Combining High-Resolution Monitoring Data and the SWAT Model to Identify Herbicide Source Areas in a High Agricultural Intensity Catchment

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Objectives

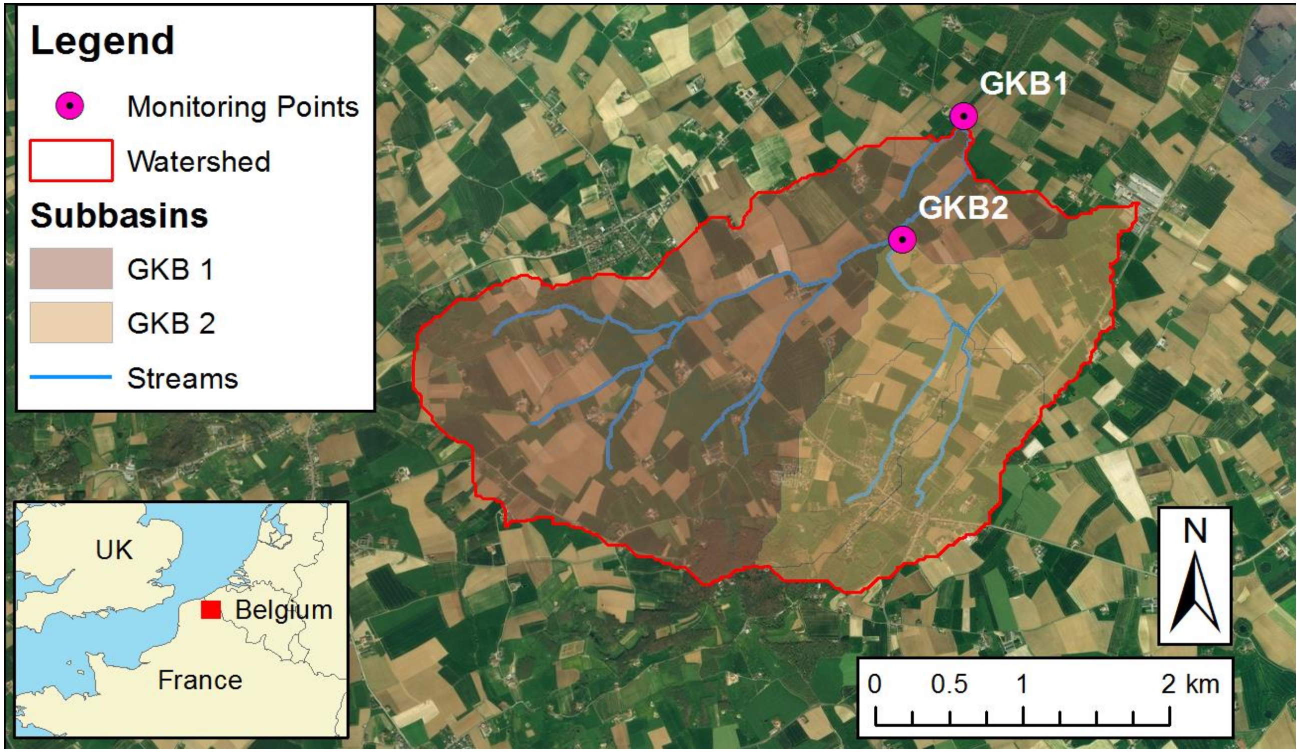
Monitoring

- Contextualization with Regulatory FOCUS SW

Modelling

- Diffuse / Point Source Differentiation
- Identify Dominating Transport Processes
- Determine spatio-temporal variability of total load and transport processes (field level)
    - Event-based source area analysis (main peaks)
    - Long-term source area analysis (total load)

Monitoring Study Area: Grote Kemmelbeek Catchment



- 992 ha, West Flanders
- >90% Agriculture
- 816 mm/a rain
- Elevation 24 m - 159 m

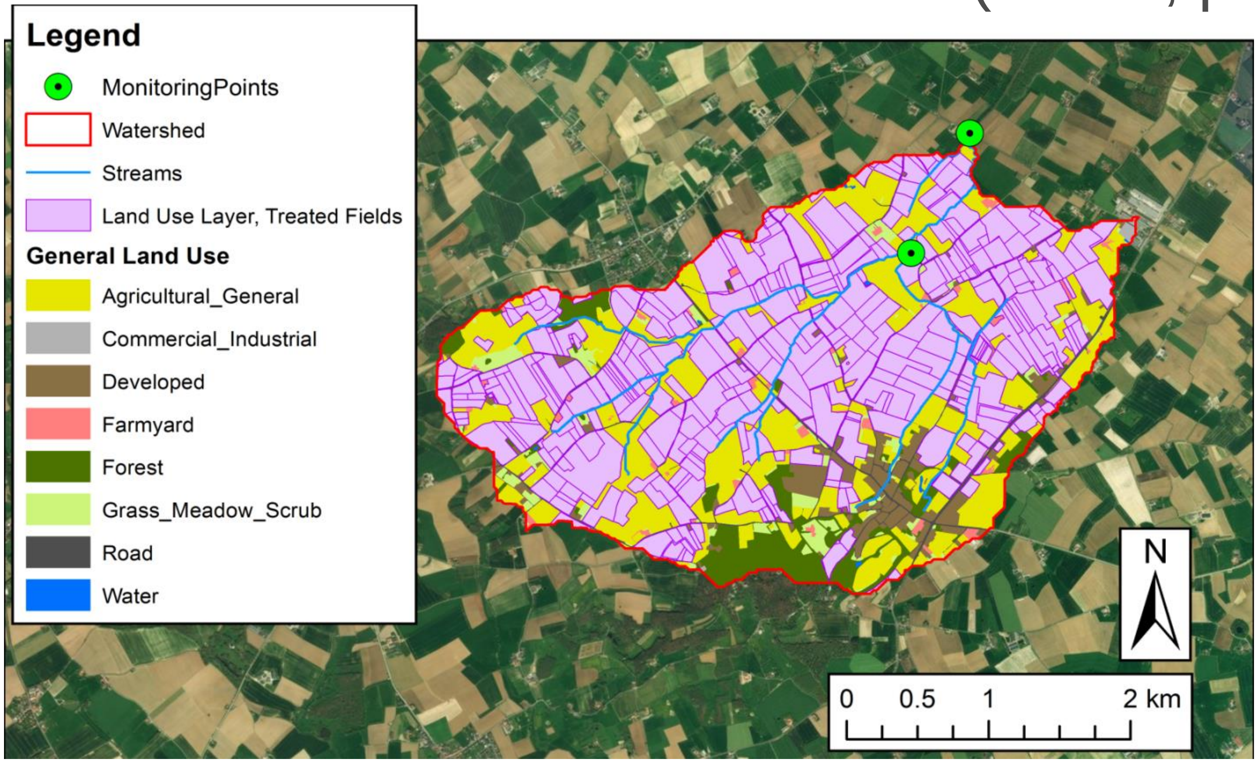
Monitoring Study Conduct / Data

- May 17th, 2010 to December 31st, 2013
- 2 sampling points (GKB1 and GKB2)
- Flow measurement (ISCO 750 Flow Velocity Module): Water level/flow every 5 min
- Grab Sampling (ISCO sampler): every 0.5 h to every 2 h and combination to 4 to 1 samples/day

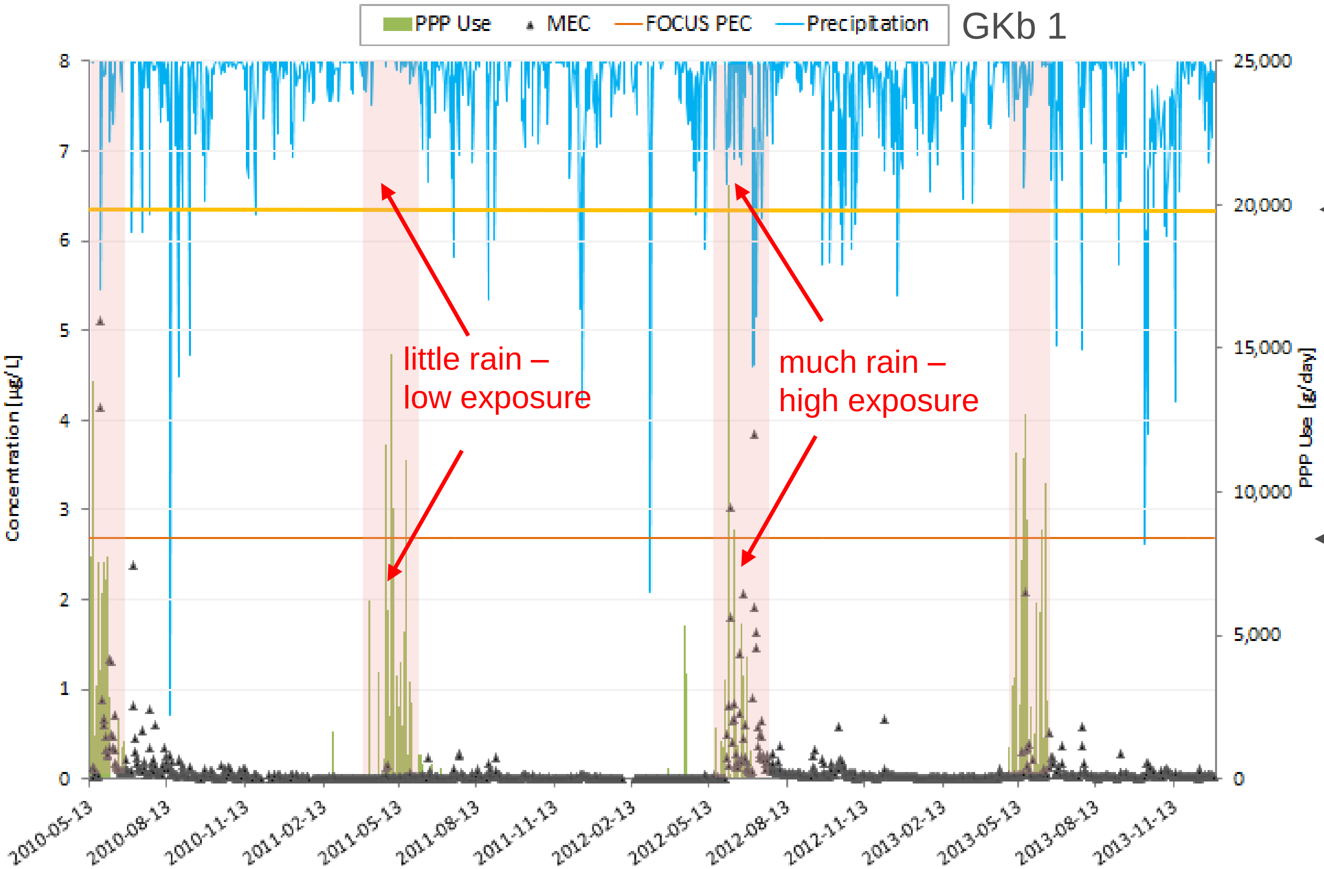
- Comprehensive farmers' survey (n = 115)
  - Product use/dose/date/crop/field
  - Presence of drainpipes
  - Use of filter strips and drift reduction nozzles
- Weather data: Hourly precipitation, temperature and wind from Flemish Government and INAGRO
- Soil data: 12 unique soil pedons for texture, BD, OC, WHC, Ksat, USLE K (Aardewerk Database)

Land Use/Application Dataset

- Field specific land use data (up to 330/580 fields treated)
- Four years of field specific cropping/application information
- 46% of area treated with one a.i. (maize, potato, cereals)



