RPTU Rheinland-Pfälzische Technische Universität Kaiserslautern Landau

BASF We create chemistry

Estimating high resolution exposure at landscape-level

On the implementation of the DAD-drift model into a SWAT+ model of an agriculturally dominated catchment

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Introduction

Background

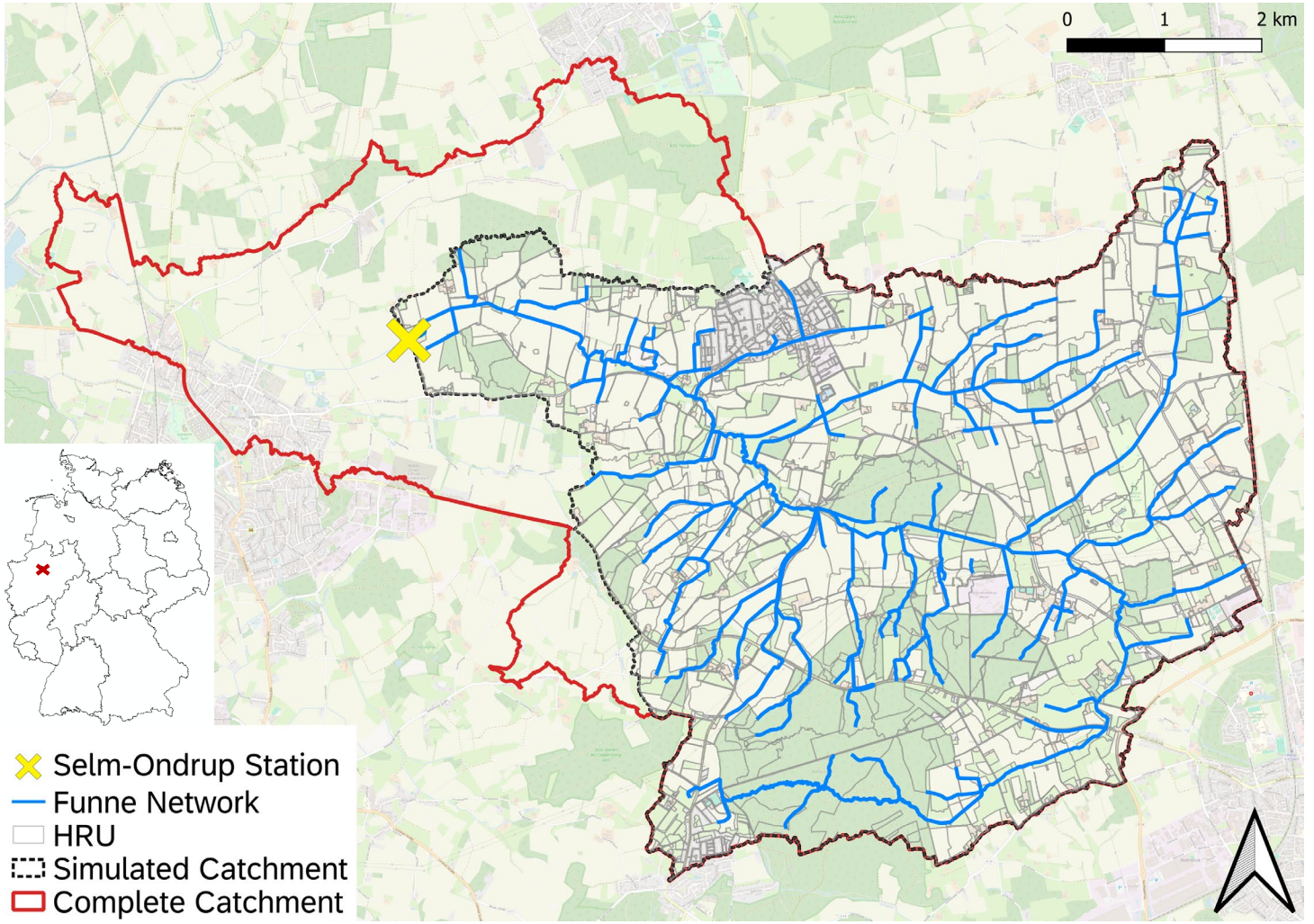
- Linking PPP application timing with environmental exposure at the landscape scale
- Development of the DAD-drift model to predict spray drift at landscape scale
- Incorporate DAD-drift in SWAT+ to enable spray drift representation

Objective

- Build a high-resolution SWAT+ model of a small-scale catchment (38.6 km²)
- Define realistic PPP application schemes
- Compare predicted environmental concentrations (PECs) with and without spray drift contribution

