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Improving the parameter identifiability of a watershed scale onsite wastewater infiltration model

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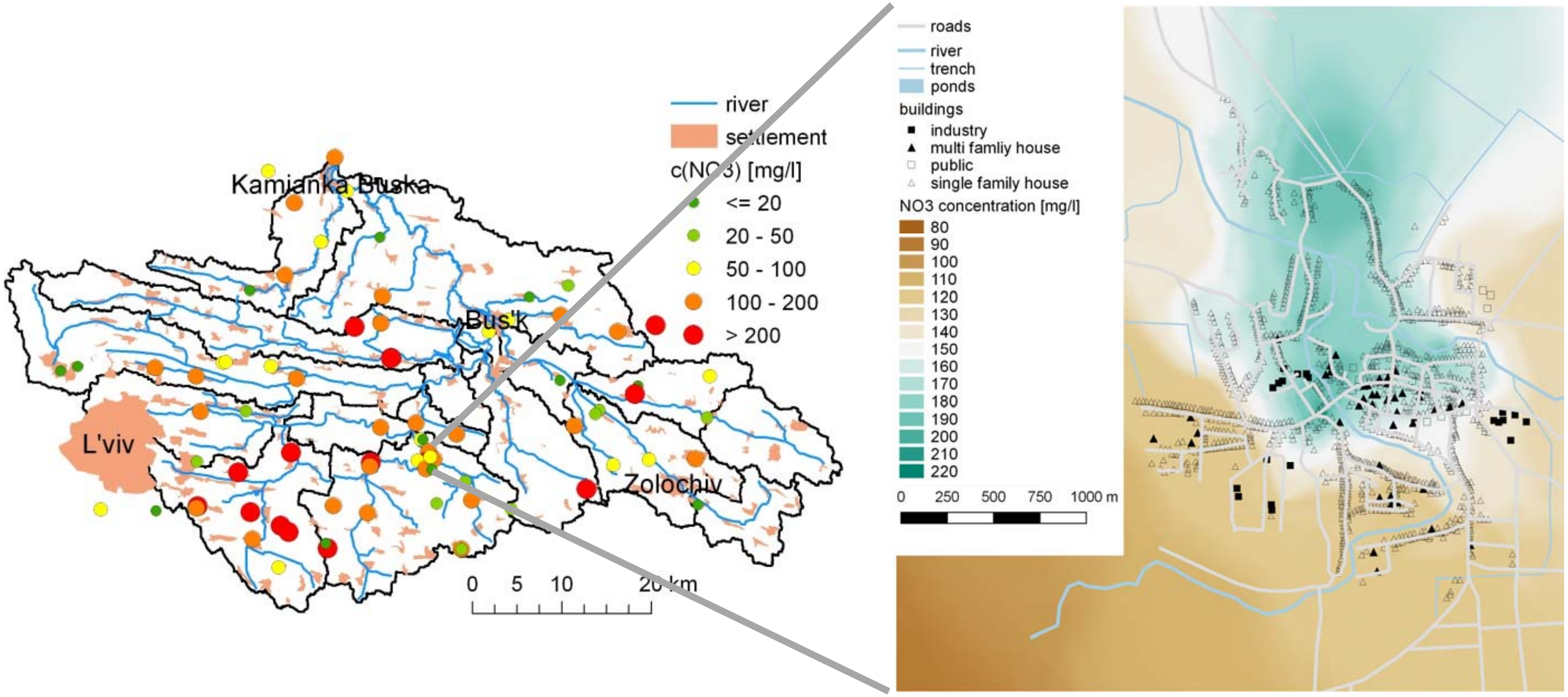
Motivation

- Infiltration based wastewater disposal globally most frequent
- Pit latrines in low income countries, onsite wastewater systems (OWS) in high income countries
- high local impact on groundwater quality
- explanatory variables:
  - pit latrine density
  - groundwater level
  - hydraulic properties
- few systematic monitoring studies!

