Christian-Albrechts-Universität zu Kiel

2024 SWAT Conference, Strasbourg

Modelling climate resilience measures with SWAT+

Impacts of land use adaptations on water retention

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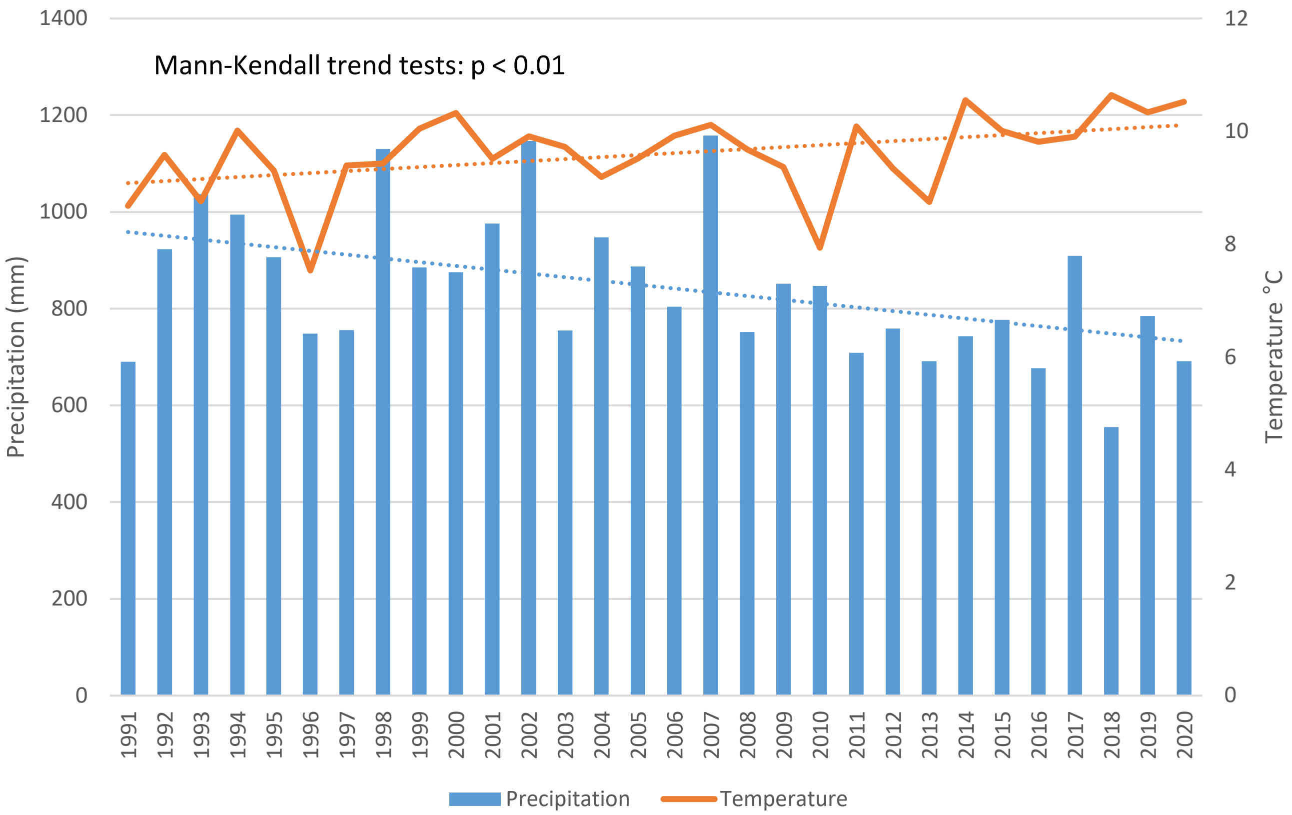
KliMaWerk WASSER:LANDSCHAFT
FONA Forschung für Nachhaltigkeit
WaX Wasser-Extremereignisse
GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