Monitoring Results



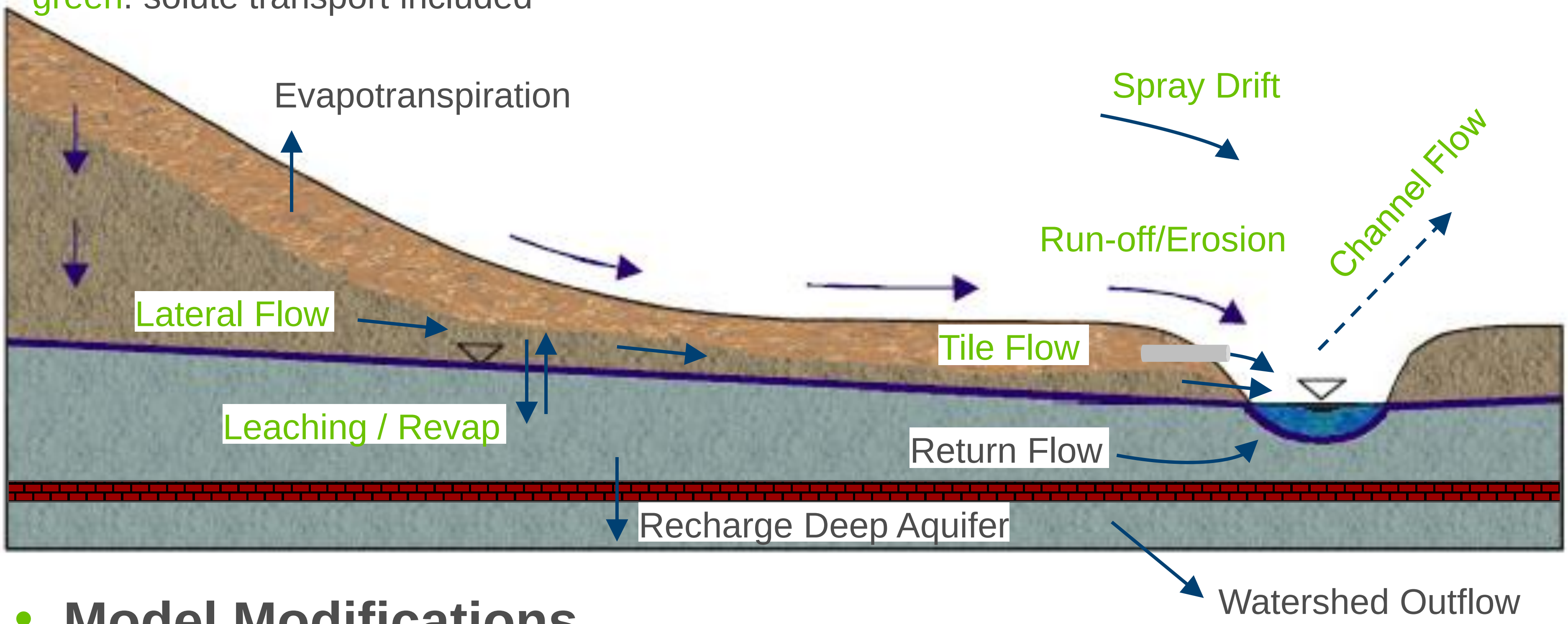
FOCUS Step 3 R1 (R1-stream)

FOCUS Step 4 R1 (10 m VFS - not required)

- FOCUS Step 3 R1 scenario (relevant for Belgium) highly protective
- Findings correlate with wet application seasons (run-off, drainflow)

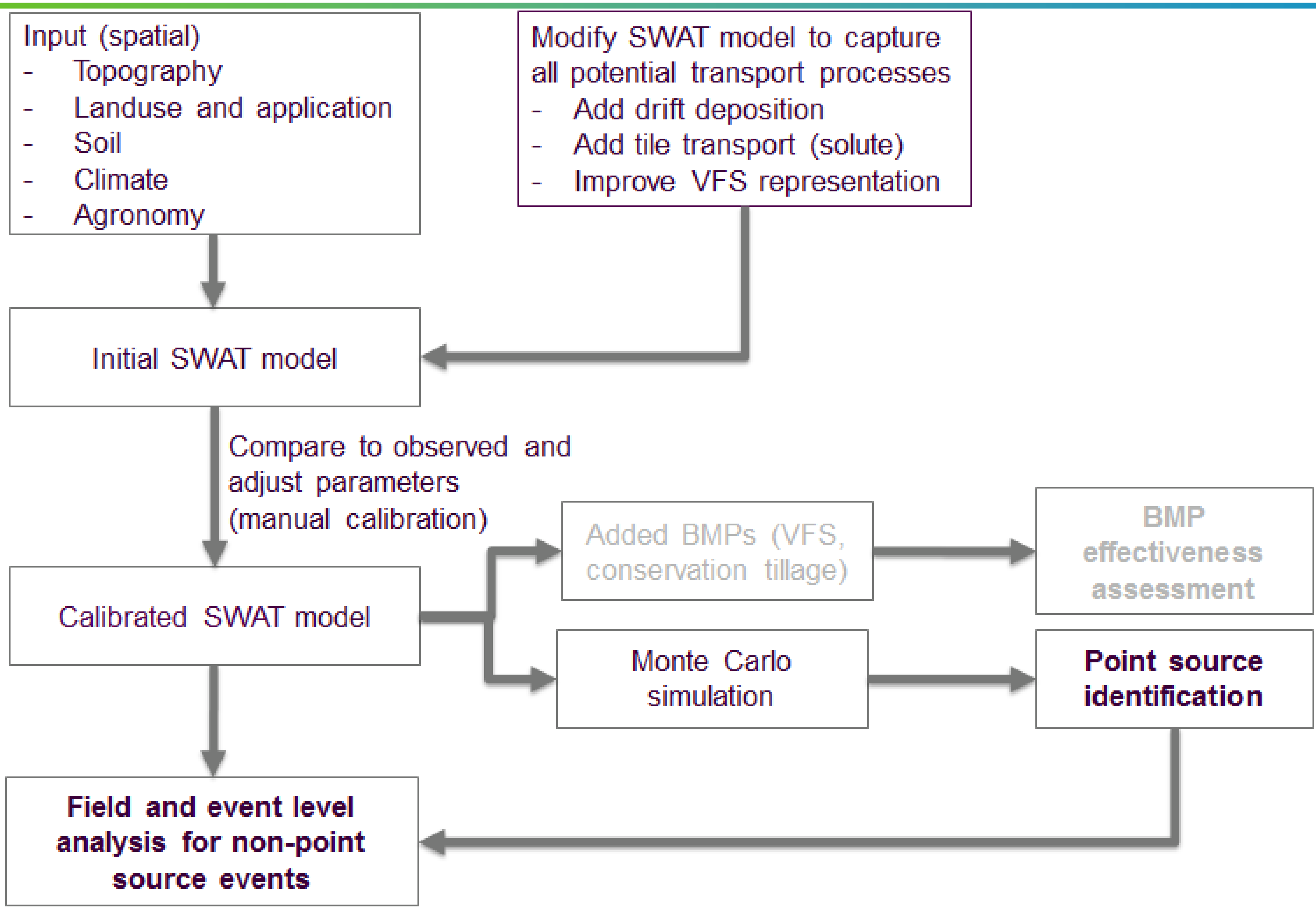
Modelling Study: Transport Processes in SWAT

green: solute transport included



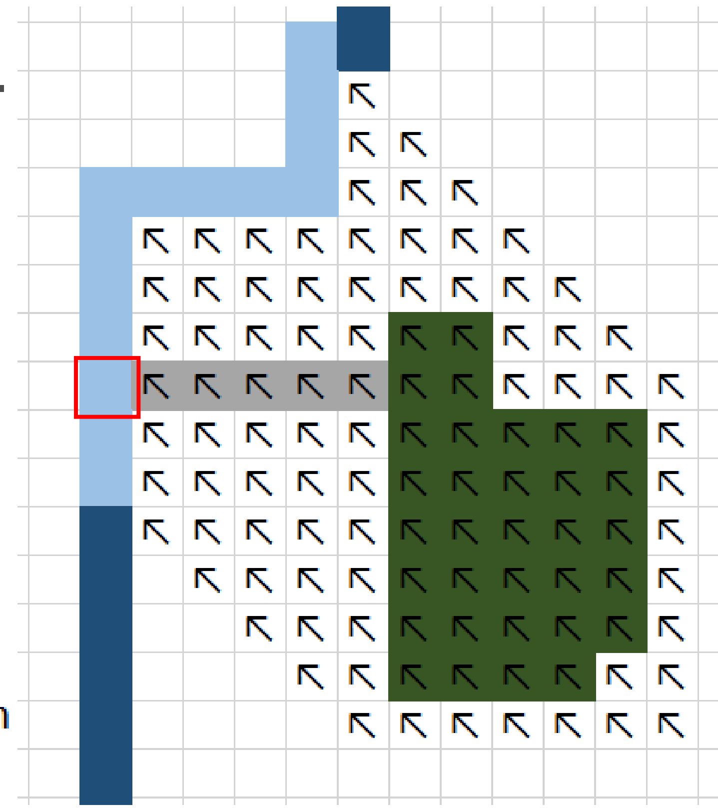
- **Model Modifications**
  - Chemical transport through tile drains added
  - Drift Deposition added (spatially explicit)