Motivation

Nitrate concentrations in house wells in Ukraine



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OWS Models

- site scale models:
  - conceptual reactive transport (Wilhelm et al. 1994)
  - coupled vadose zone and kinetic reaction models (Heatwole et al. (2007), MacQuarrie et al. (2001))
- cross scale approaches:
  - simplified aquifer with reactive transport (Wang (2013)
- watershed models:
  - constant removal rate (Behrendt, 1998)
  - biozone mass balance (McCray et al. 2002).

SWAT OWS Module

Biozone moisture balance
- percolation into / out of biozone
- water balance of biozone
- update hydraulic conductivity

Decay reactions
- BOD, fecal coliforms, TSS, N species, P species concentration and decay

Bacterial biomass (BB) balance
- BB concentration
- BB growth, respiration, mortality and slough off
- dead BB conversion to plaque

Soil properties
- update field capacity
- update saturated moisture content

- adapted from McCray (2002)
- model unit: HRU → aggregation of OWS in one unit
- daily time step
- biozone below OWS as additional soil layer
- mass balance of wastewater constituents, bacteria and interaction with soil properties
- OWS specific effluent values

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Parameters

Parameter	Explanation	Unit	Min	Mean	Max
QSTE	Pit latrine effluent discharge	m^3*d^{-1}	0.05	0.1	0.2
cBODSTE	Pit latrine effluent BOD concentration	$g*m^{-3}$	75	150	300
cTSSSTE	Pit latrine effluent TSS concentration	$g*m^{-3}$	150	300	600
cFCSTE	Pit latrine effluent FC concentration	$cfu*ml^{-1}$	50000	100000	200000
cNH4STE	Pit latrine effluent NH4 concentration	$g*m^{-3}$	38	76	154
cNO3STE	Pit latrine effluent NO3 concentration	$g*m^{-3}$	2	4	8
BzThk	Thickness of biozone	mm	25	50	100
BioD	Density of biomass	$kg*m^{-3}$	900	1000	1100
CBODLBB	BOD to LBB conversion rate	-	0.21	0.42	0.84
CRespR	LBB respiration rate coefficient	d^{-1}	0.008	0.016	0.032
CMortR	LBB mortality rate coefficient	d^{-1}	0.0125	0.025	0.05
LCSlgR	LBB sloughing rate coefficient	d^{-1}	0.000002	0.000004	0.000008
ECSlgR	LBB sloughing rate exponent	-	1.2	1.5	1.875
SlgRPlqCF	slough off to plaque conversion coeff.	-	0.020	0.039	0.078
CTSSPlq	TSS to plaque conversion coefficient	-	0.05	0.1	0.2
LCFC	FC coefficient	-	345	690	1380
ECFC	FC exponent	-	0.64	0.8	1
CBODDR	BOD decay rate coefficient	d^{-1}	25	50	100
CFCBDR	fecal coliform decay rate coefficient	d^{-1}	2.5	5	10
CNitrR	nitrification rate coefficient	d^{-1}	0.193	3.2	53
CDenitrR	denitrification rate exponent	d^{-1}	0.0045	0.0416	0.385

