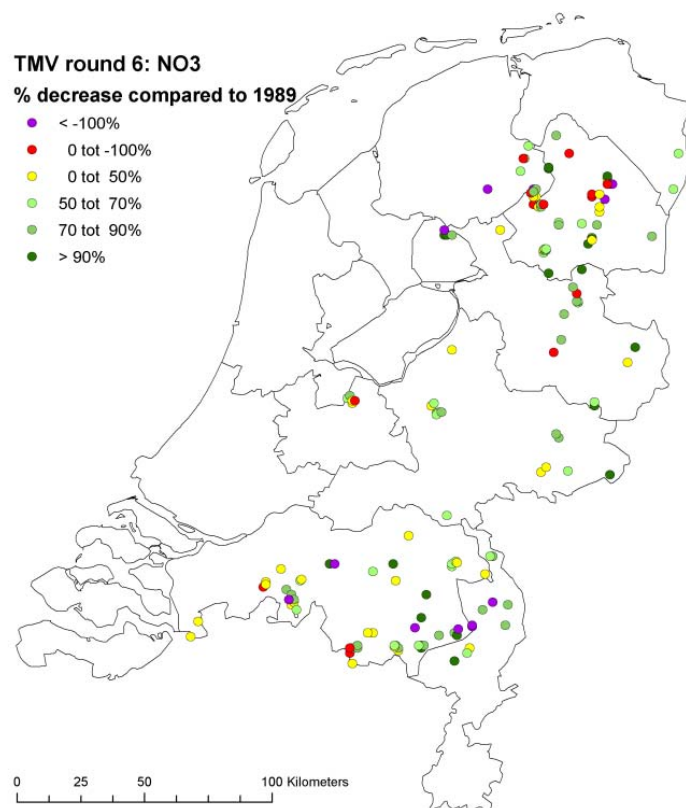


Nitrate concentrations per location: 2014-1989





Results: significant but variable decreases in groundwater quality (1m)





National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Content

1. Emissions-Depositions
2. Rainwater quality or wet deposition
3. Groundwater quality at 1 m depth
(leaching water)
- 4. Groundwater quality at 10 m depth**
5. Comparing rainwater and groundwater
trends



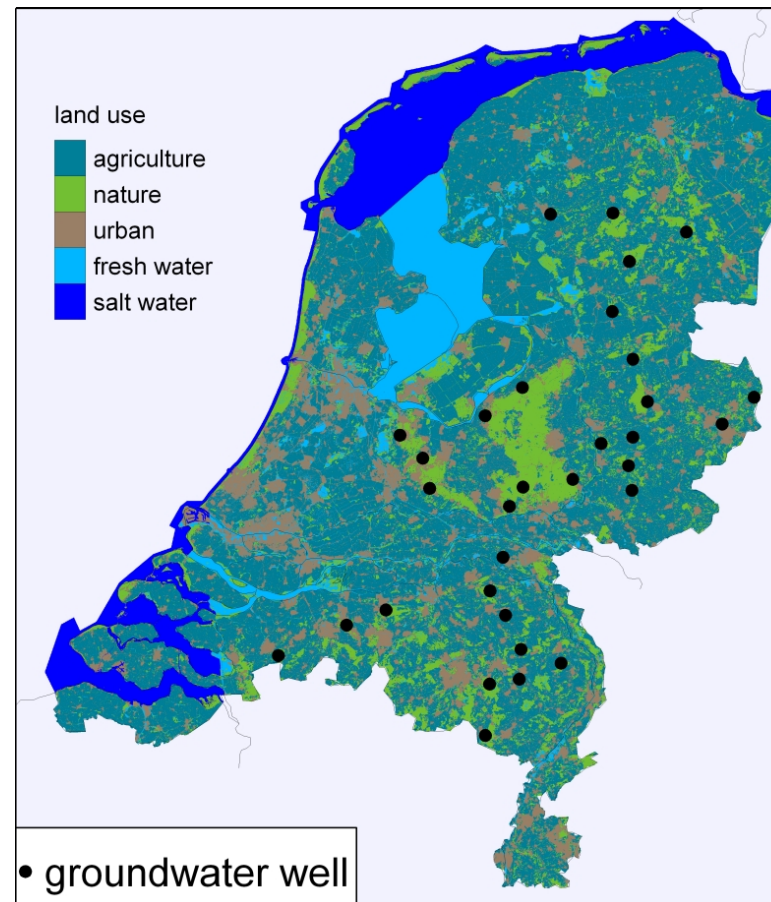
Sampling deeper groundwater

- 32 selected monitoring wells with recent fresh water in nature areas on sandy soils
- Started in 1984, sampled annually
- Sampling of groundwater at 10 m depth