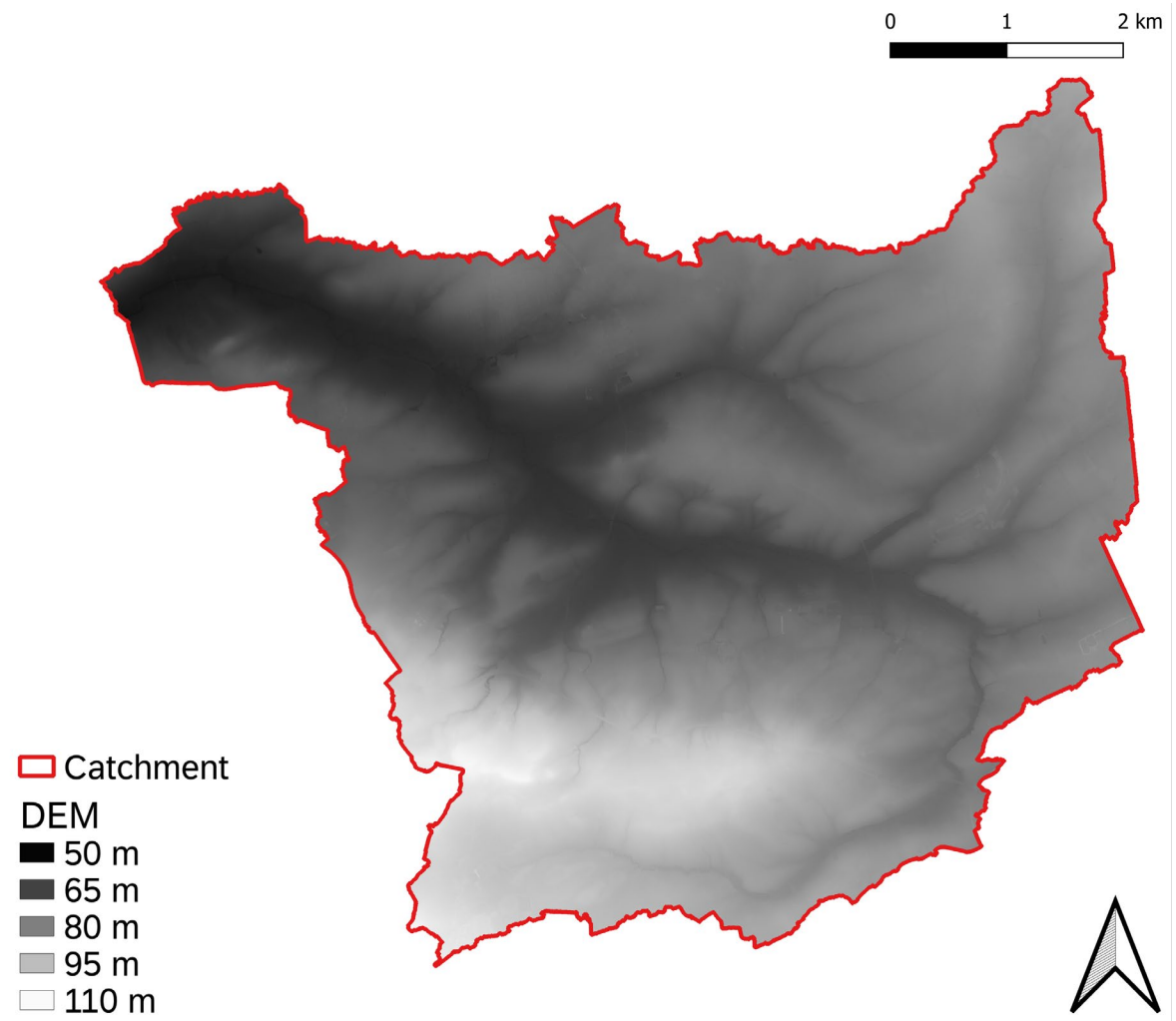
Funne Catchment

- Located in Germany in North Rhine-Westphalia (NRW)
- Stever and Haltern reservoir tributary, with agriculturally dominated land use
- Total catchment area of 54.6 km², 38.6 km² simulated upstream of Selm-Ondrup station
- Shallow catchment gradient of 2.3‰
- Mean elevation of 73.5 m

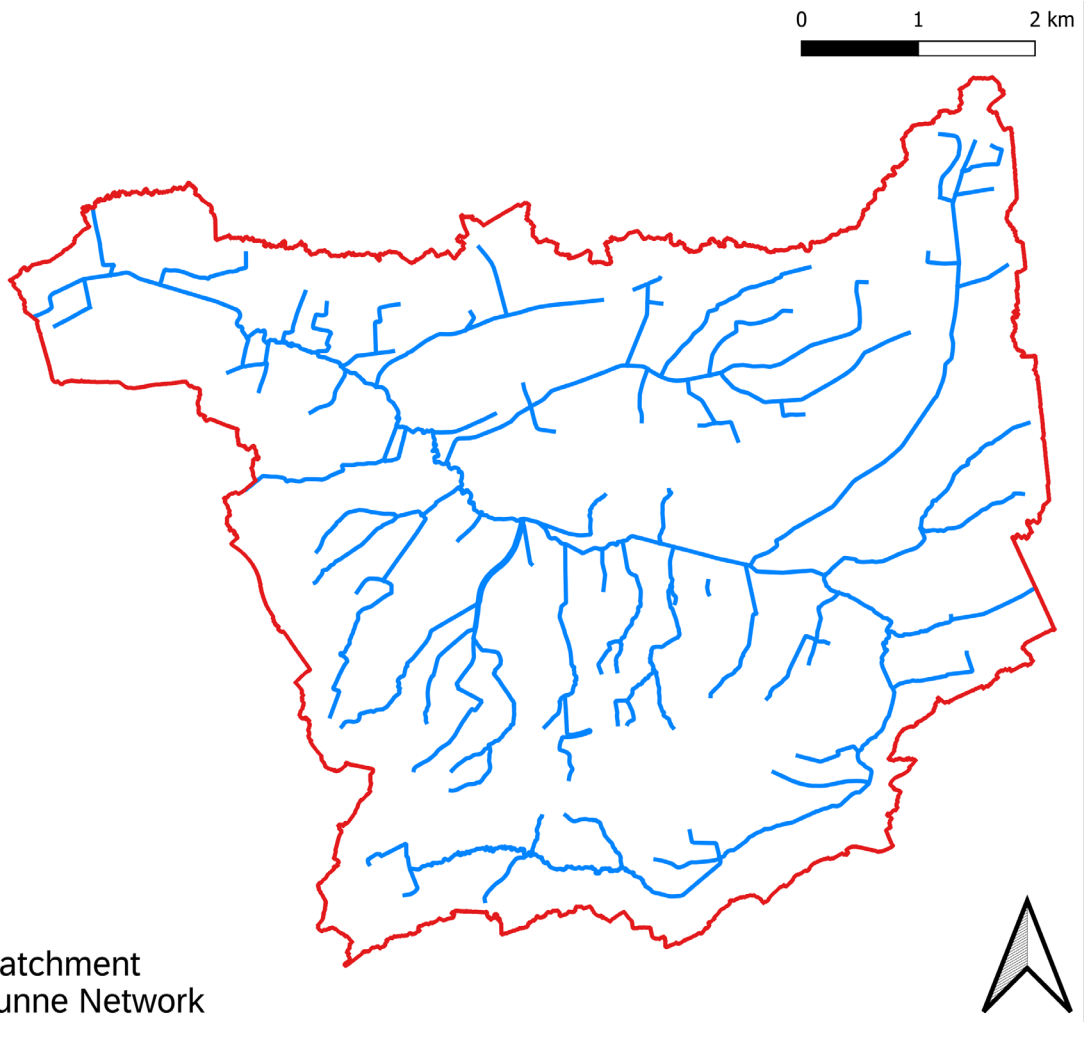


Input Data

Digital Elevation Model (DEM) [1]