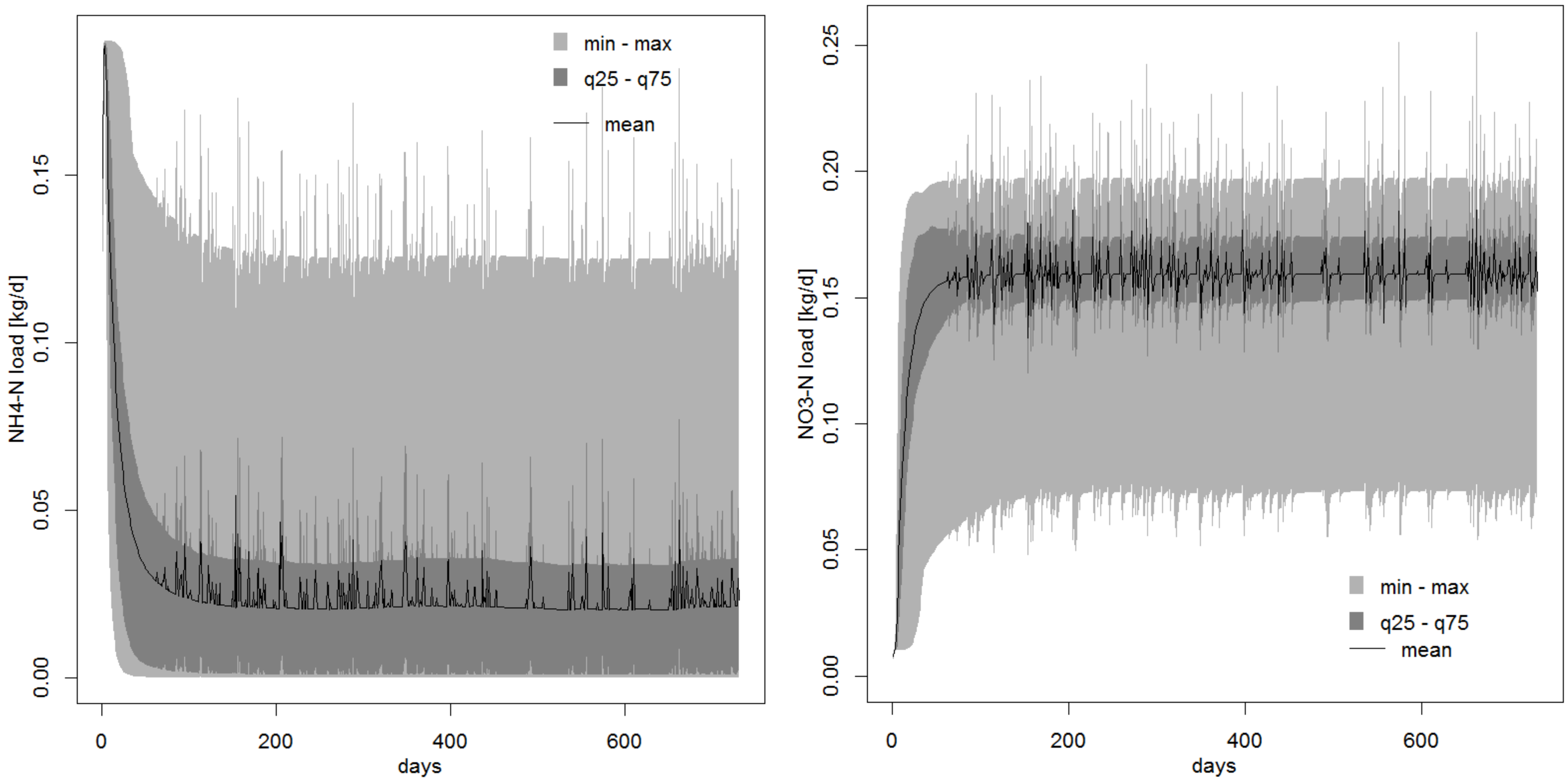
Parameters

Parameter interrelation in SoE

	BzThk	BODLB	RespR	MortR	LSlgR	ESlgR	TSSPlq	LFC	EFC	BioD	BODDR	FCDR	NitDR	DenDR
BzThk										1	1	1	1	1
BODLB			1	1	1	1								
RespR		1		1	1	1								
MortR		1	1		2	2	1							
LSlgR		1	1	2		2	1							
ESlgR		1	1	2	2		1							
TSSPlq				1	1	1								
LFC									1	1				
EFC								1		1				
BioD	1							1	1					
BODDR	1													
FCDR	1													
NitDR	1													
DenDR	1													
interaction	5	4	4	7	7	7	3	2	2	3	1	1	1	1