Department of Hydrology and Water Resources Management

Need for increased water retention



Data source: German Weather Service, HYRAS Product

Endangered water supply

Low water level at Hullern reservoir, 2019 (Gelsenwasser)

Reduced agricultural yields

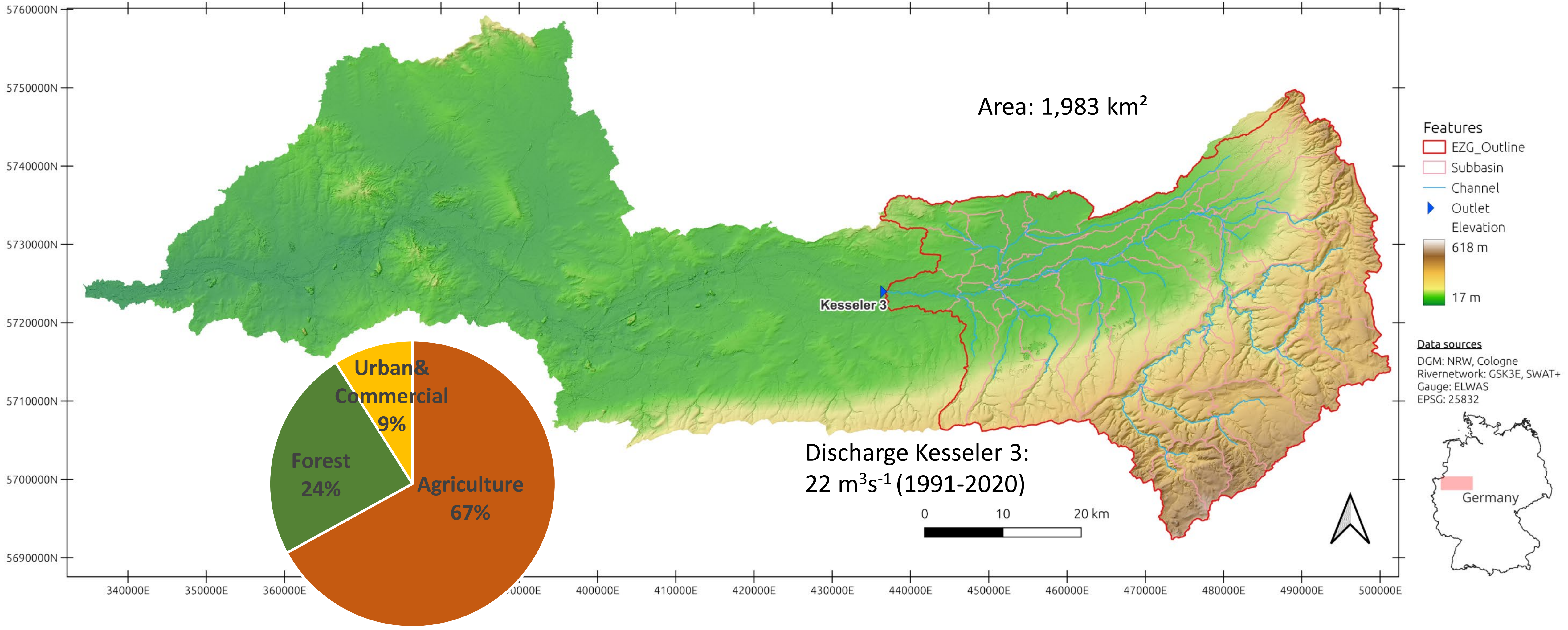
Dried maize (Bernd Brueggemann / Fotolia)

Degradation of ecosystem services

Dried up river Rotbach in Dinslaken, 2022 (EGLV/Fritsche)

Can landuse adaptions change water retention?