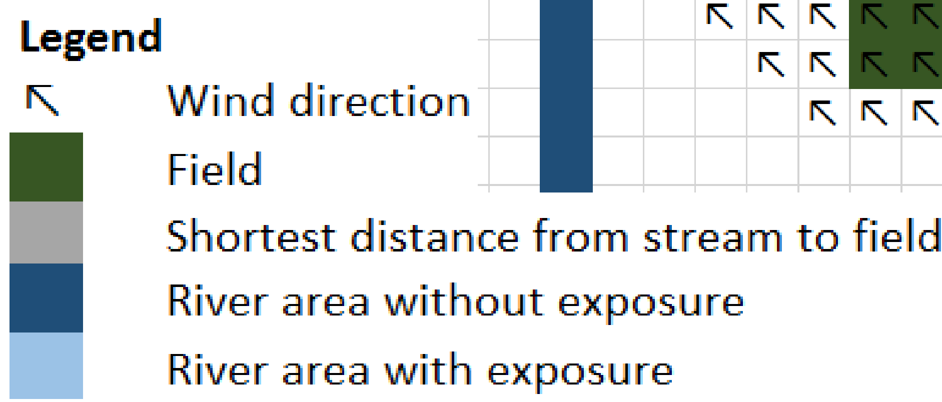
Modelling Approach



Drift Modelling

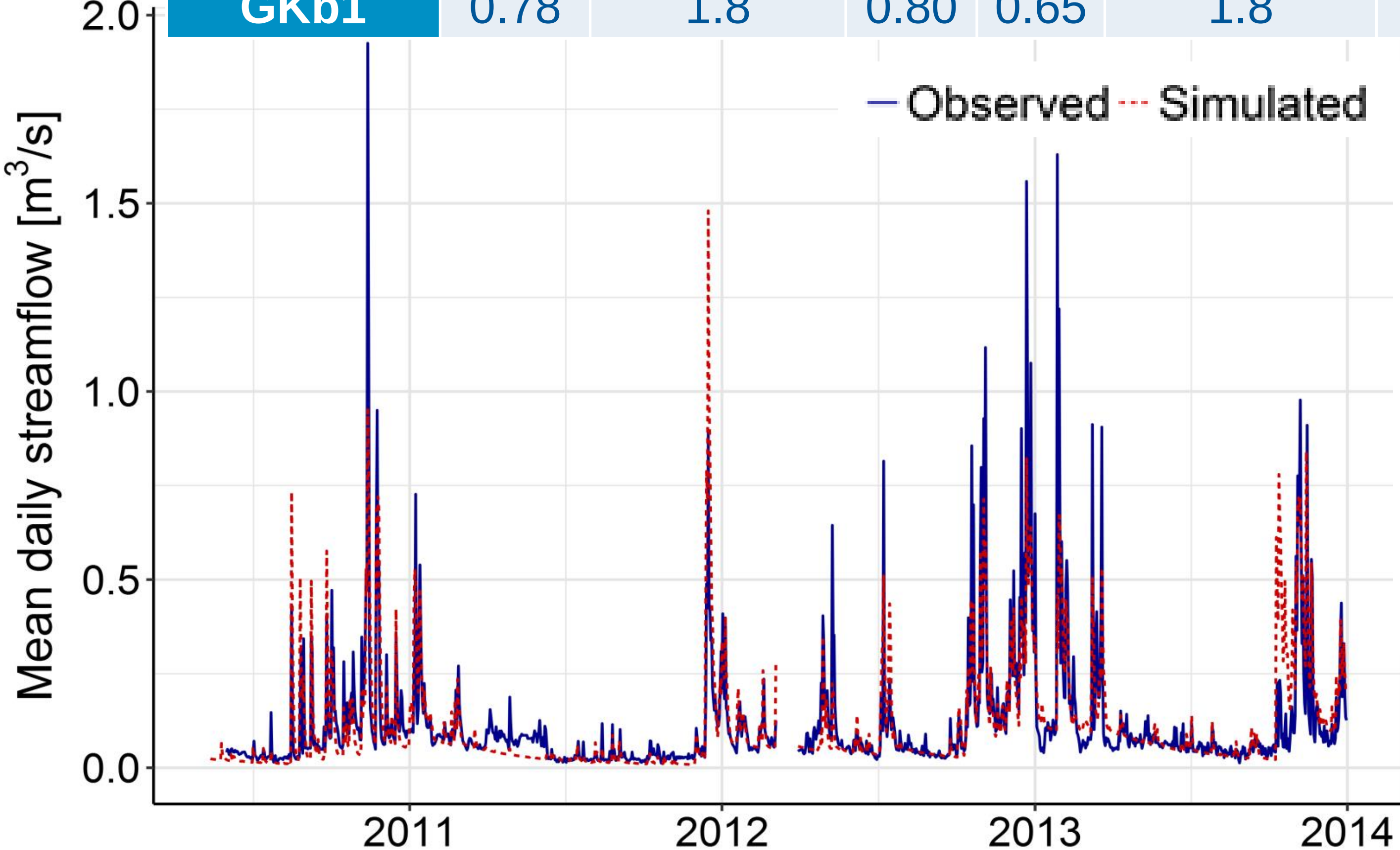
- Ganzelmeier curve (arable), 50th perc.
- Drift reducing nozzles after 2011
- Account for wind direction
- Edge-of-field distance to stream is assumed to be the closest distance from a given stream section to the field





Hydrograph

Location	Monthly			Daily		
	NSE	PBIAS (%)	R^2	NSE	PBIAS (%)	R^2
GKb1	0.78	1.8	0.80	0.65	1.8	0.65



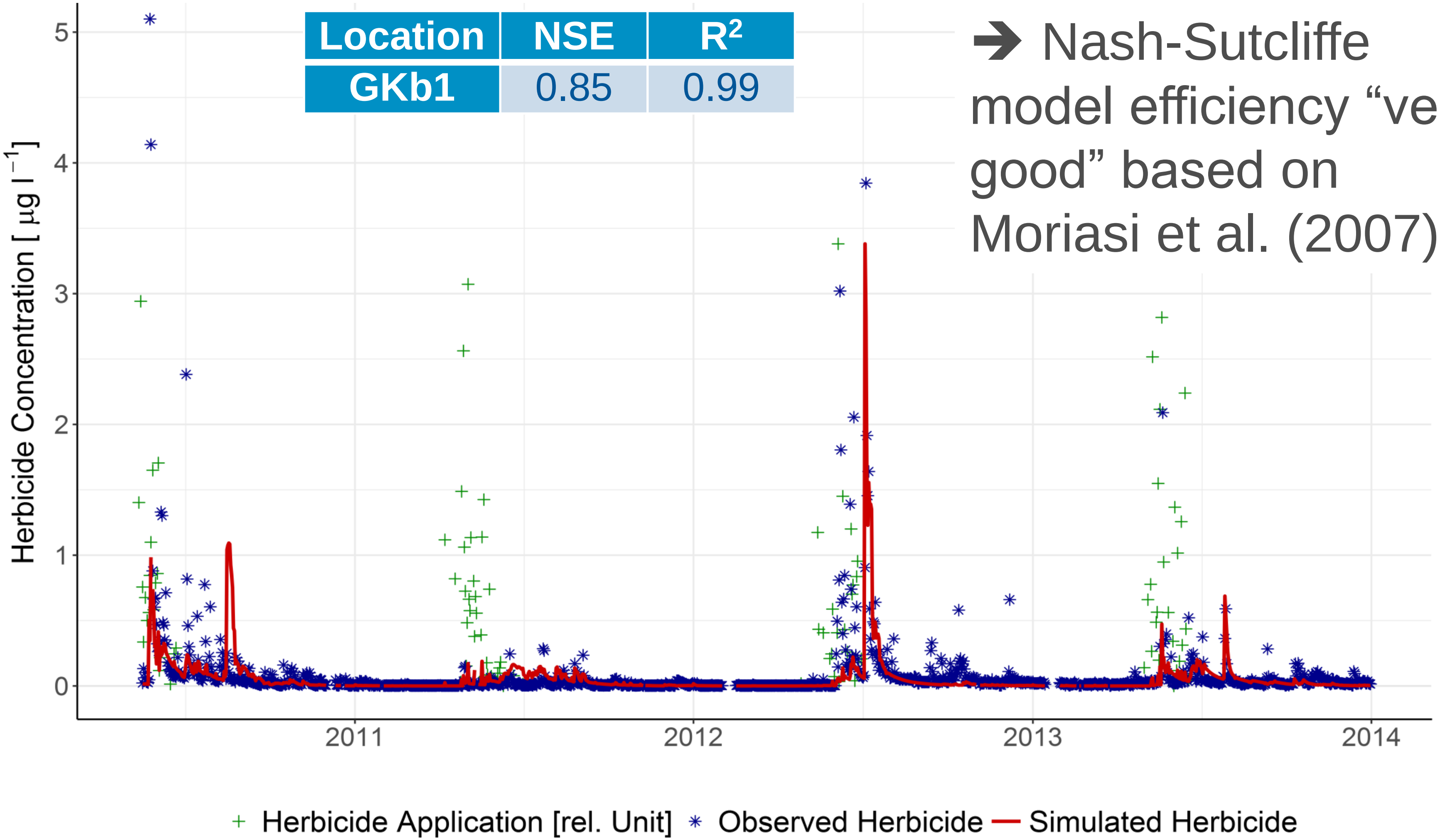
➔ Nash-Sutcliffe model efficiency "very good" to "good" based on Moriasi et al. (2007)

PBIAS: Percent Bias

Chemograph

Location	NSE	R^2
GKb1	0.85	0.99

➔ Nash-Sutcliffe model efficiency “very good” based on Moriasi et al. (2007)



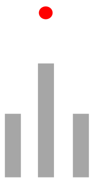
Point/Diffuse Source Identification

Monte Carlo Simulation → **Classification** (Peaks >0.25 µg/l)

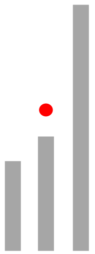
- Hydrology
  - surface flow (curve number)
  - subsurface flow (aquifer parameters)
- Pesticide extraction for run-off
- Drift (50th / 90th percentile and drift reducing nozzles)

- Likely diffuse source
  - $O_i \leq S_i$

- Unlikely diffuse source
  - $O_i > S_i$ and $O_i >$ average (S_{i-1}, S_i, S_{i+1})

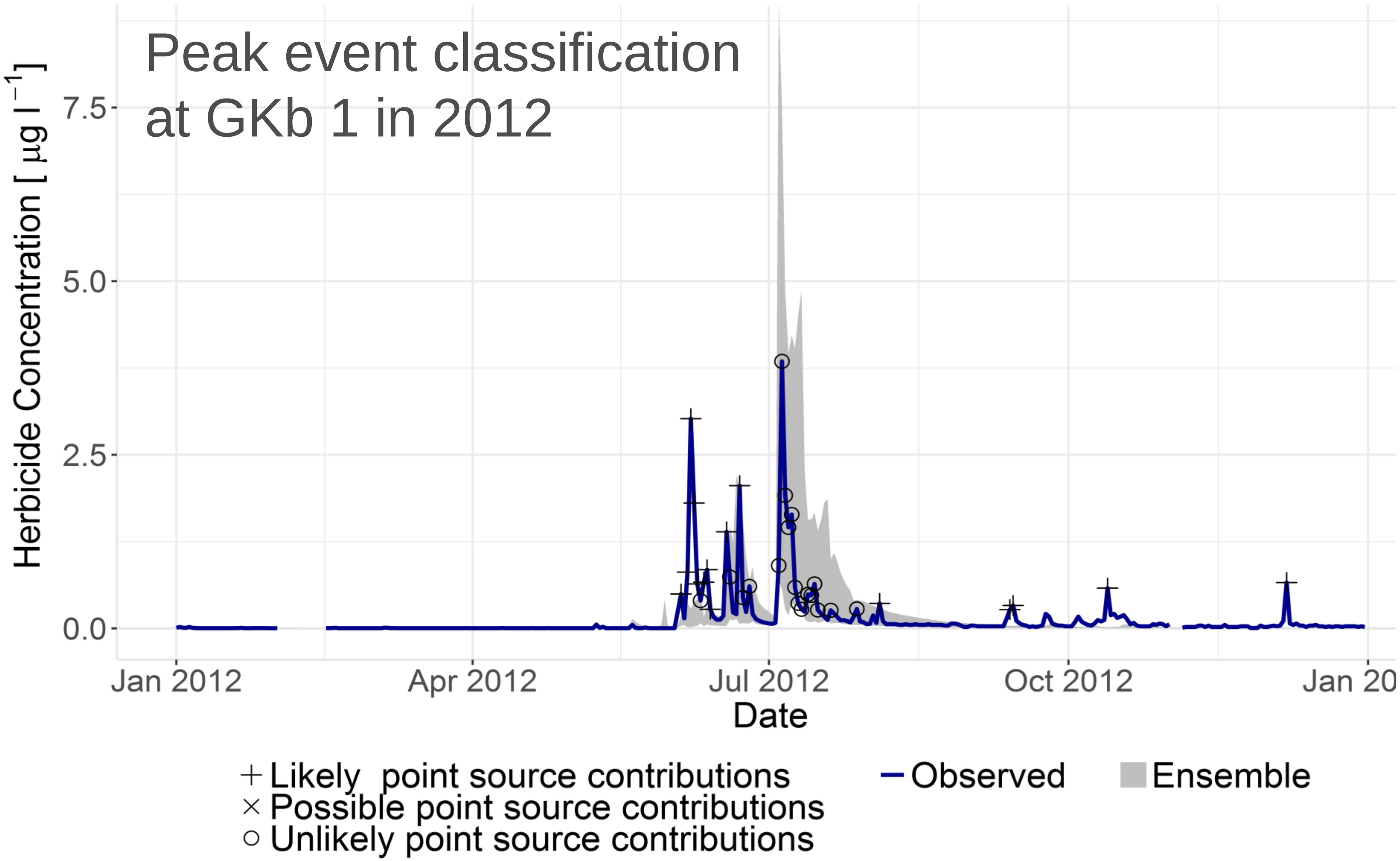


- Possible diffuse source
  - $O_i > S_i$ and $O_i \leq$ average (S_{i-1}, S_i, S_{i+1})