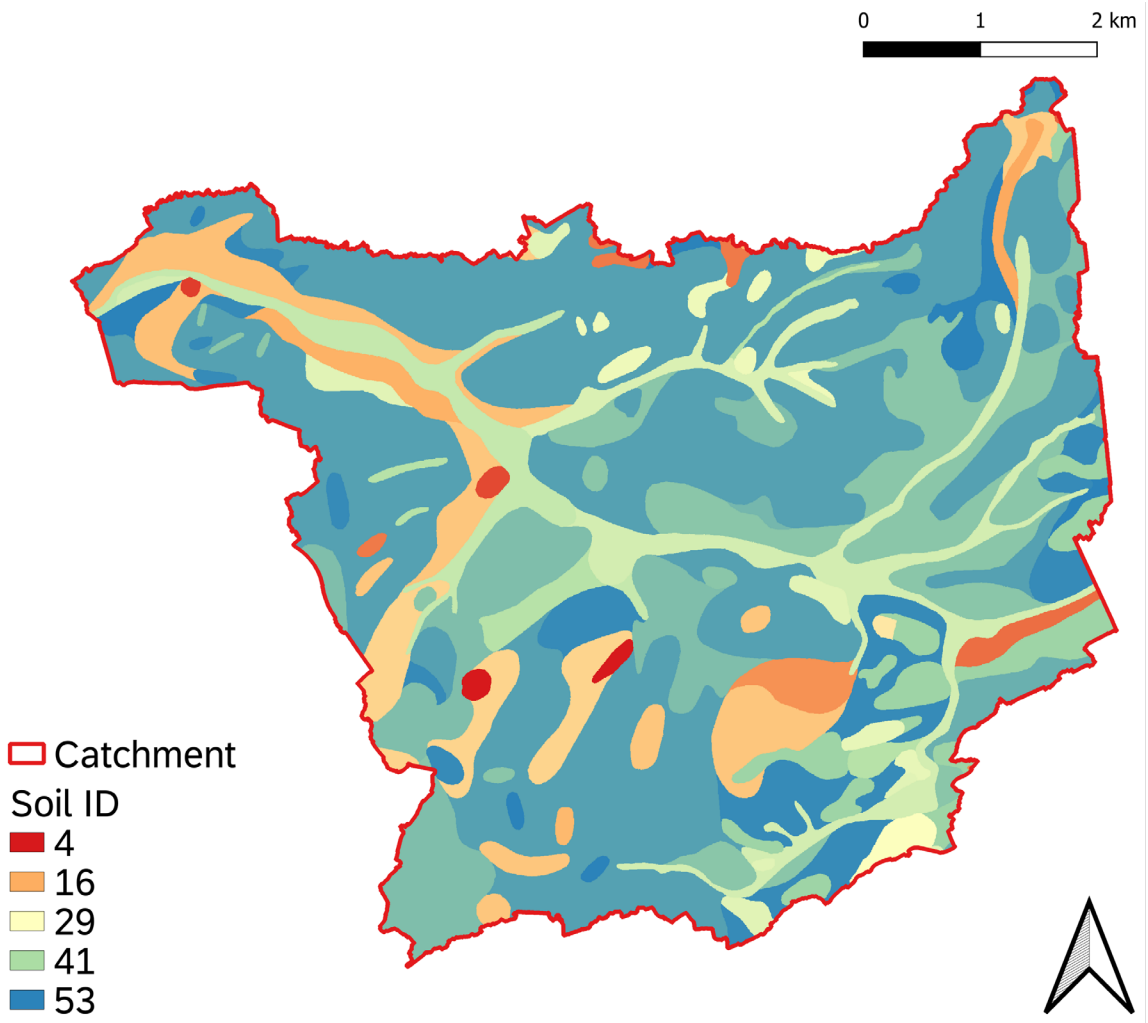


Funne Stream Network [2]

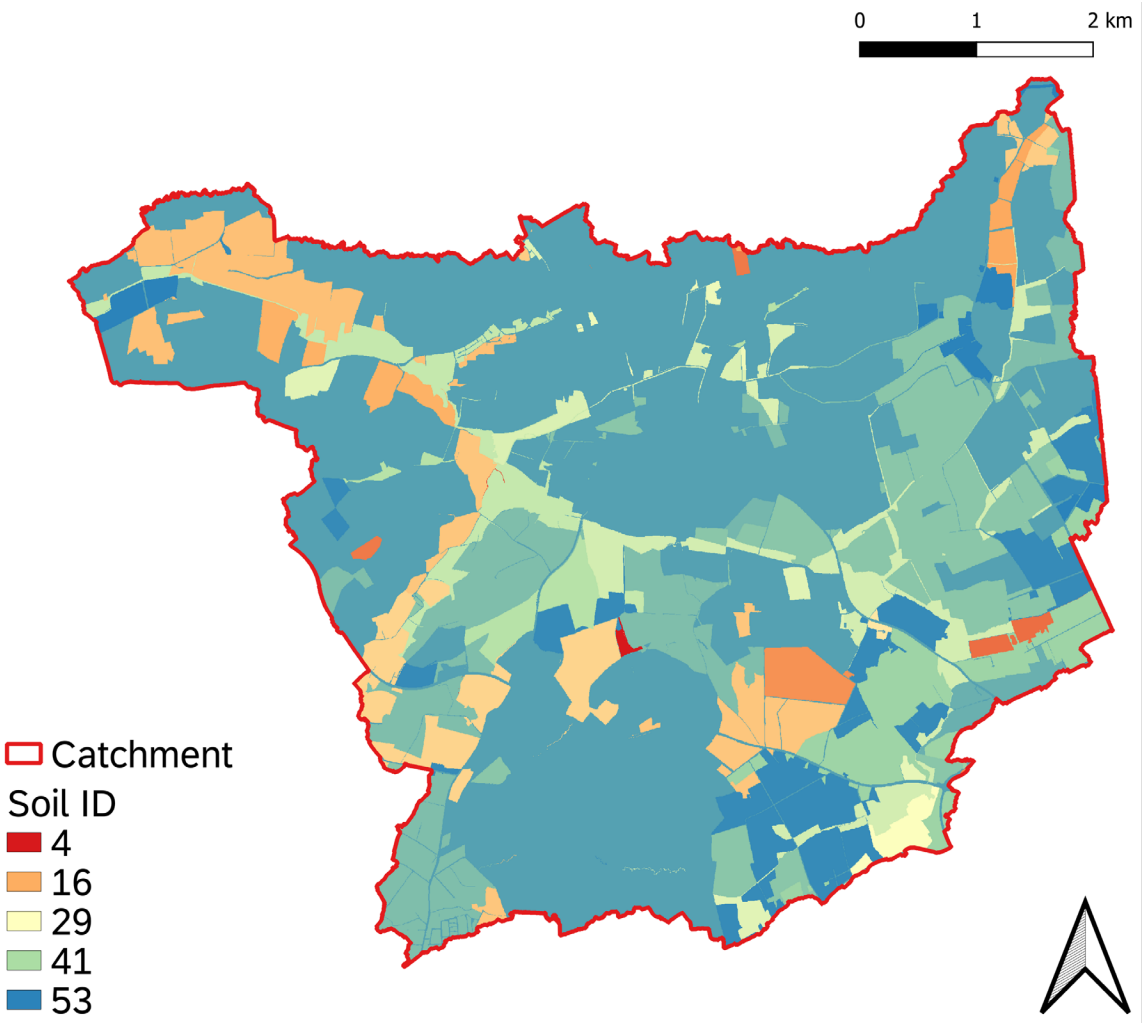


Input Data

BK50 Soil Map [3]