Upper Catchment of the Lippe River

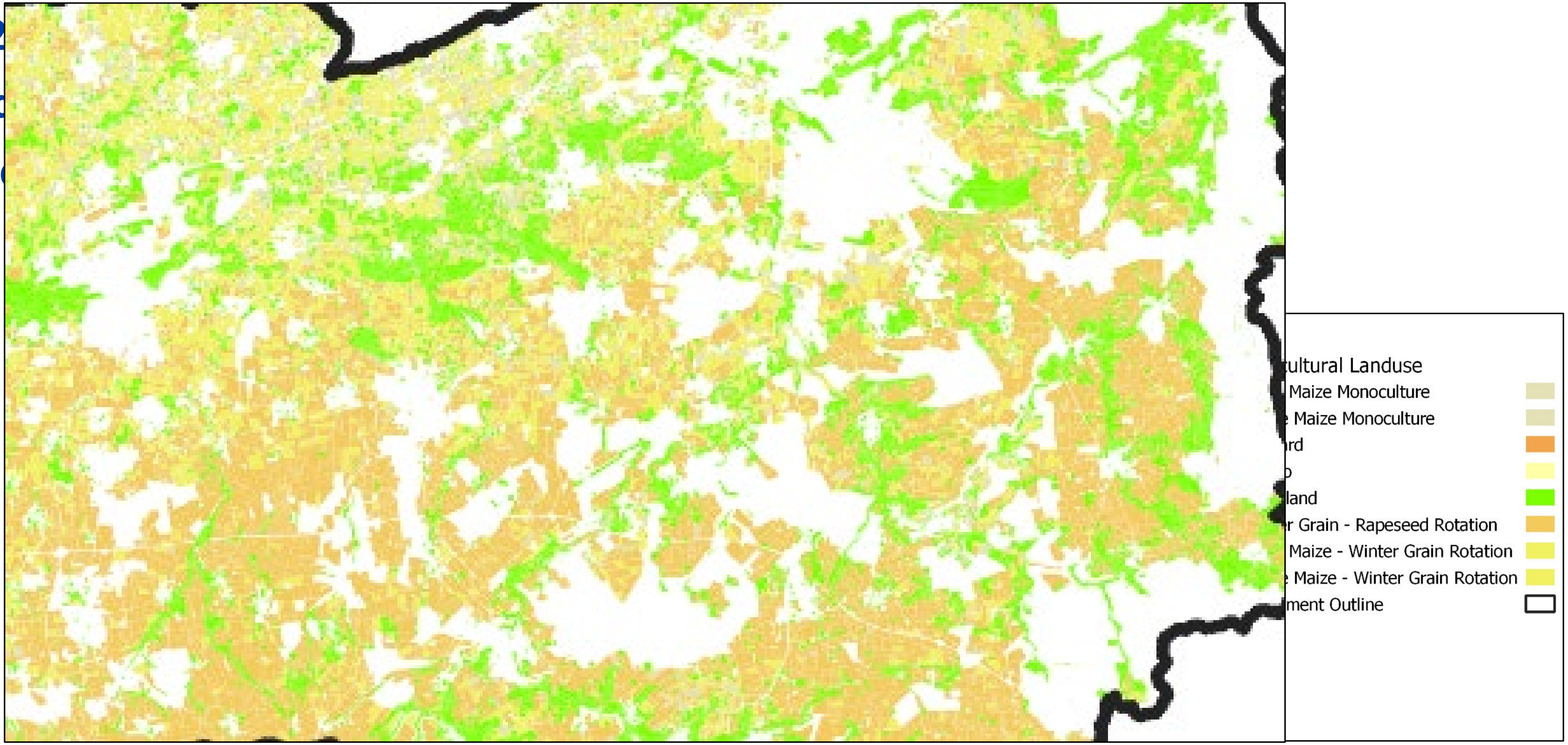


Representation of agricultural areas

2016-2022

→ detailed

→ identifi



Representation of agricultural management practices

- Land management parameters based on literature (KTBL, 2009) and expert interviews with the regional Chamber of Agriculture (2024)

- For sorghum (*Sorghum bicolor LM*), management information is based on field experiments (Bavarian LfL, 2024)

- Spatial distribution of tile drainage based on potentially drained areas assessed by Tetzlaff (2021)