O_i: Observation on day i
S_i: Ensemble maximum on day i

Time Series of Source Classification

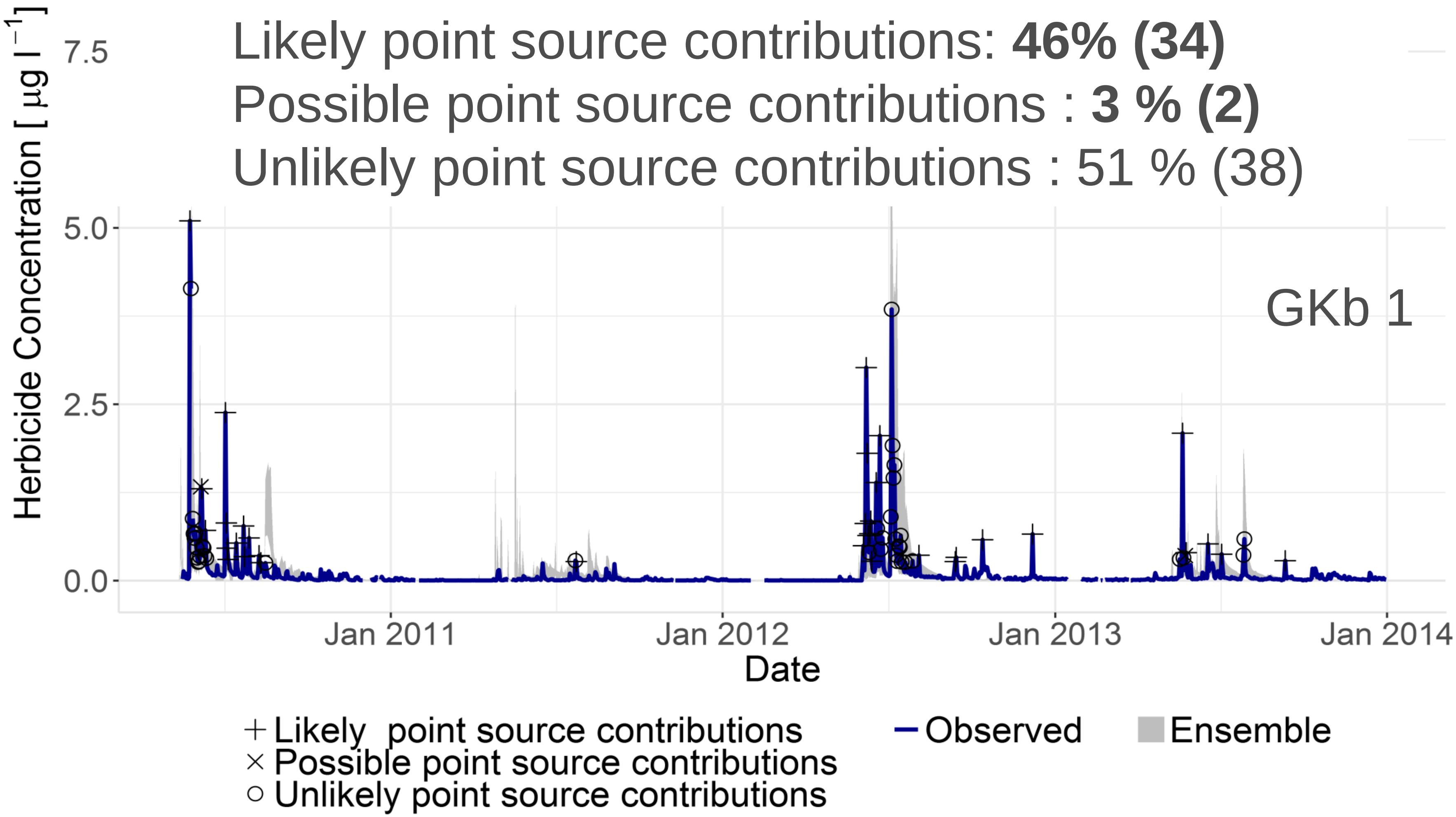


Time Series of Source Classification

Likely point source contributions: **46% (34)**

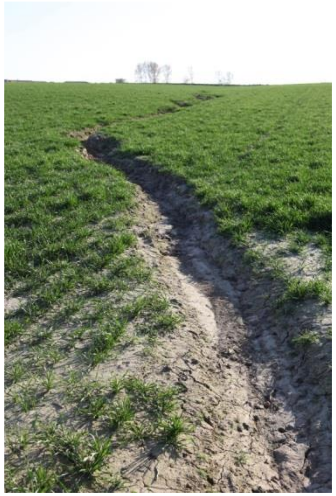
Possible point source contributions : **3 % (2)**

Unlikely point source contributions : 51 % (38)

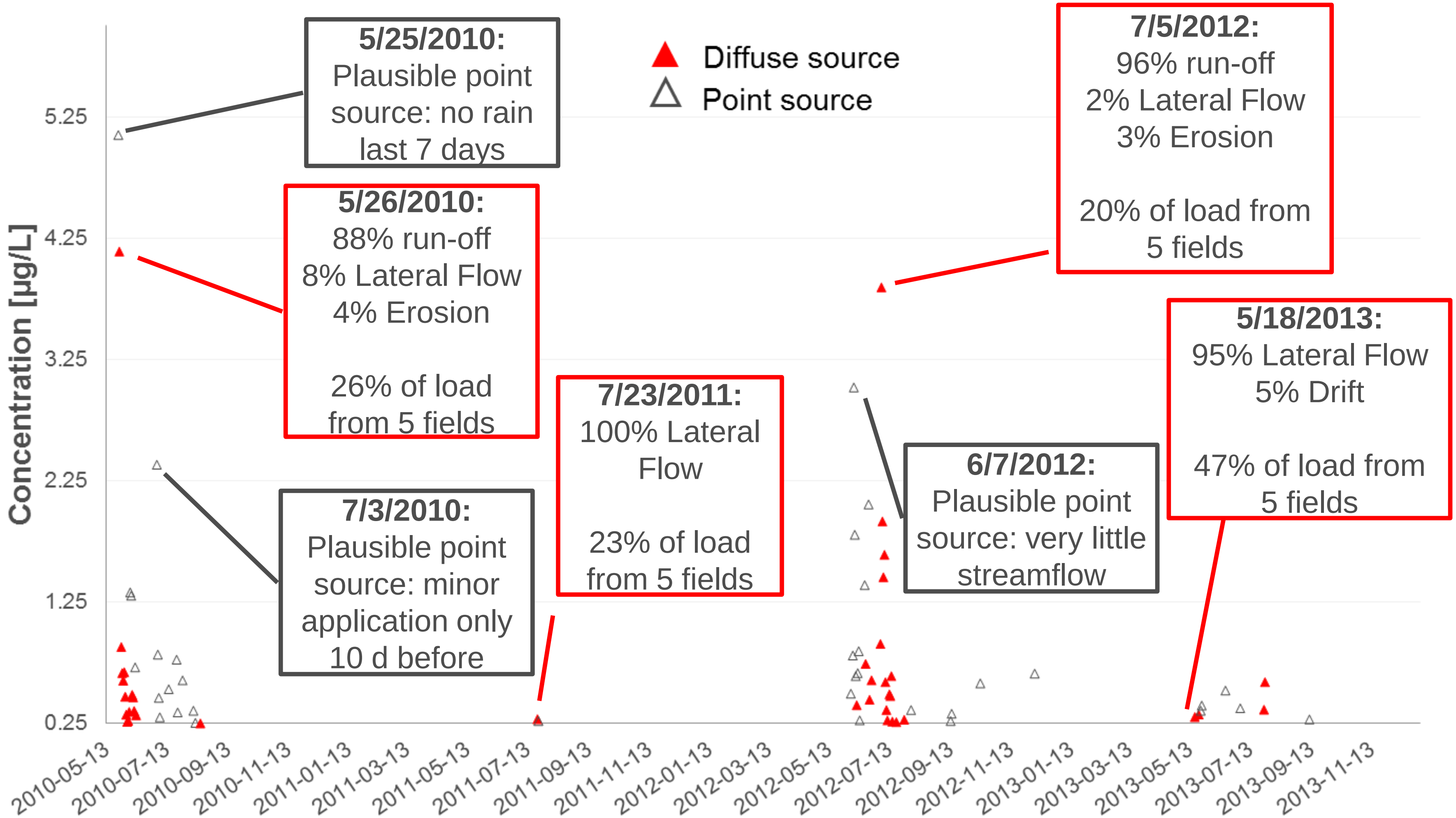


Possible Causes for Point Sources

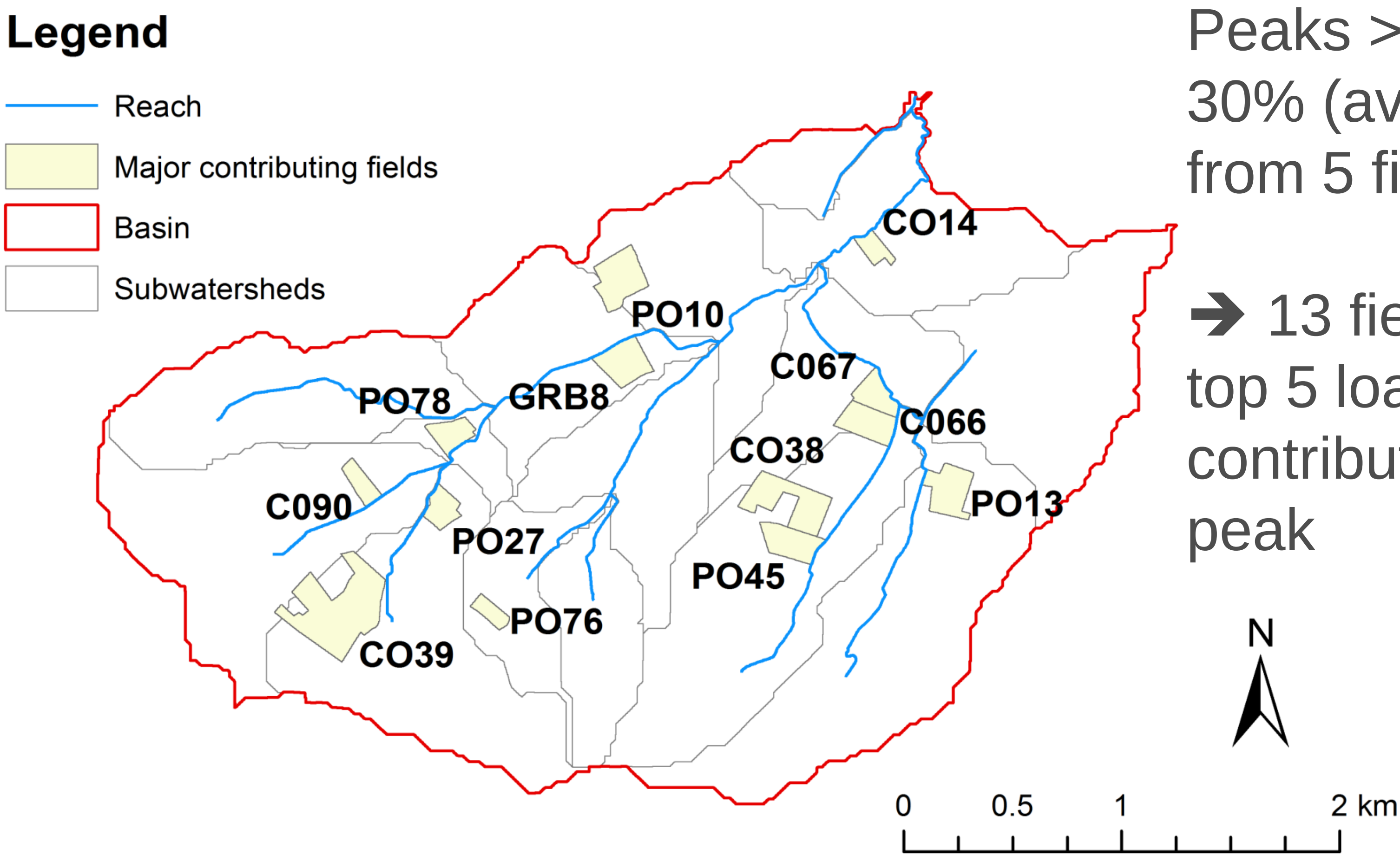
- Washing of sprayer equipment on impervious surfaces directly connected to drains
- Filling area directly adjacent to stream
- Improper disposal of empty containers (into stream)
- Artificial run-off via furrows installed by farmers to drain water from fields
- Undocumented agricultural/non-agricultural uses
- Misuse of the product