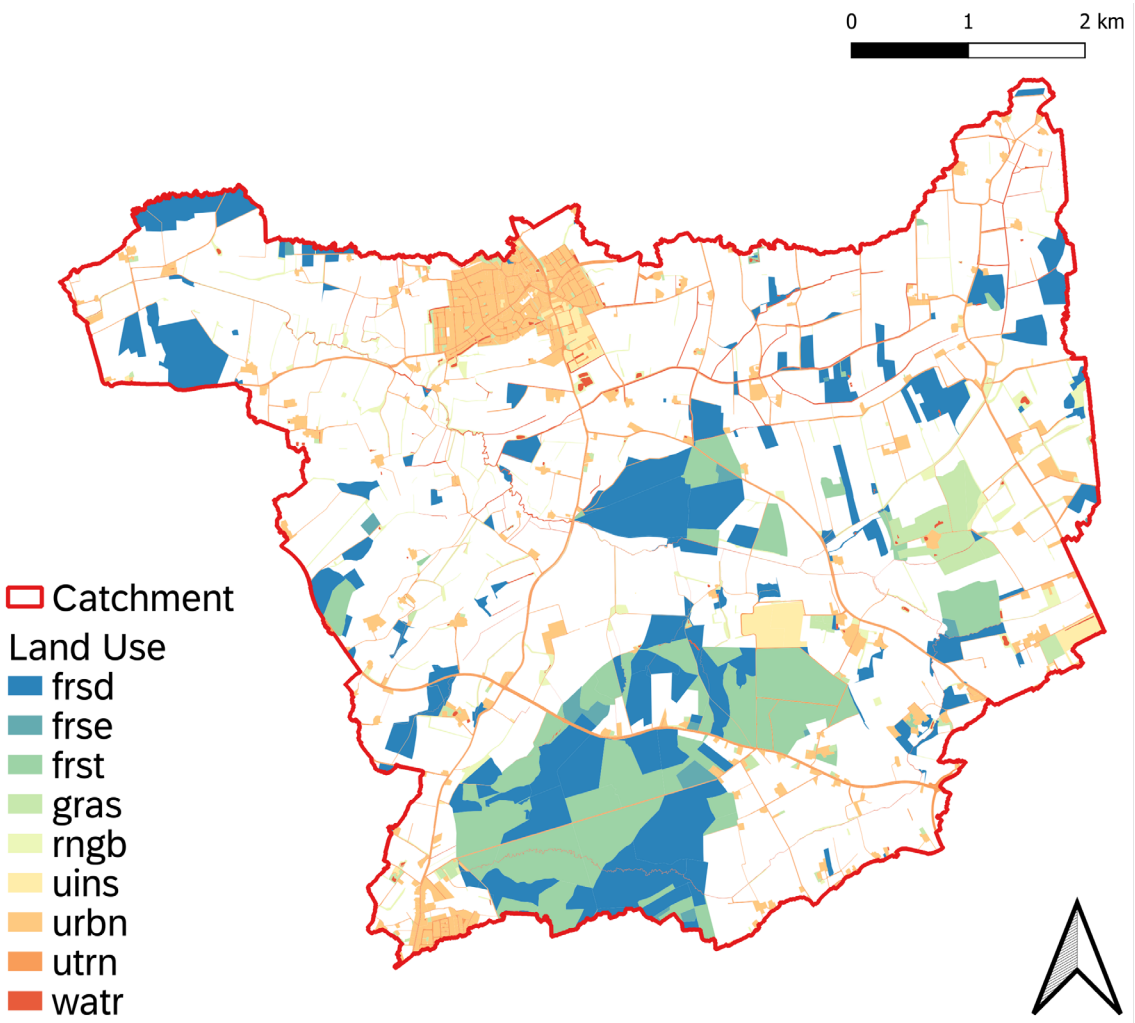


Dominant Soil Map



Input Data

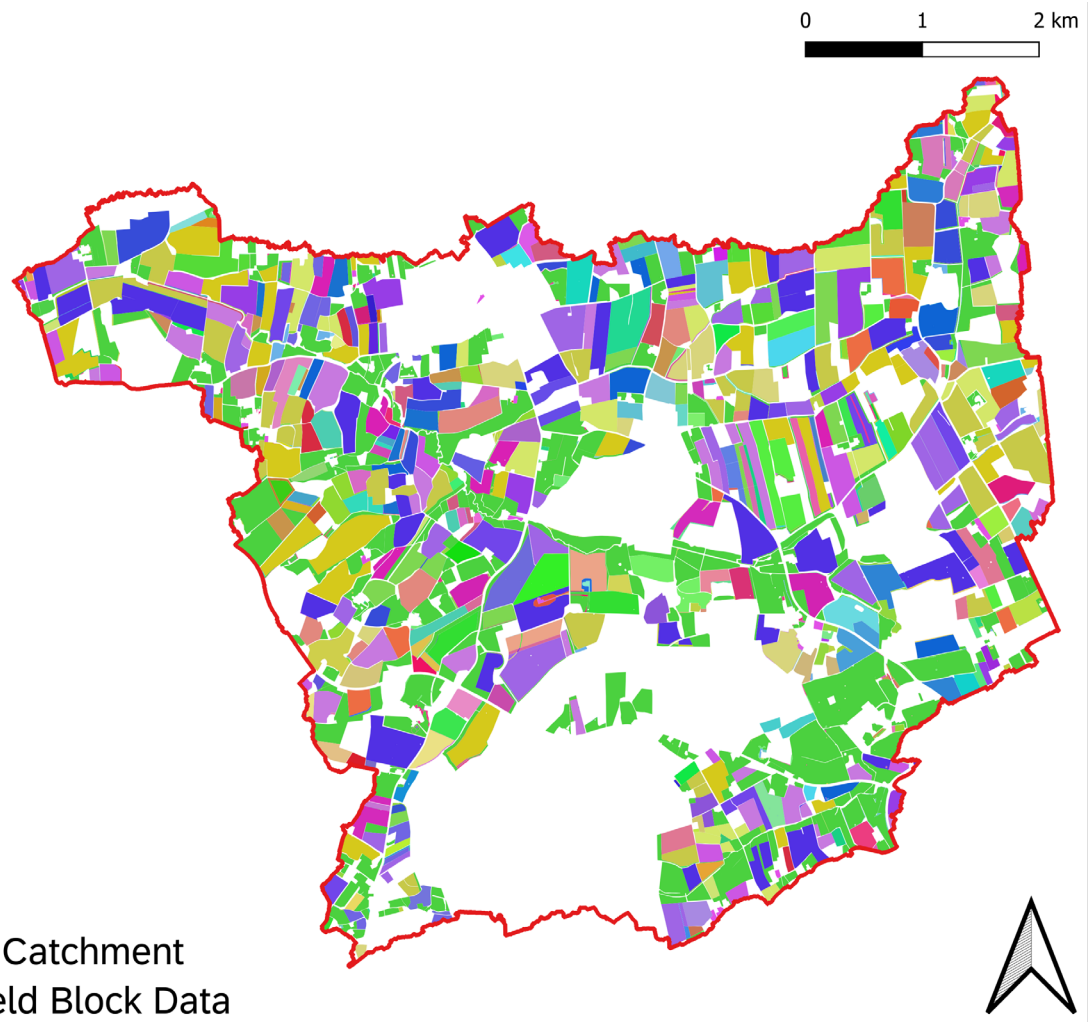
Land Use Map



- Land use map [4] contains general information:
  - Urban areas
  - Roads
  - Forests
  - Grasslands
  - Agriculture
- Crop rotations based on field block data