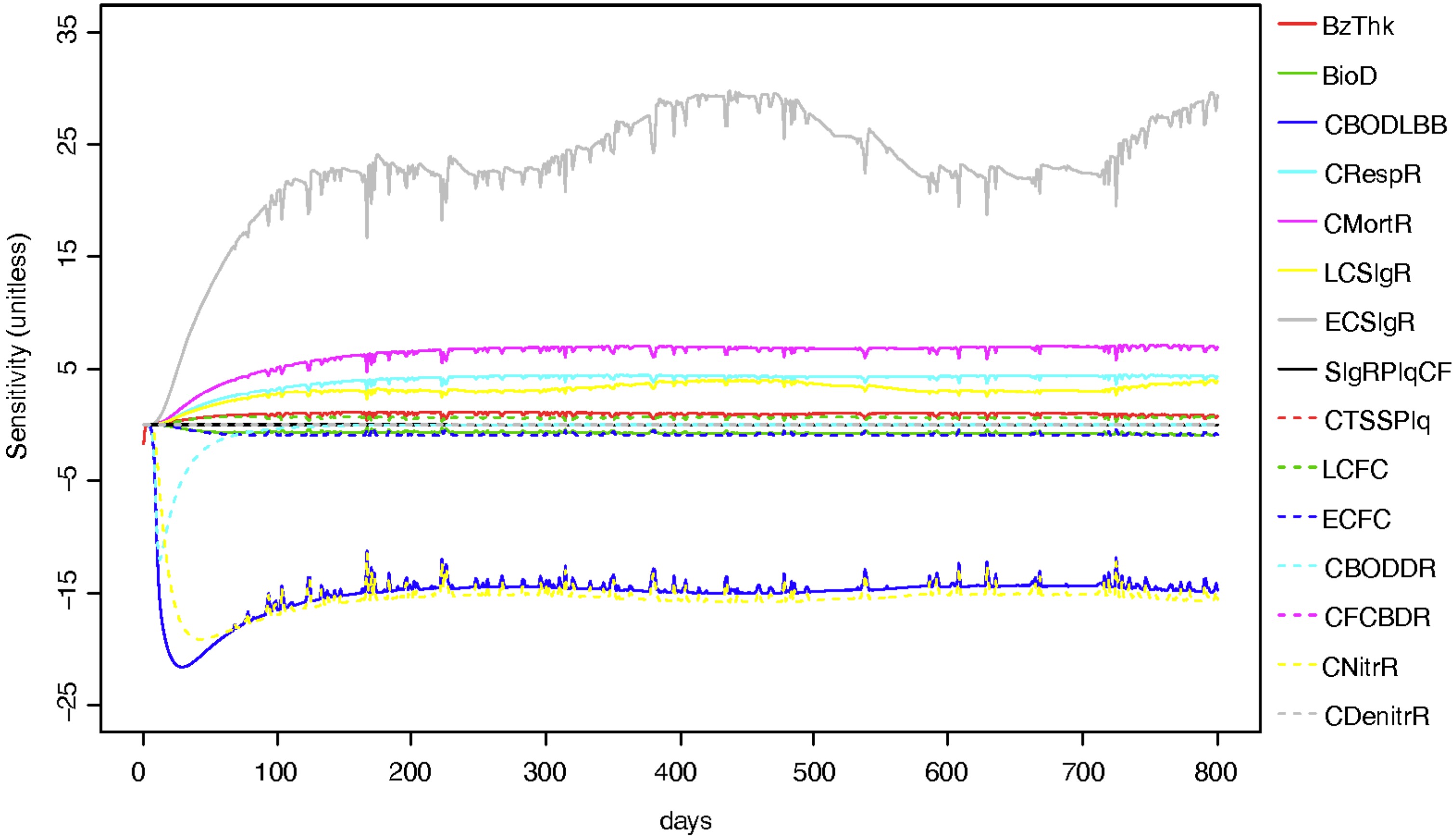
Sensitivity

Global sensitivity and model performance



Sensitivity

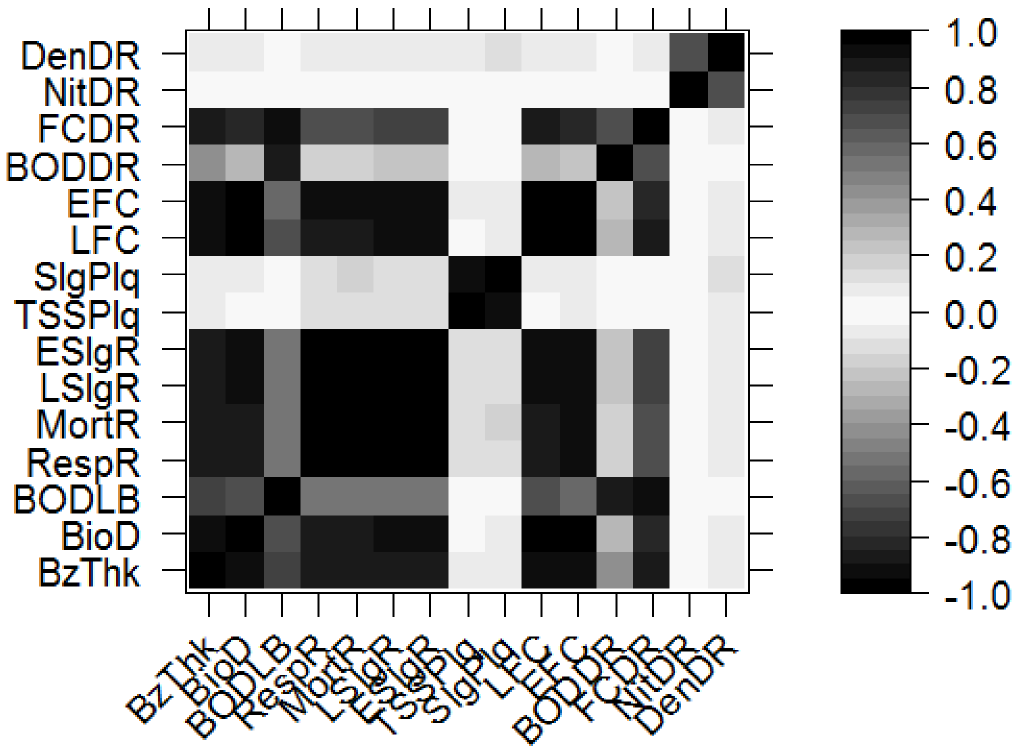