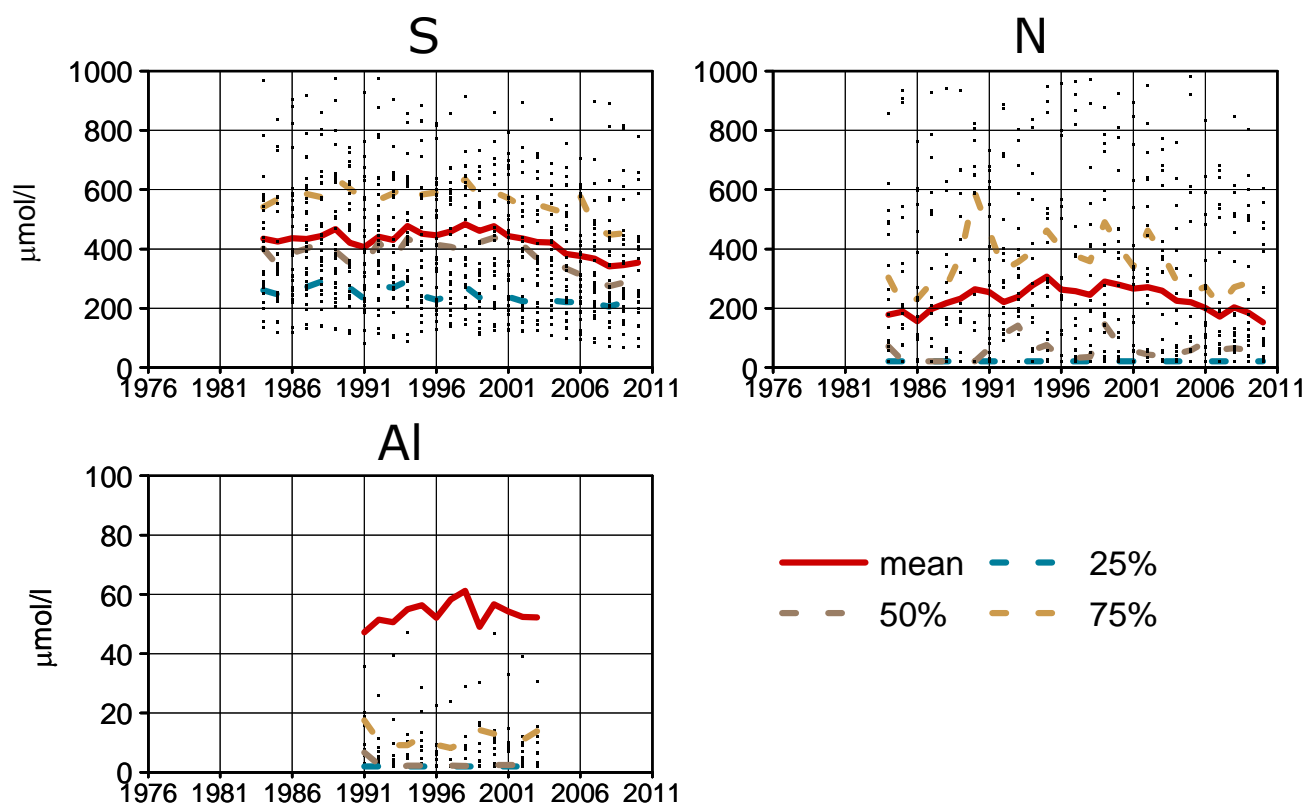


Locations of selected deeper groundwater wells





Results - Sampled groundwater concentrations at 10m depth





National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Content

1. Emissions-Depositions
2. Rainwater quality or wet deposition
3. Groundwater quality at 1 m depth
(leaching water)
4. Groundwater quality at 10 m depth
5. **Comparing rainwater and
groundwater trends**

Changes in rainwater and groundwater quality as a
result of emission reduction policy - ICP Forests 2015



Results: upper groundwater compared to rainwater

($\mu\text{mol/l}$)	% decrease
N – rain	44%
N – groundwater	61%
S – rain	81%
S – groundwater	54%



Conclusions

During 1989-2014

- **S** in rain and upper groundwater decreased
- **N** in rain and upper groundwater decreased
- **S** and **N** in deeper groundwater decreased
- **Aluminium and heavy metals** in upper groundwater decreased

Less deposition is reflected in a better groundwater quality



Conclusions

1. **Emission reduction policy works!**

There is less acidification in rainwater and upper groundwater.



2. **Long term monitoring** is necessary to indicate effect of policy measures.

3. Other research shows, that despite these positive developments, **ecosystems** have not yet recovered from acidifying and eutrophying effects of air pollution.



Thank you for you attention....

Questions?