Input Data

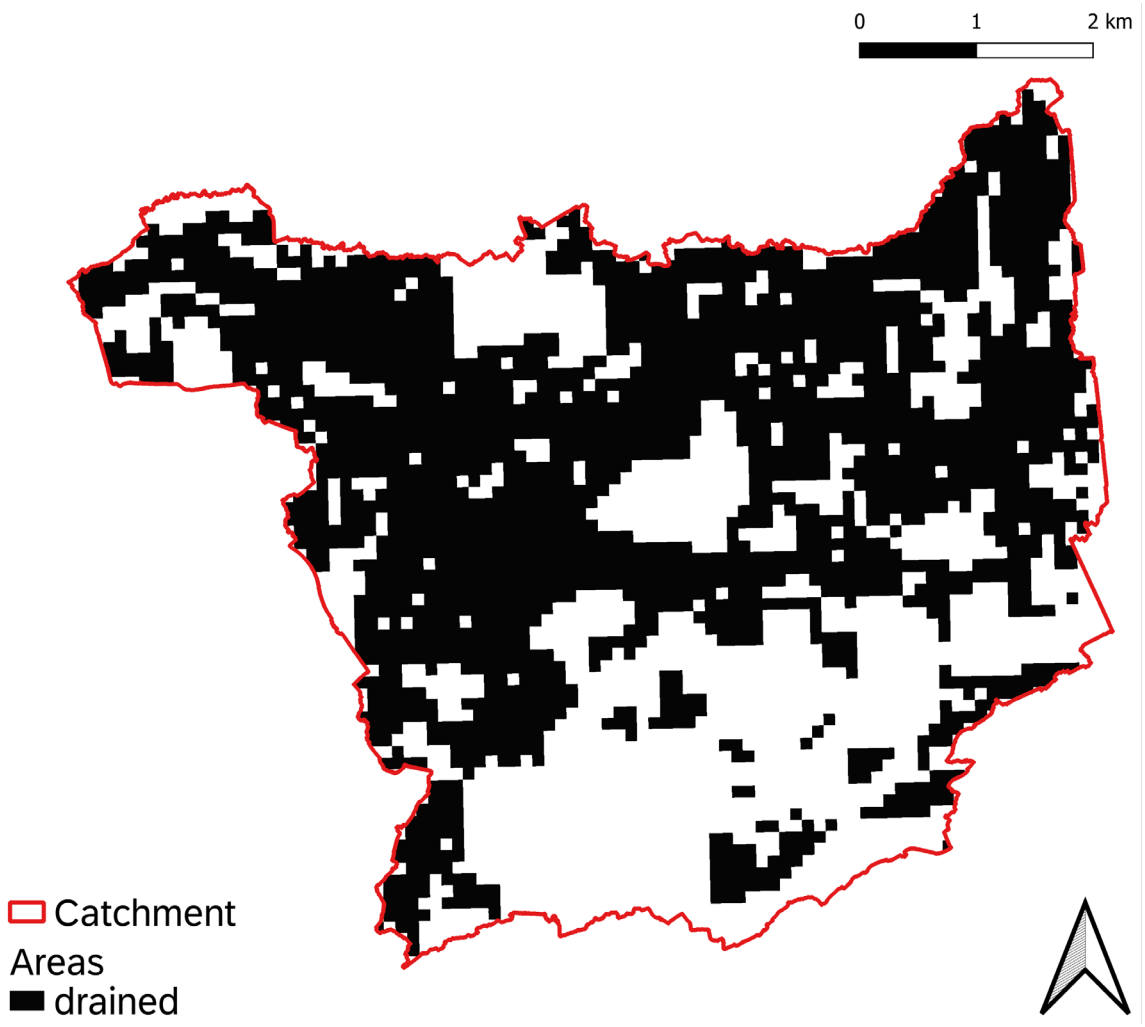
Field Block Data



- Field block data [5] contains land use information for 5 years from 2019 to 2023
- Over 100 unique land uses defined
- Land uses simplified into 6 groups:
  - Winter wheat (wwht)
  - Spring cereal (swht)
  - Maize (corn)
  - Winter rye (rye)
  - Legumes (dryb)
  - Grassland (gras)

Input Data

Potentially Drained Areas



- mGROWA data [6] contains estimation of potentially drained areas
- Each agricultural field intersecting with potentially drained areas, was defined as drained

Crop Rotation

- Field block data [5] reports one main crop per field for 2019-2023 leading to ~300 unique crop rotations
- Planting dates according to C2D2 database [7], harvest dates are heat unit based and limited by harvest dates due to AppDate 3.06
- Plowing operations during the whole plant cycle
- To improve hydrology red clover is planted as catch crop, if no crop is growing over winter period (winter wheat and winter rye)
- From 2010 until 2018 main crops were assigned randomly, with equal frequency as in field block data
- 112 modular decision tables defined (*lum.dtl, management.sch)*

Planting of Winter Wheat

name	conds	alts	acts											
wwht_2023_pl_hv	12	7	8											
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3						
year_cal	hru	0	null	-	2022	=	=	=						
year_cal	hru	0	null	-	2023	-	-	-						
jday	hru	0	null	-	273	=	=	-						
jday	hru	0	null	-	273	-	-	>						
jday	hru	0	null	-	279	-	-	-						
jday	hru	0	null	-	280	-	-	<						
jday	hru	0	null	-	266	-	-	-						
phu_plant	hru	0	phu_mat	-	1.15	-	-	-						
plant_name_gro	hru	0	gras	-	1	=	-	-						
plant_name_gro	hru	0	clvr	-	1	-	=	-						
plant_name_gro	hru	0	wwht	-	1	-	-	-						
days_harv	hru	0	null	-	2	-	-	=						
act_typ	obj	obj_num	name	option	const	const2	fp	outcome						
harvest_kill	hru	0	grass_bag	gras	0	1	grain	y	n	n	n	n	n	n
harvest_kill	hru	0	vegetables	clvr	0	1	grain	n	y	n	n	n	n	n
till	hru	0	moldboardplow	mldboard	0	1	null	n	n	y	n	n	n	n
cn_update	hru	0	increase_cn_till	abschg	6	1	null	n	n	y	n	n	n	n
till	hru	0	fieldcultivat	fldcult	0	1	null	n	n	n	y	n	n	n
plant	hru	0	plant_wwht	wwht	0	1	null	n	n	n	n	y	n	n
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	n	n	y	n	n
harvest_kill	hru	0	grain_harv	wwht	0	1	grain	n	n	n	n	n	y	y

Planting of Winter Wheat

name	conds	alts	acts											
wwht_2023_pl_hv	12	7	8											
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3						
year_cal	hru	0	null	-	2022	=	=	=						
year_cal	hru	0	null	-	2023	-	-	-						
jday	hru	0	null	-	273	=	=	-						
jday	hru	0	null	-	273	-	-	>						
jday	hru	0	null	-	279	-	-	-						
jday	hru	0	null	-	280	-	-	<						
jday	hru	0	null	-	266	-	-	-						
phu_plant	hru	0	phu_mat	-	1.15	-	-	-						
plant_name_gro	hru	0	gras	-	1	=	-	-						
plant_name_gro	hru	0	clvr	-	1	-	=	-						
plant_name_gro	hru	0	wwht	-	1	-	-	-						
days_harv	hru	0	null	-	2	-	-	=						
act_typ	obj	obj_num	name	option	const	const2	fp	outcome						
harvest_kill	hru	0	grass_bag	gras	0	1	grain	y	n	n	n	n	n	n
harvest_kill	hru	0	vegetables	clvr	0	1	grain	n	y	n	n	n	n	n
till	hru	0	moldboardplow	mldboard	0	1	null	n	n	y	n	n	n	n
cn_update	hru	0	increase_cn_till	abschg	6	1	null	n	n	y	n	n	n	n
till	hru	0	fieldcultivat	fldcult	0	1	null	n	n	n	y	n	n	n
plant	hru	0	plant_wwht	wwht	0	1	null	n	n	n	n	y	n	n
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	n	n	y	n	n
harvest_kill	hru	0	grain_harv	wwht	0	1	grain	n	n	n	n	n	y	y

Harvest catch crops

Planting of Winter Wheat

name	conds	alts	acts												
wwht_2023_pl_hv	12	7	8												
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3							
year_cal	hru	0	null	-	2022	=	=	=							
year_cal	hru	0	null	-	2023	-	-	-							
jday	hru	0	null	-	273	=	=	-							
jday	hru	0	null	-	273	-	-	>							
jday	hru	0	null	-	279	-	-	-							
jday	hru	0	null	-	280	-	-	<							
jday	hru	0	null	-	266	-	-	-							
phu_plant	hru	0	phu_mat	-	1.15	-	-	-							
plant_name_gro	hru	0	gras	-	1	=	-	-							
plant_name_gro	hru	0	clvr	-	1	-	=	-							
plant_name_gro	hru	0	wwht	-	1	-	-	-							
days_harv	hru	0	null	-	2	-	-	=							
act_typ	obj	obj_num	name	option	const	const2	fp	outcome							
harvest_kill	hru	0	grass_bag	gras	0	1	grain	y	n	n	n	n	n	n	
harvest_kill	hru	0	vegetables	clvr	0	1	grain	n	y	n	n	n	n	n	
till	hru	0	moldboardplow	mldboard	0	1	null	n	n	y	n	n	n	n	
cn_update	hru	0	increase_cn_till	abschg	6	1	null	n	n	y	n	n	n	n	
till	hru	0	fieldcultivat	fldcult	0	1	null	n	n	n	y	n	n	n	
plant	hru	0	plant_wwht	wwht	0	1	null	n	n	n	n	y	n	n	
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	n	n	y	n	n	
harvest_kill	hru	0	grain_harv	wwht	0	1	grain	n	n	n	n	n	y	y	