Local sensitivity of parameters to NH4 concentration



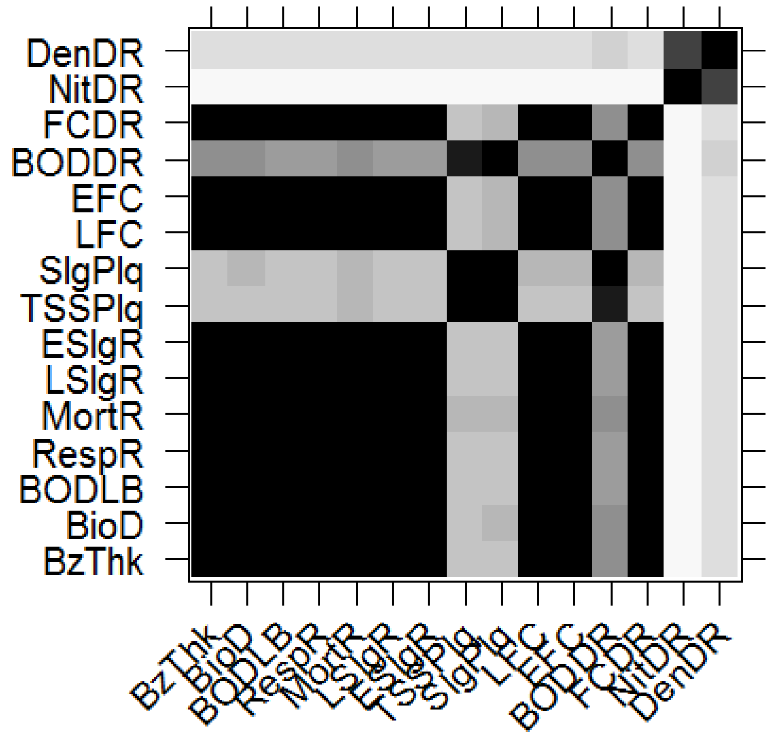
Sensitivity

Correlation of local sensitivity indices for:

build-up phase



steady phase



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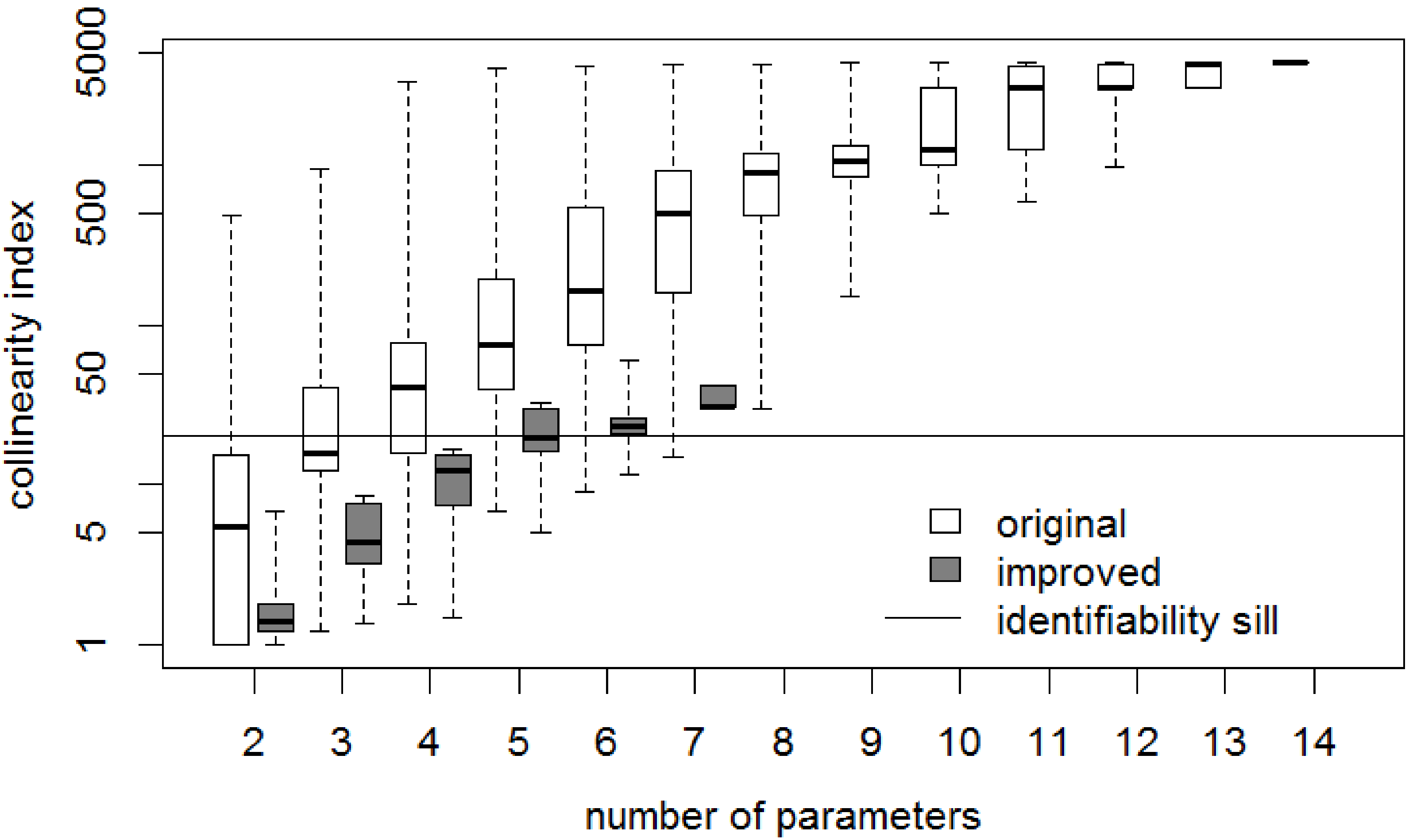
Model adaptations

- grouping of bacterial biomass parameters (ESlgR, LSlgR, MortR, RespR) to LBB decay
- exponential sloughing rate constant (ESlgR)
- biomass density (BioD) as a constant
- exponential field capacity parameter (EFC) constant
- BOD to biomass conversion constant

→ seven out of 14 parameters preserved

Identifiability

Collinearity as measure of identifiability



Conclusions

- OWS algorithm in SWAT capable for regional impact modelling
- adaptation for other systems e.g. pit latrines possible
- algorithm highly collinear
- systematic procedure for model adaptation transferable to other models
- lag of benchmarking monitoring of OWS impact

Thank you for your attention