Agricultural landscape in the Lippe catchment, 2024

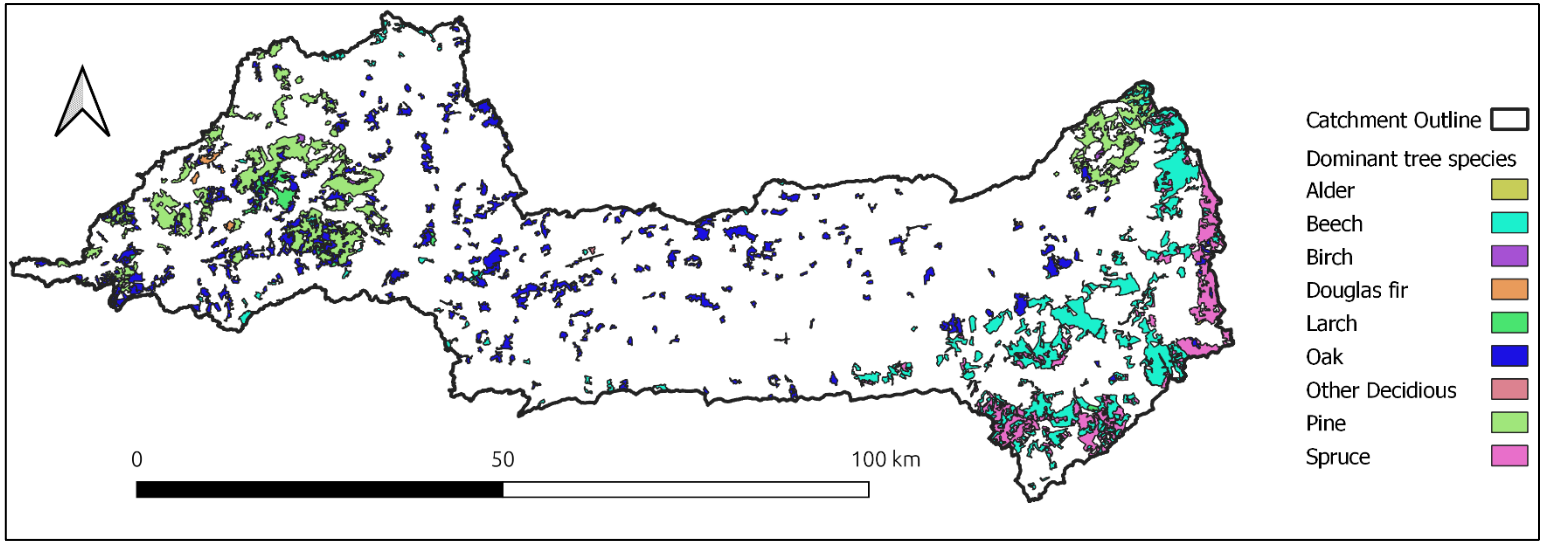
Field trials with sorghum millet cultivation, 2024

Representation of forested areas

General forest types (CORINE 2018)