Till field and update CN value

Planting of Winter Wheat

name	conds	alts	acts												
wwht_2023_pl_hv	12	7	8												
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3							
year_cal	hru	0	null	-	2022	=	=	=							
year_cal	hru	0	null	-	2023	-	-	-							
jday	hru	0	null	-	273	=	=	-							
jday	hru	0	null	-	273	-	-	>							
jday	hru	0	null	-	279	-	-	-							
jday	hru	0	null	-	280	-	-	<							
jday	hru	0	null	-	266	-	-	-							
phu_plant	hru	0	phu_mat	-	1.15	-	-	-							
plant_name_gro	hru	0	gras	-	1	=	-	-							
plant_name_gro	hru	0	clvr	-	1	-	=	-							
plant_name_gro	hru	0	wwht	-	1	-	-	-							
days_harv	hru	0	null	-	2	-	-	=							
act_typ	obj	obj_num	name	option	const	const2	fp	outcome							
harvest_kill	hru	0	grass_bag	gras	0	1	grain	y	n	n	n	n	n	n	
harvest_kill	hru	0	vegetables	clvr	0	1	grain	n	y	n	n	n	n	n	
till	hru	0	moldboardplow	mldboard	0	1	null	n	n	y	n	n	n	n	
cn_update	hru	0	increase_cn_till	abschg	6	1	null	n	n	y	n	n	n	n	
till	hru	0	fieldcultivat	fldcult	0	1	null	n	n	n	y	n	n	n	
plant	hru	0	plant_wwht	wwht	0	1	null	n	n	n	n	y	n	n	
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	n	n	y	n	n	
harvest_kill	hru	0	grain_harv	wwht	0	1	grain	n	n	n	n	n	y	y	

Cultivate field

Planting of Winter Wheat

name	conds	alts	acts												
wwht_2023_pl_hv	12	7	8												
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3							
year_cal	hru	0	null	-	2022	=	=	=							
year_cal	hru	0	null	-	2023	-	-	-							
jday	hru	0	null	-	273	=	=	-							
jday	hru	0	null	-	273	-	-	>							
jday	hru	0	null	-	279	-	-	-							
jday	hru	0	null	-	280	-	-	<							
jday	hru	0	null	-	266	-	-	-							
phu_plant	hru	0	phu_mat	-	1.15	-	-	-							
plant_name_gro	hru	0	gras	-	1	=	-	-							
plant_name_gro	hru	0	clvr	-	1	-	=	-							
plant_name_gro	hru	0	wwht	-	1	-	-	-							
days_harv	hru	0	null	-	2	-	-	=							
act_typ	obj	obj_num	name	option	const	const2	fp	outcome							
harvest_kill	hru	0	grass_bag	gras	0	1	grain	y	n	n	n	n	n	n	
harvest_kill	hru	0	vegetables	clvr	0	1	grain	n	y	n	n	n	n	n	
till	hru	0	moldboardplow	mldboard	0	1	null	n	n	y	n	n	n	n	
cn_update	hru	0	increase_cn_till	abschg	6	1	null	n	n	y	n	n	n	n	
till	hru	0	fieldcultivat	fldcult	0	1	null	n	n	n	y	n	n	n	
plant	hru	0	plant_wwht	wwht	0	1	null	n	n	n	n	y	n	n	
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	n	n	y	n	n	
harvest_kill	hru	0	grain_harv	wwht	0	1	grain	n	n	n	n	n	y	y	

Plant winter wheat and update CN value

Planting of Winter Wheat

name	conds	alts	acts											
wwht_2023_pl_hv	12	7	8											
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3						
year_cal	hru	0	null	-	2022	=	=	=						
year_cal	hru	0	null	-	2023	-	-	-						
jday	hru	0	null	-	273	=	=	-						
jday	hru	0	null	-	273	-	-	>						
jday	hru	0	null	-	279	-	-	-						
jday	hru	0	null	-	280	-	-	<						
jday	hru	0	null	-	266	-	-	-						
phu_plant	hru	0	phu_mat	-	1.15	-	-	-						
plant_name_gro	hru	0	gras	-	1	=	-	-						
plant_name_gro	hru	0	clvr	-	1	-	=	-						
plant_name_gro	hru	0	wwht	-	1	-	-	-						
days_harv	hru	0	null	-	2	-	-	=						
act_typ	obj	obj_num	name	option	const	const2	fp	outcome						
harvest_kill	hru	0	grass_bag	gras	0	1	grain	y	n	n	n	n	n	n
harvest_kill	hru	0	vegetables	clvr	0	1	grain	n	y	n	n	n	n	n
till	hru	0	moldboardplow	mldboard	0	1	null	n	n	y	n	n	n	n
cn_update	hru	0	increase_cn_till	abschg	6	1	null	n	n	y	n	n	n	n
till	hru	0	fieldcultivat	fldcult	0	1	null	n	n	n	y	n	n	n
plant	hru	0	plant_wwht	wwht	0	1	null	n	n	n	n	y	n	n
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	n	n	y	n	n
harvest_kill	hru	0	grain_harv	wwht	0	1	grain	n	n	n	n	n	y	y

Harvest winter wheat

Post Crop Tillage with Catch Crop

name	conds	alts	acts						
post_crop_till_clvr_2023	5	3	5						
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2		alt3
jday	hru	0	null	-	185	>	>		>
days_harv	hru	0	null	-	2	=	-		-
days_harv	hru	0	null	-	7	-	=		-
days_harv	hru	0	null	-	8	-	-		=
year_cal	hru	0	null	-	2023	=	=		=
act_typ	obj	obj_num	name	option	const	const2	fp	outcome	
till	hru	0	moldboardplow	mldboard	0	1	null	y	n n
cn_update	hru	0	increase_cn_till	abschg	6	1	null	y	n n
till	hru	0	fieldcultivat	fldcult	0	1	null	n	y n
plant	hru	0	plant_clvr	clvr	0	1	null	n	n y
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n y

Post Crop Tillage with Catch Crop

name	conds	alts	acts								
post_crop_till_clvr_2023	5	3	5								
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3			
jday	hru	0	null	-	185	>	>	>			
days_harv	hru	0	null	-	2	=	-	-			
days_harv	hru	0	null	-	7	-	=	-			
days_harv	hru	0	null	-	8	-	-	=			
year_cal	hru	0	null	-	2023	=	=	=			
act_typ	obj	obj_num	name	option	const	const2	fp	outcome			
till	hru	0	moldboardplow	mldboard	0	1	null	y	n	n	
cn_update	hru	0	increase_cn_till	abschg	6	1	null	y	n	n	
till	hru	0	fieldcultivat	fldcult	0	1	null	n	y	n	
plant	hru	0	plant_clvr	clvr	0	1	null	n	n	y	
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	y	