Event-Based Source Analysis (GkB1, >0.25 µg/l)



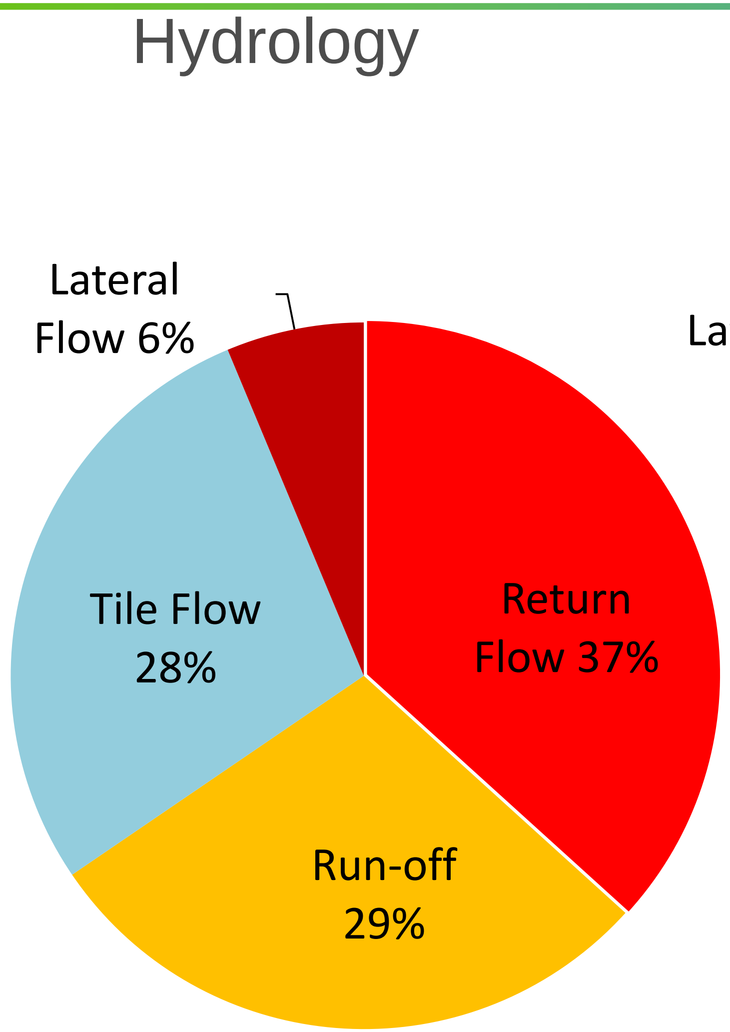
Event-Based Source Analysis

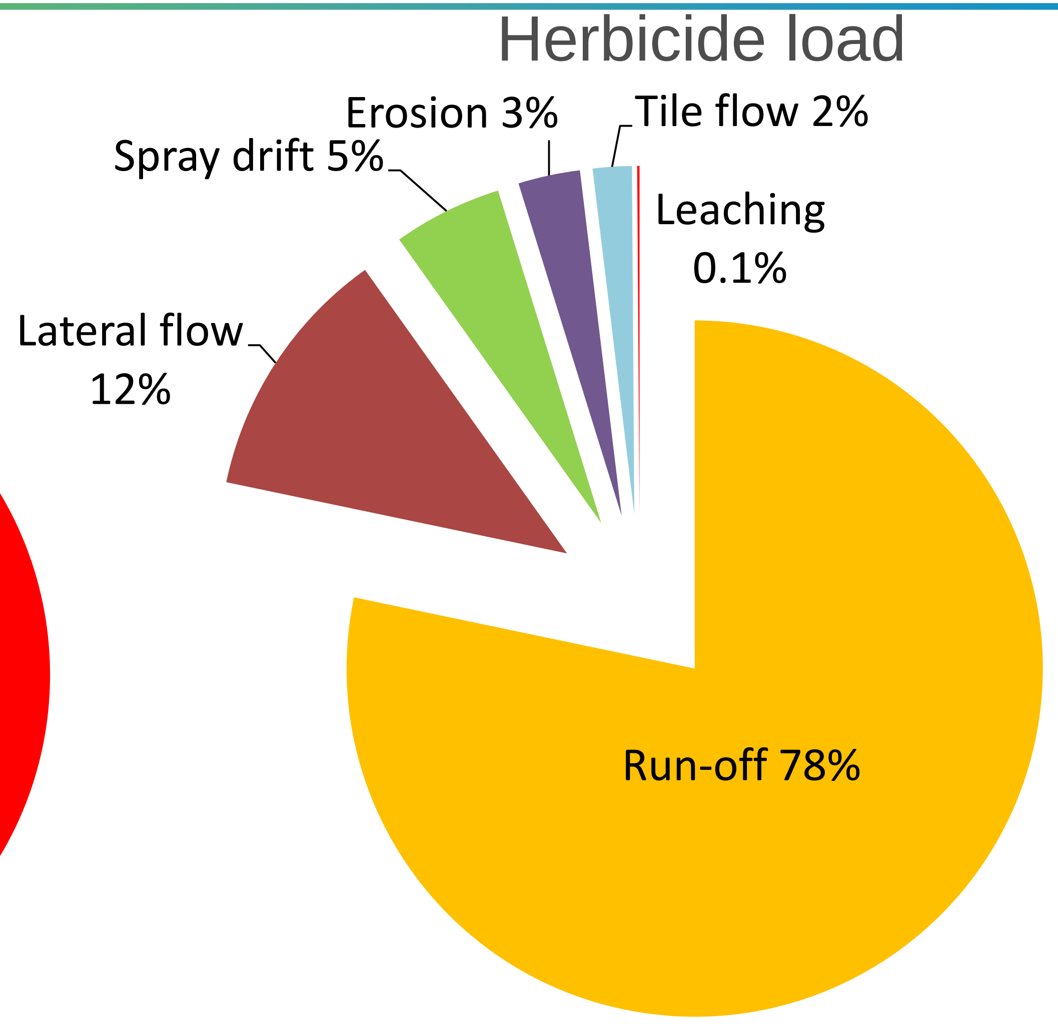


Peaks >0.25 µg/l: 30% (avg.) of load from 5 fields or fewer

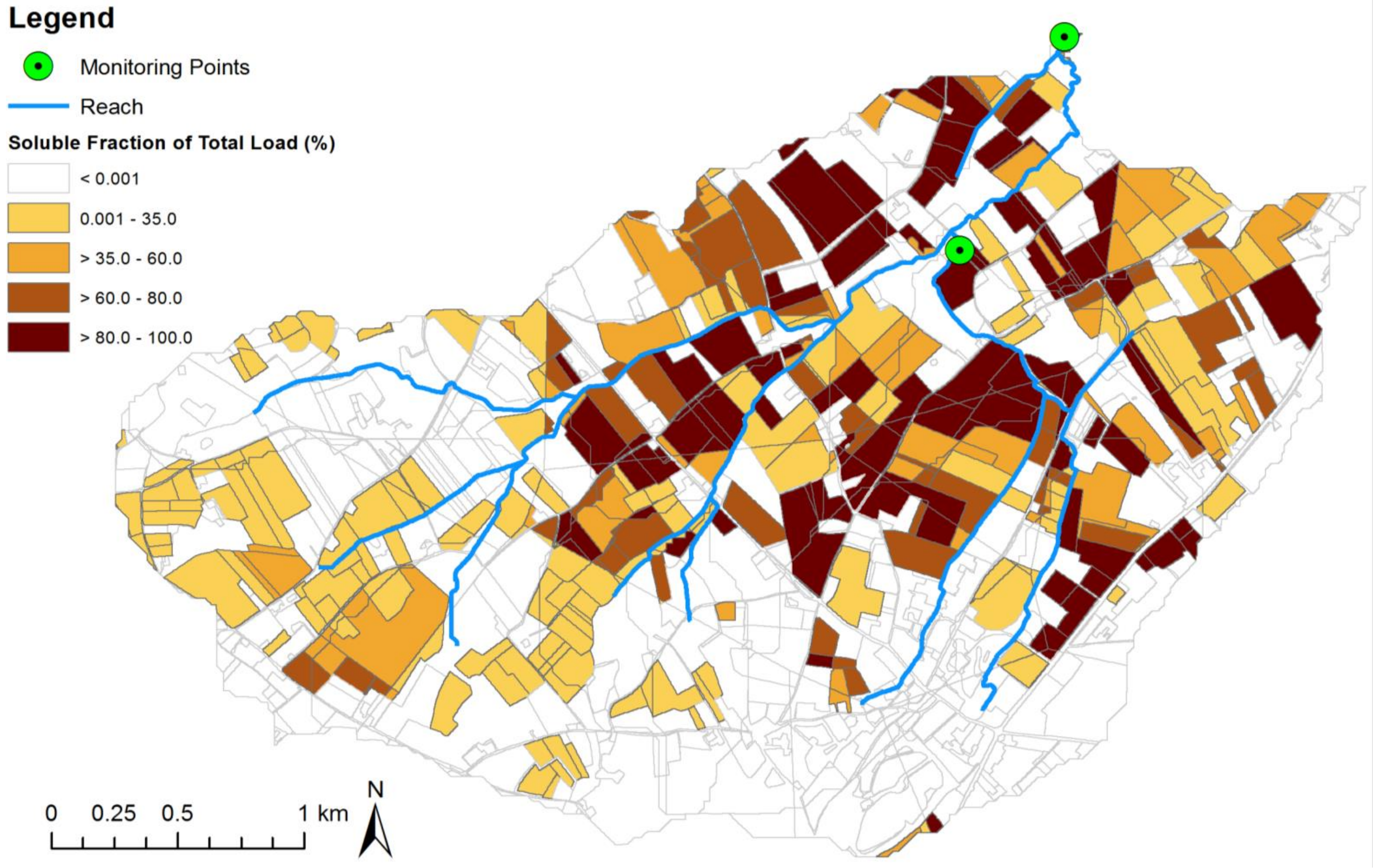
➔ 13 fields among top 5 load contributors to each peak

Long-Term Source Analysis

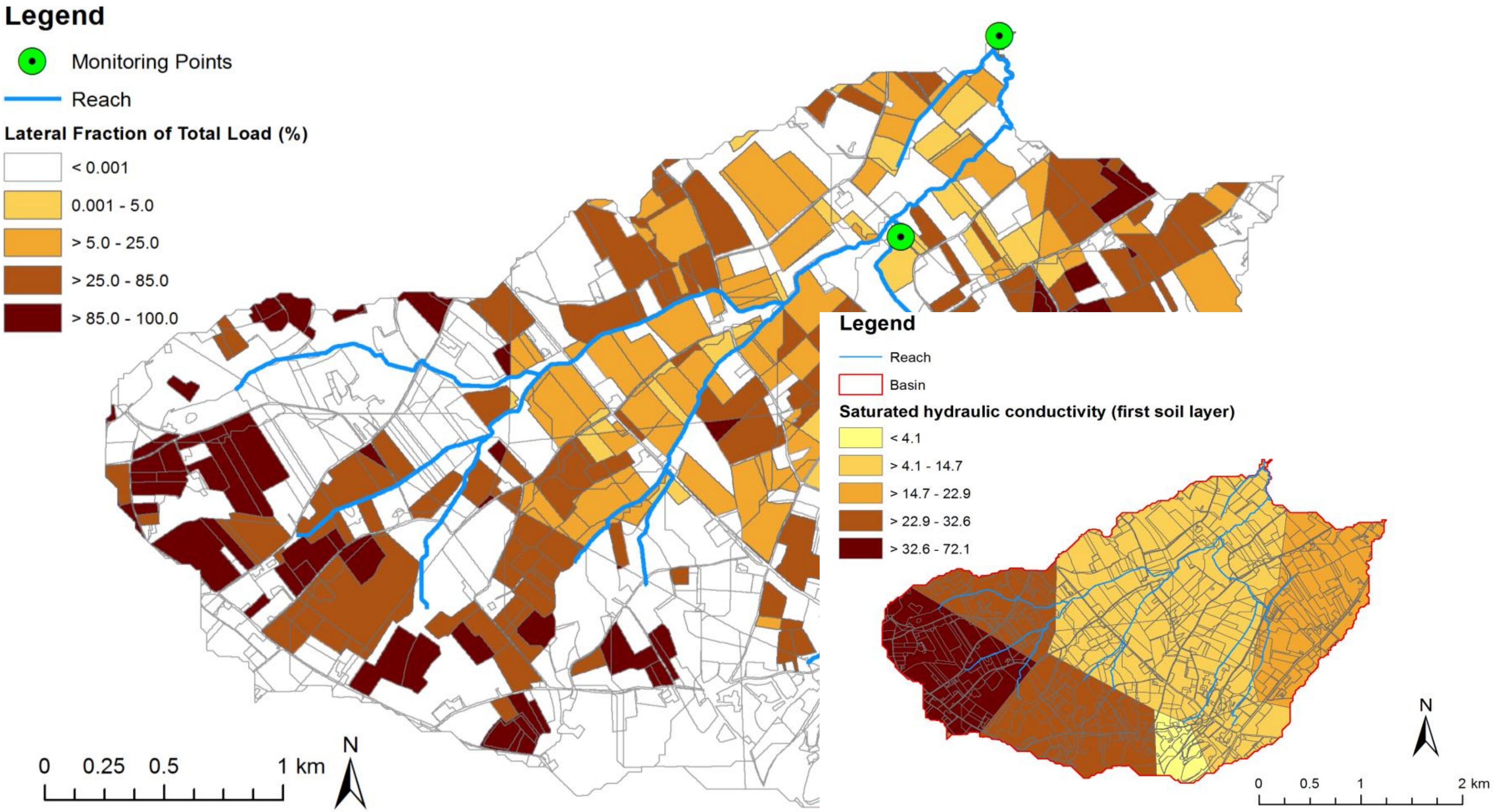




Long-Term Source Analysis (Run-off)



Long-Term Source Analysis (Lateral Flow)



➔ West: Lateral flow >50% of total load to streams (correlates with K_{SAT})

Conclusions

- FOCUS SW protective of findings in monitoring programme
- Event-based analysis (large peaks >0.25 µg/l)
  - About 51% likely caused by diffuse entries from applications according to GAP, remainder: point sources, undocumented applications or misuses
  - 13 fields among top 5 contributors to each peak
- Total load analysis
  - Run-off was primary transport process into surface water (78%) followed by lateral flow (12%) and drift (5%)
  - Spatial variability of total load and all exposure routes on field level basis could be derived

➔ Consequent reduction of point source entries

➔ Focus on run-off reduction

➔ Concentrate stewardship efforts on main contributing fields

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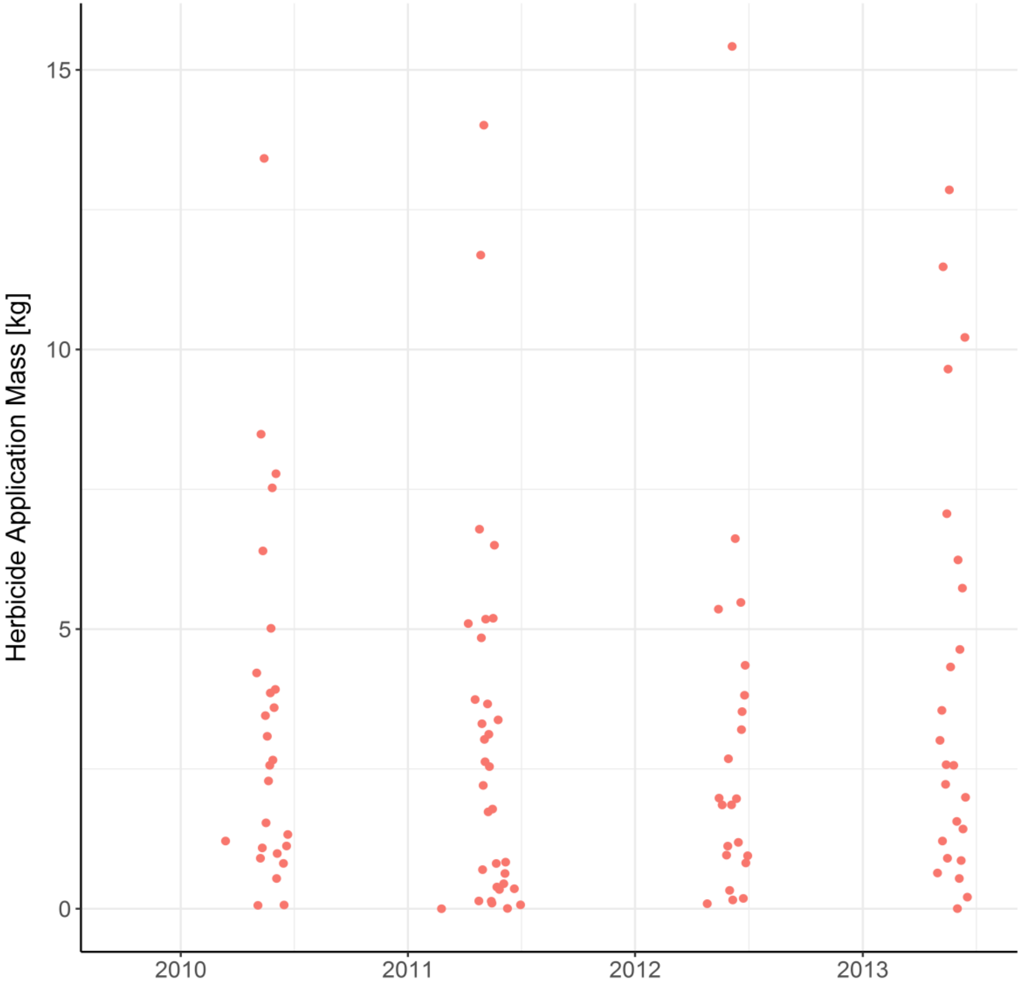
Thank you!

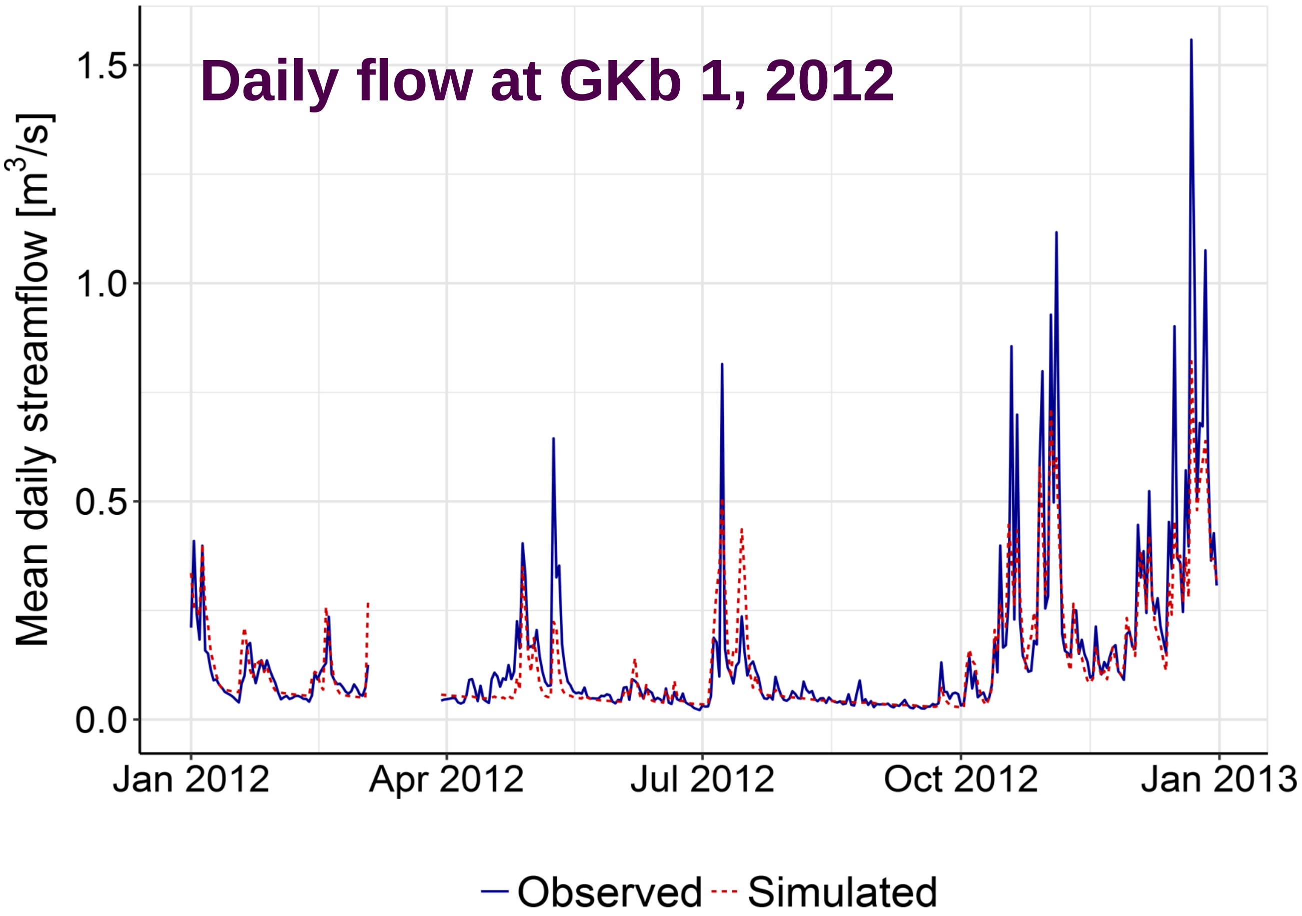
Herbicide Application Data



Field specific application data available

46% of watershed area treated with herbicide (maize, potato, cereals)