Till field and update CN value

Post Crop Tillage with Catch Crop

name	conds	alts	acts								
post_crop_till_clvr_2023	5	3	5								
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3			
jday	hru	0	null	-	185	>	>	>			
days_harv	hru	0	null	-	2	=	-	-			
days_harv	hru	0	null	-	7	-	=	-			
days_harv	hru	0	null	-	8	-	-	=			
year_cal	hru	0	null	-	2023	=	=	=			
act_typ	obj	obj_num	name	option	const	const2	fp	outcome			
till	hru	0	moldboardplow	mldboard	0	1	null	y	n	n	
cn_update	hru	0	increase_cn_till	abschg	6	1	null	y	n	n	
till	hru	0	fieldcultivat	fldcult	0	1	null	n	y	n	
plant	hru	0	plant_clvr	clvr	0	1	null	n	n	y	
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	y	

Cultivate field

Post Crop Tillage with Catch Crop

name	conds	alts	acts								
post_crop_till_clvr_2023	5	3	5								
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3			
jday	hru	0	null	-	185	>	>	>			
days_harv	hru	0	null	-	2	=	-	-			
days_harv	hru	0	null	-	7	-	=	-			
days_harv	hru	0	null	-	8	-	-	=			
year_cal	hru	0	null	-	2023	=	=	=			
act_typ	obj	obj_num	name	option	const	const2	fp	outcome			
till	hru	0	moldboardplow	mldboard	0	1	null	y	n	n	
cn_update	hru	0	increase_cn_till	abschg	6	1	null	y	n	n	
till	hru	0	fieldcultivat	fldcult	0	1	null	n	y	n	
plant	hru	0	plant_clvr	clvr	0	1	null	n	n	y	
cn_update	hru	0	lower_cn_plant	abschg	-6	1	null	n	n	y	

Plant catch crop and update CN value

Parametrization and Validation

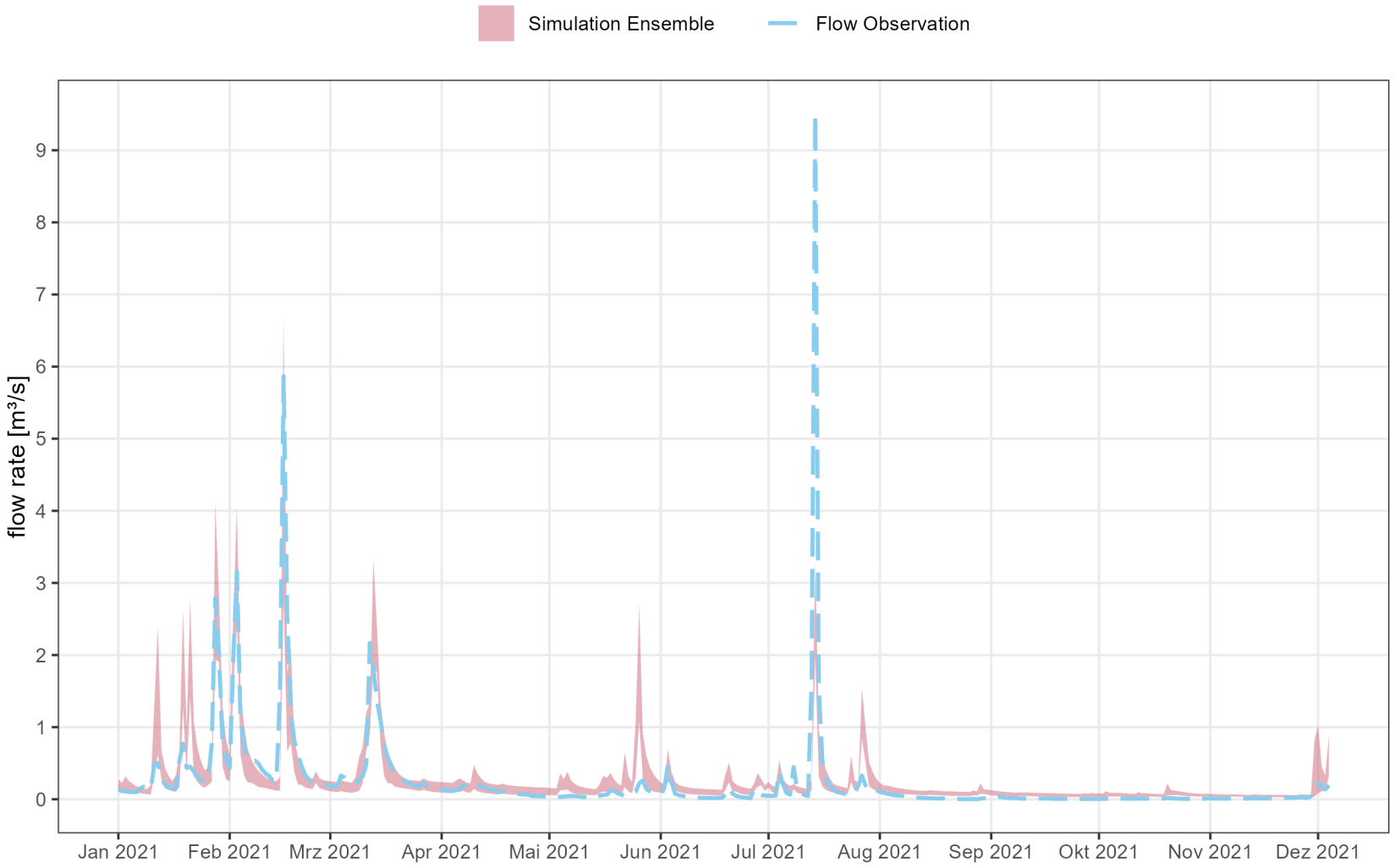
- Parameterization of 23 input parameters:

  awc, bd, can_max, cov_fact, dep_bot, dep_wt, dp_tile, drain, epco, esco, fall_tmp, flo_min, lag, lat_len, lat_ttime, mann, melt_max, melt_min, melt_tmp, perco, revap_min, snow_h2o, soil_k

- Validation period from 2013 until 2017
- Parameterization period from 2018 until 2022
- Flow observation at outlet for hard calibration
- mGROWA [8] data for soft calibration:
  - et-runoff ratio
  - lateral flow
  - drain tile flow

	Unit	2013-2022	2013-2017	2018-2022
Temperature	[C°]	10.91	10.73	11.09
Solar Radiation	[MJ/m²d]	10.55	10.15	10.93
Relative Humidity	[-]	0.79	0.81	0.77
Precipitation	[mm]	676	713	639

Parameterization and Validation - Hydrology



	2013-2017		2018-2022	
	NSE	KGE	NSE	KGE
Min	0.47	0.70	0.57	0.64
Mean	0.63	0.79	0.65	0.72
Max	0.73	0.84	0.69	0.79

NSE: Nash-Sutcliffe Efficiency
KGE: Kling-Gupta Efficiency

PPP Application

- Compounds with representative physical and chemical properties were defined based on monitoring reports
- One herbicide and one fungicide application for winter wheat, winter rye, spring cereal, and maize
- No PPP application data available, random allocation of compounds for each field
- Application timing for each crop:
  - BBCH based on product label
  - DOY window based on C2D2 database [7]
  - Exact date based on forward oriented PAT adapted from GERDA project by UBA
- Reading routine of *management.sch* was modified, so application can be defined by one line