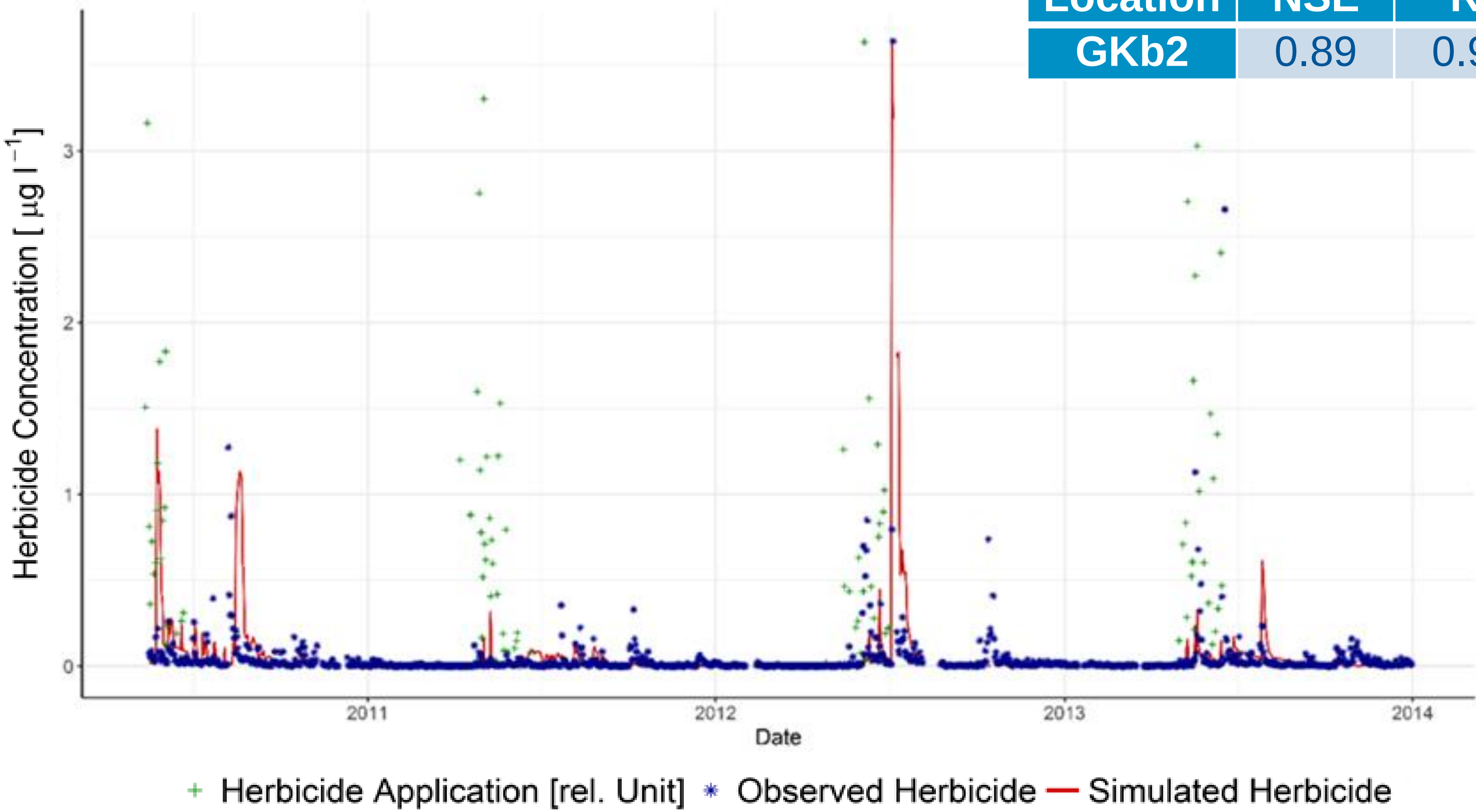
Hydrograph



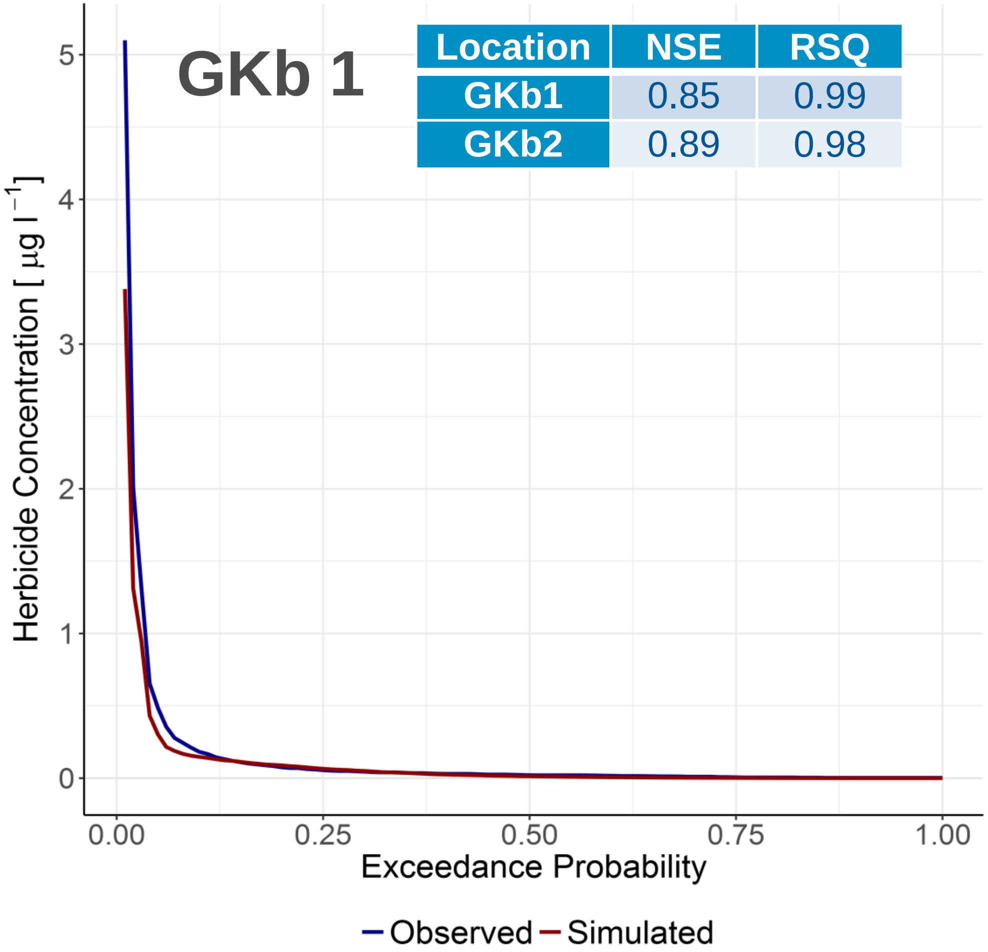
Daily flow at GKb 1, 2012
Mean daily streamflow [m3/s]
1.5
1.0
0.5
0.0
Jan 2012
Apr 2012
Jul 2012
Oct 2012
Jan 2013
Observed
Simulated

Chemograph

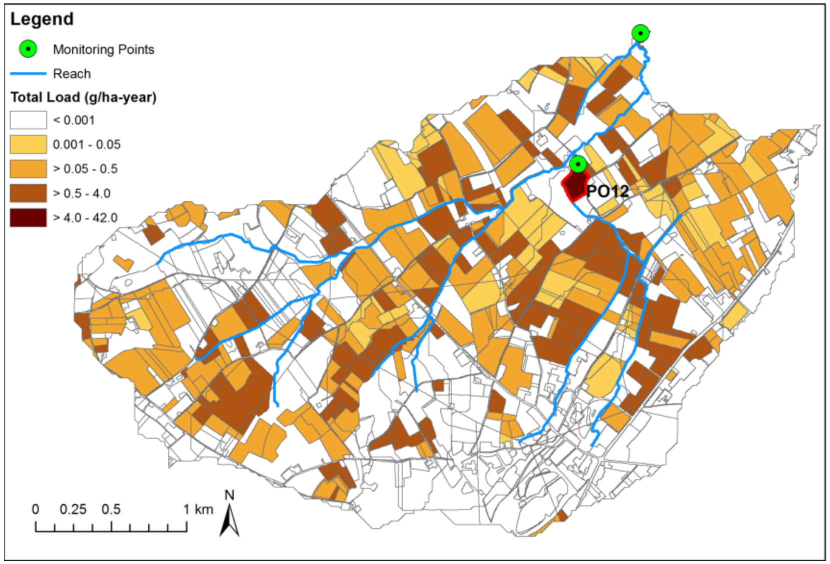
Location	NSE	R^2
GKb2	0.89	0.98

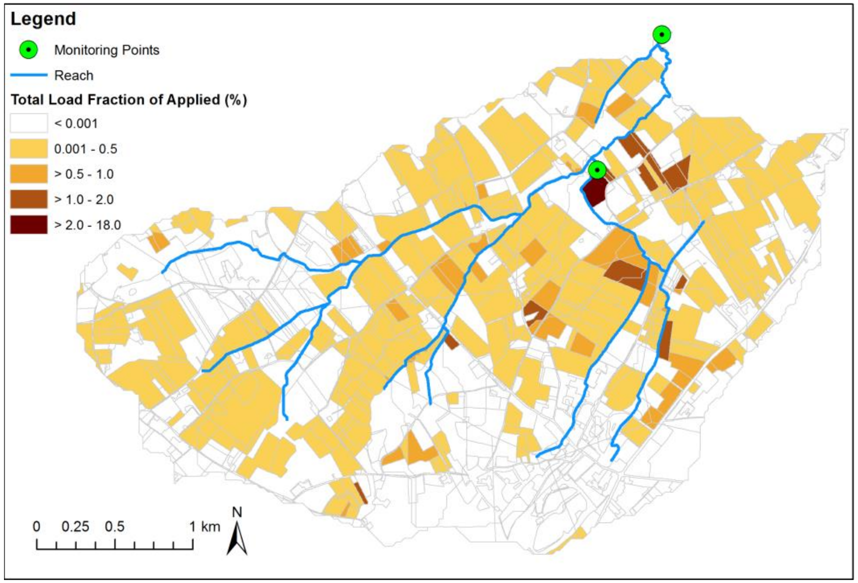


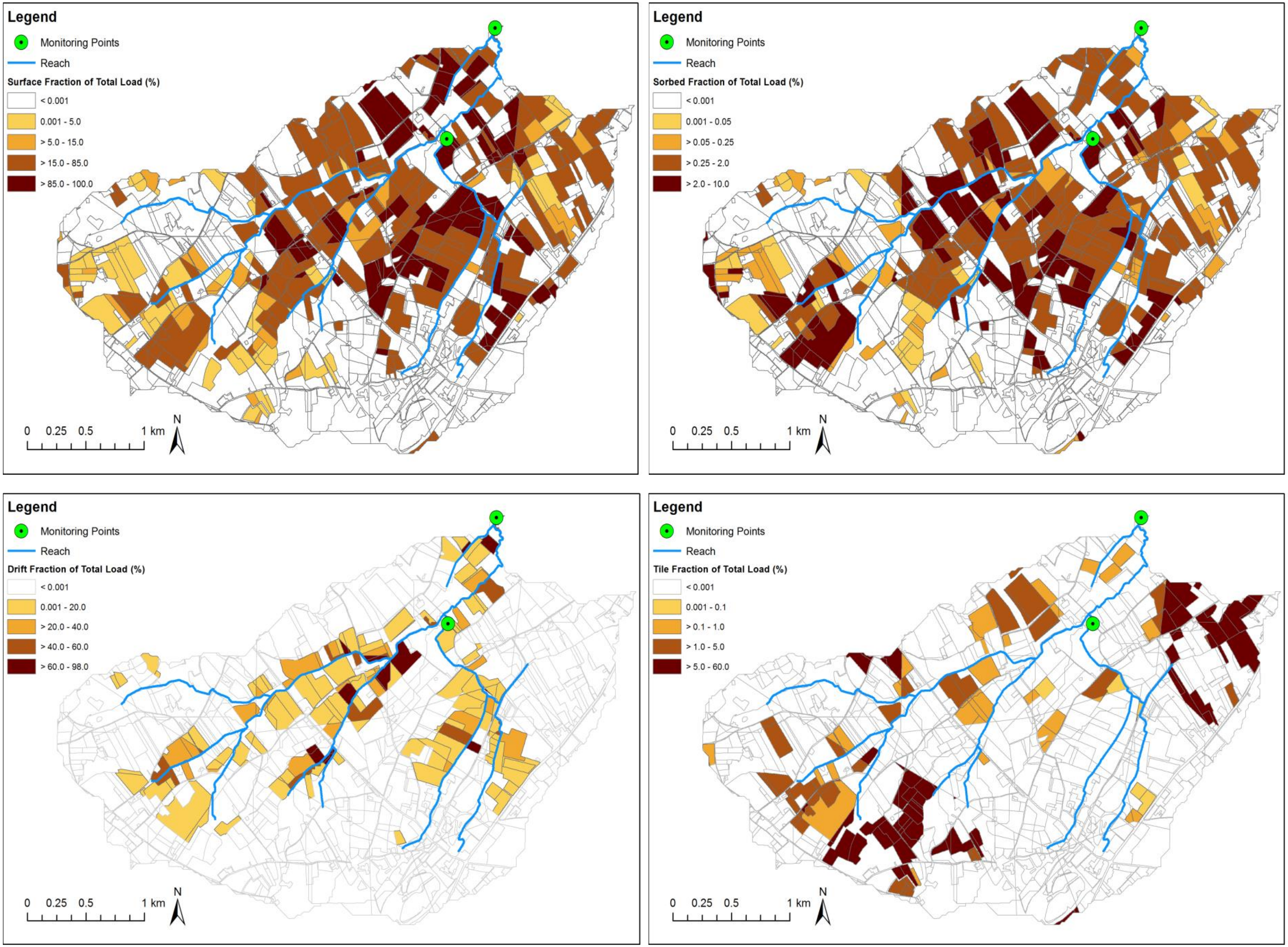
Cumulative Distributions of Daily Herbicide Concentrations