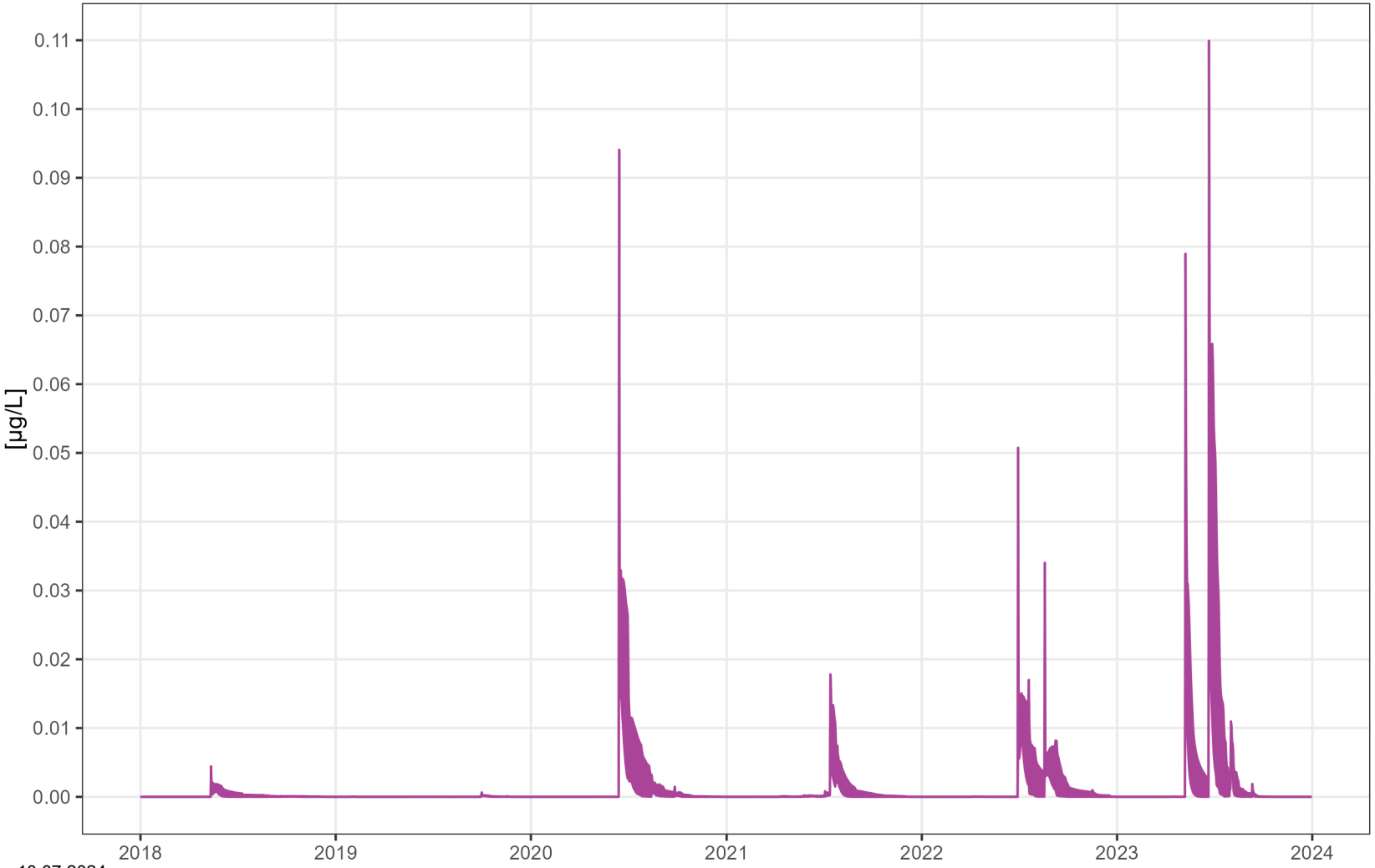
PPP Application

name	numb_ops	numb_auto	op_typ	mon	day	year	op_data1	op_data2	op_data3
agr_98_drain_7_sch	28	28							
			wwht_2010_pl_hv						
			post_crop_till_2010						
			wwht_2011_pl_hv						
			post_crop_till_2011						
			wwht_2012_pl_hv						
			post_crop_till_2012						
			wwht_2013_pl_hv						
			post_crop_till_clvr_2013						
			corn_2014_pl_hv						
			post_crop_till_clvr_2014						
			corn_2015_pl_hv						
			post_crop_till_2015						
			rye_2016_pl_hv						
			post_crop_till_clvr_2016						
			corn_2017_pl_hv						
			post_crop_till_2017						
			wwht_2018_pl_hv						
			post_crop_till_clvr_2018						
			corn_2019_pl_hv						
			post_crop_till_clvr_2019						
			corn_2020_pl_hv						
			post_crop_till_2020						
			wwht_2021_pl_hv						
			post_crop_till_clvr_2021						
			corn_2022_pl_hv						
			post_crop_till_clvr_2022						
			corn_2023_pl_hv						
			post_crop_till_clvr_2023						
			pest	11	15	2010	dummy_4	foliar	0.050000000
			pest	4	6	2011	dummy_3	foliar	0.200000000
			pest	11	11	2011	dummy_4	foliar	0.050000000
			pest	4	5	2012	dummy_3	foliar	0.200000000
			pest	11	11	2012	dummy_4	foliar	0.050000000
			pest	4	7	2013	dummy_3	foliar	0.200000000
			pest	11	11	2013	dummy_4	foliar	0.050000000
			pest	4	9	2014	dummy_3	foliar	0.200000000
			pest	5	20	2014	dummy_6	foliar	0.045000000
			pest	6	25	2014	dummy_2	foliar	0.125000000
			pest	5	21	2015	dummy_6	foliar	0.045000000
			pest	6	25	2015	dummy_2	foliar	0.125000000
			pest	10	29	2016	dummy_4	foliar	0.050000000
			pest	4	2	2017	dummy_3	foliar	0.200000000
			pest	5	21	2017	dummy_6	foliar	0.045000000
			pest	6	25	2017	dummy_2	foliar	0.125000000
			pest	11	14	2018	dummy_4	foliar	0.050000000
			pest	4	6	2019	dummy_3	foliar	0.200000000
			pest	5	21	2019	dummy_6	foliar	0.045000000
			pest	6	25	2019	dummy_2	foliar	0.125000000
			pest	5	19	2020	dummy_6	foliar	0.045000000
			pest	6	24	2020	dummy_2	foliar	0.125000000
			pest	11	11	2021	dummy_4	foliar	0.050000000
			pest	4	10	2022	dummy_3	foliar	0.200000000
			pest	5	30	2022	dummy_6	foliar	0.045000000
			pest	6	25	2022	dummy_2	foliar	0.125000000
			pest	5	20	2023	dummy_6	foliar	0.045000000
			pest	6	25	2023	dummy_2	foliar	0.125000000

Automated crop rotations

Application

Preliminary Results



- Subject to change!
- Represents the overall magnitude of reported data.
- Differences between ensemble runs.
- High annual variance in:
  - Amplitude
  - Timing

Conclusion & Outlook

- High quality and resolution geo-data is available in Germany (NRW)
- A high resolution (3m) SWAT+ model of the upper Funne catchment was built
- 5 years of field block data allowed for the creation of highly realistic crop rotations
- Successful parametrization of the hydrology and implementation of PPP transport

- Refinement of application scenario is ongoing
- Spray drift prediction with DAD-drift is ongoing
- Comparison of predicted environmental concentrations with and without drift

We create chemistry

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