Location	NSE	RSQ
GKb1	0.85	0.99
GKb2	0.89	0.98


Legend
Monitoring Points
Reach
Total Load (g/ha-year)
< 0.001
0.001 - 0.05
> 0.05 - 0.5
> 0.5 - 4.0
> 4.0 - 42.0
PO12
0 0.25 0.5 1 km
N


Legend
Monitoring Points
Reach
Total Load Fraction of Applied (%)
< 0.001
0.001 - 0.5
> 0.5 - 1.0
> 1.0 - 2.0
> 2.0 - 18.0
0 0.25 0.5 1 km
N


Legend
Monitoring Points
Reach
Surface Fraction of Total Load (%)
< 0.001
0.001 - 5.0
> 5.0 - 15.0
> 15.0 - 85.0
> 85.0 - 100.0
0 0.25 0.5 1 km
N
Legend
Monitoring Points
Reach
Sorbed Fraction of Total Load (%)
< 0.001
0.001 - 0.05
> 0.05 - 0.25
> 0.25 - 2.0
> 2.0 - 10.0
0 0.25 0.5 1 km
N
Legend
Monitoring Points
Reach
Drift Fraction of Total Load (%)
< 0.001
0.001 - 20.0
> 20.0 - 40.0
> 40.0 - 60.0
> 60.0 - 98.0
0 0.25 0.5 1 km
N
Legend
Monitoring Points
Reach
Tile Fraction of Total Load (%)
< 0.001
0.001 - 0.1
> 0.1 - 1.0
> 1.0 - 5.0
> 5.0 - 60.0
0 0.25 0.5 1 km
N

Flow Calibration

SWAT Parameter	Parameter Description	Initial Value	Calibrated Value
ALPHA_BF	Baseflow alpha factor	0.048	0.01
GWDELAY	Groundwater delay (d)	31	1
RCHRG_DP	Deep aquifer percolation fraction	0.05	0.15
AWC	Available water capacity	default by soil	1.33*default
ESCO	Soil evaporation compensation factor	0.95	1.00
HEATUNITS	Total heat units for cover/plant to reach maturity (ag crops)	1800	1200
IPET	Potential evapotranspiration method	Priestley-Taylor	Hargreaves
ICN	Daily curve number method	0 (soil moisture method)	1 (ET method)
CH_N1	Manning's "n" value for the tributary channels	0.014	0.055
CH_N2	Manning's "n" value for the main channel	0.014	0.035
SURLAG	Surface runoff lag time (d)	1.0	0.5
DEPIMP	Depth to restrictive layer (mm)	N/A	ZMX + 1000
GDRAIN	Drain tile lag time (hr)	0.00	12

Pesticide Calibration

SWAT Parameter	Parameter Description	Initial Value	Calibrated Value
PERCOP	Pesticide percolation coefficient	0.5	0.6
Pesticide Till	Vertical incorporation of pesticide at application	4 cm, linearly decreasing	None
HLIFE_S	Soil Half-Life	17.87	35.7
CHPST_RSP	Resuspension velocity for pesticide sorbed to sediment (m/d)	0.002	0.001
CHPST_STL	Settling velocity for pesticide sorbed to sediment (m/d)	1.000	0.001
SEDPST_BRY	Pesticide burial velocity in reach bed sediment (m/d)	0.002	0.0001

Monte-Carlo-Simulation

Parameter	Range / Values	Description and reason for parameter selected
Drift curve	• 90th percentile curve • 90th percentile curve (2009-2010), with DRT after 2010 • 50th percentile curve • 50th percentile curve (2009-2010), with DRT after 2010	Variety of drift curves (see Section 2.4.3) representing conservative assumptions (90th percentile) and the implementation of drift reducing technologies after 2010.
Curve number coefficient (CNCOEF)	• 0.75 • 1.00 • 1.25	Account for range in surface runoff to subsurface flow ratios and uncertainty.
Pesticide percolation coefficient (PERCOP)	• 0.35 • 0.50 • 0.65	Account for uncertainty in pesticide concentration in surface runoff and lateral flow relative to the amount in percolation.
GWQMN	• 700 • 1000 • 1700	Account for uncertainty in aquifer parametrization and baseflow contributions.

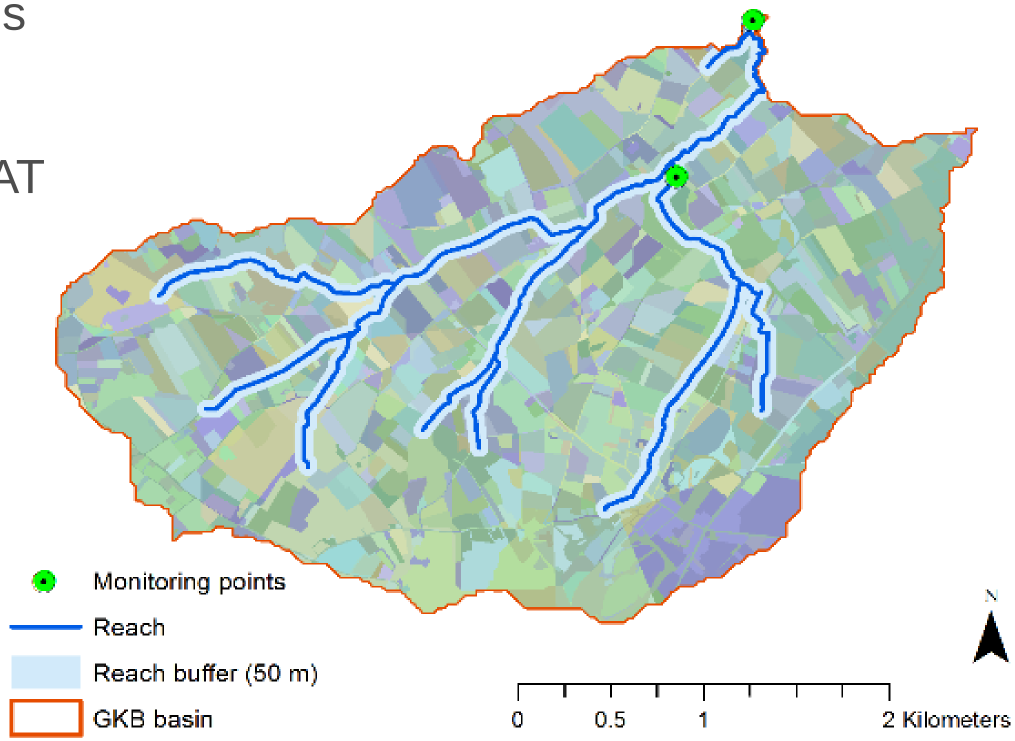
BMP Modeling Assumptions

Vegetative filter strip assumptions in SWAT

- All fields that are within 50 m of the stream get a VFS (5 m, 10 m, and 20 m)
- The SWAT VFS module calculates the reduction based on regressions obtained from various VFSMOD simulations

Reduced tillage assumptions in SWAT

- Conservation tillage is applied on any field in the GKb basin
- Conservation tillage reduces the Curve Number by 3



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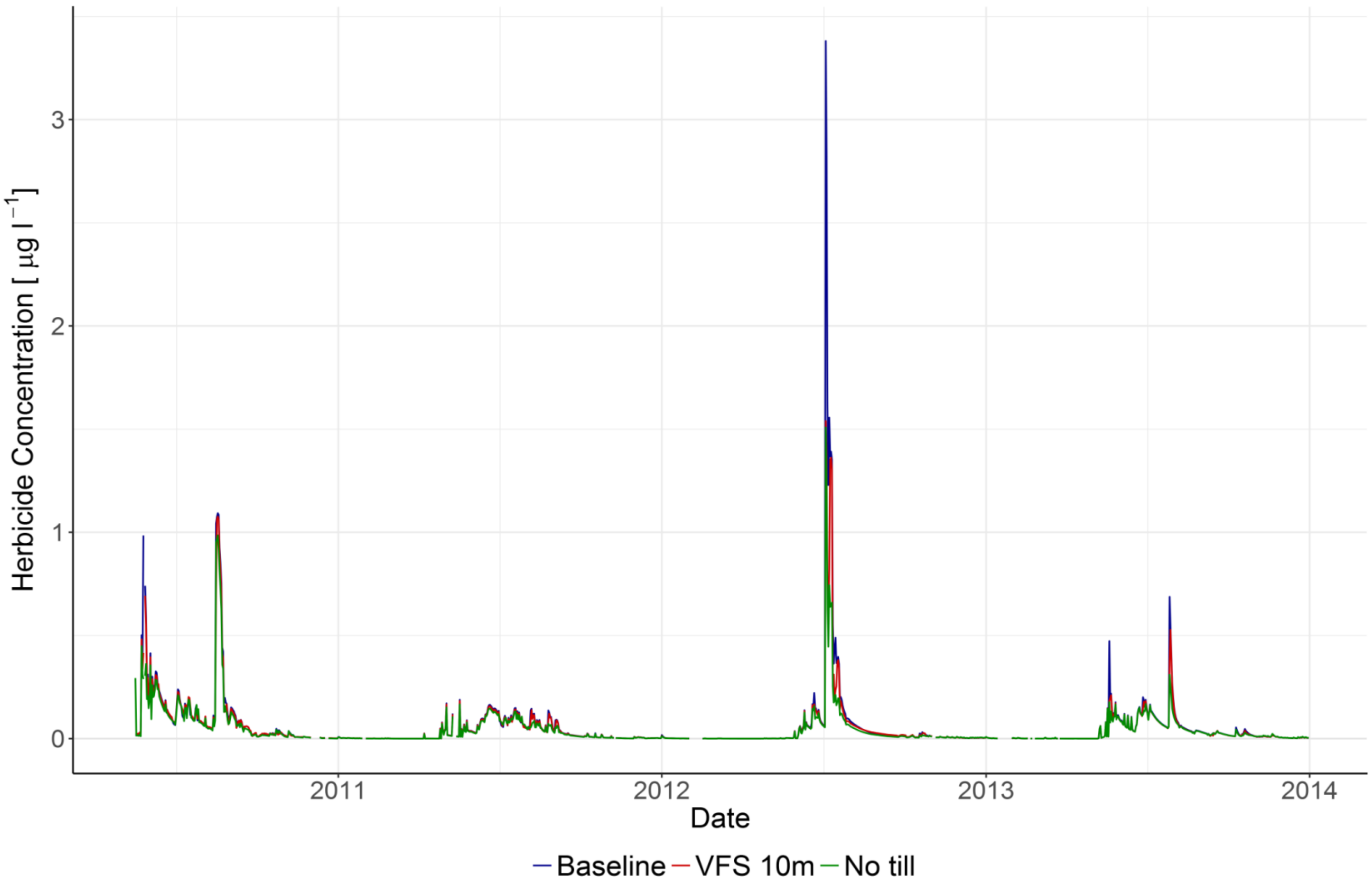
Time series of BMP simulations



BMP simulation results

Vegetative Filter Strips

- Field scale
  - High reduction can be achieved even with a 1 m wide buffer strip
  - Median reduction of 28% on VFS fields
  - Higher reduction on soils with a higher hydraulic conductivity
- Watershed scale
  - Significant solely on extreme events

Conservation Tillage

- In comparison to VFS
  - Higher reductions in peak concentration
  - Greater impacts across all parts of the chemograph