→ Dominant tree species

Blickensdörfer et al., 2024

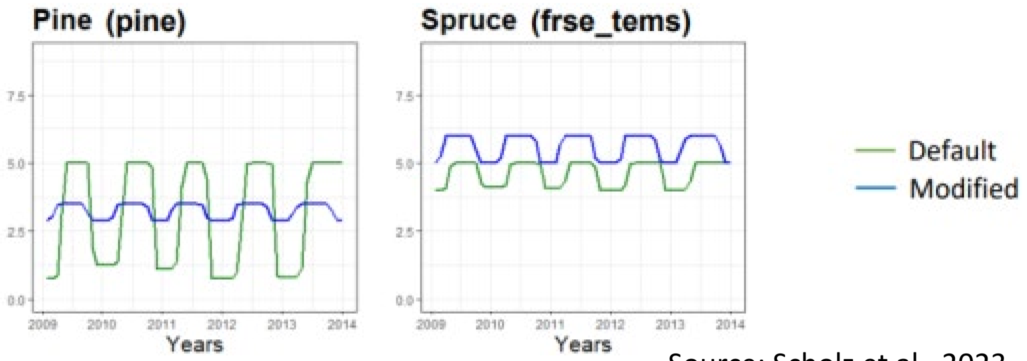


SWAT+ model's standard parameters

→ Adapted tree parameters

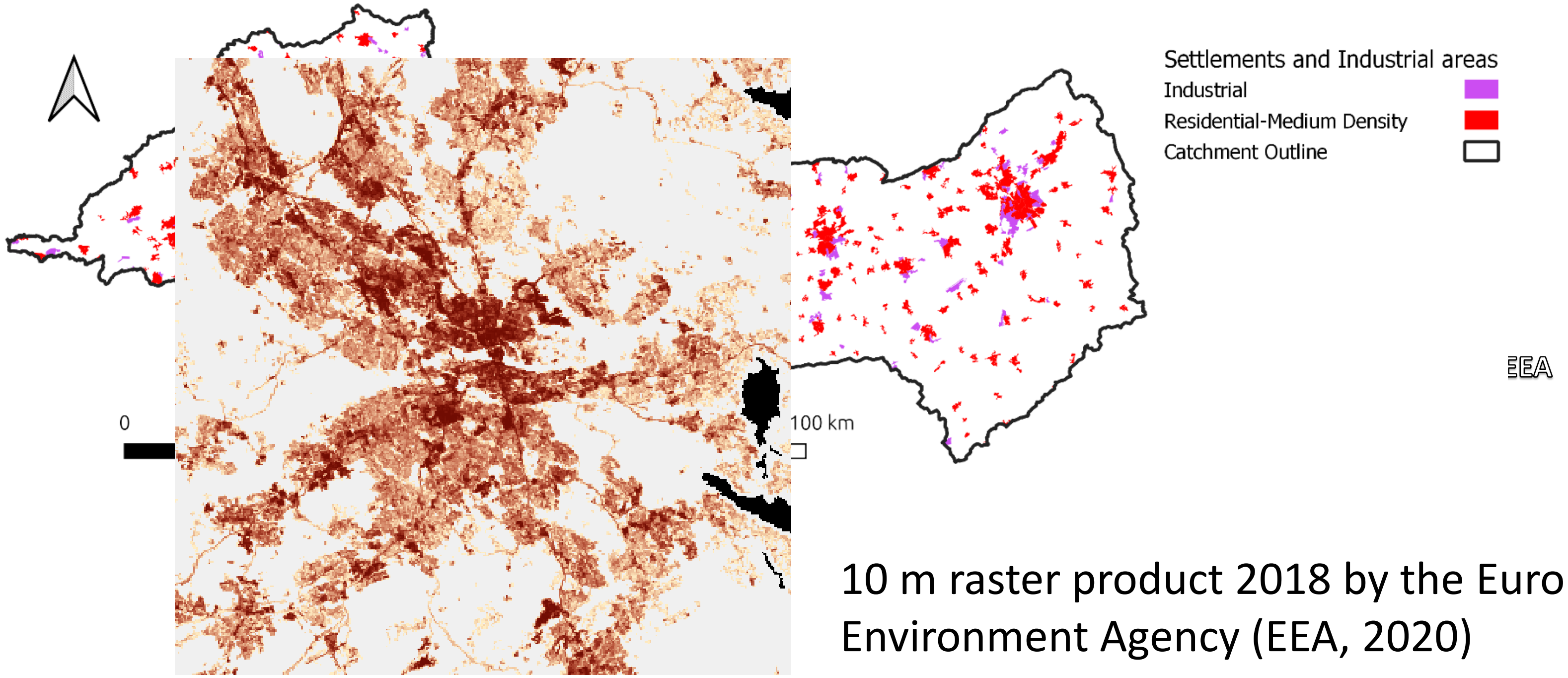
Müller, 2022

Comparison of leaf area indexes



Source: Scholz et al., 2023

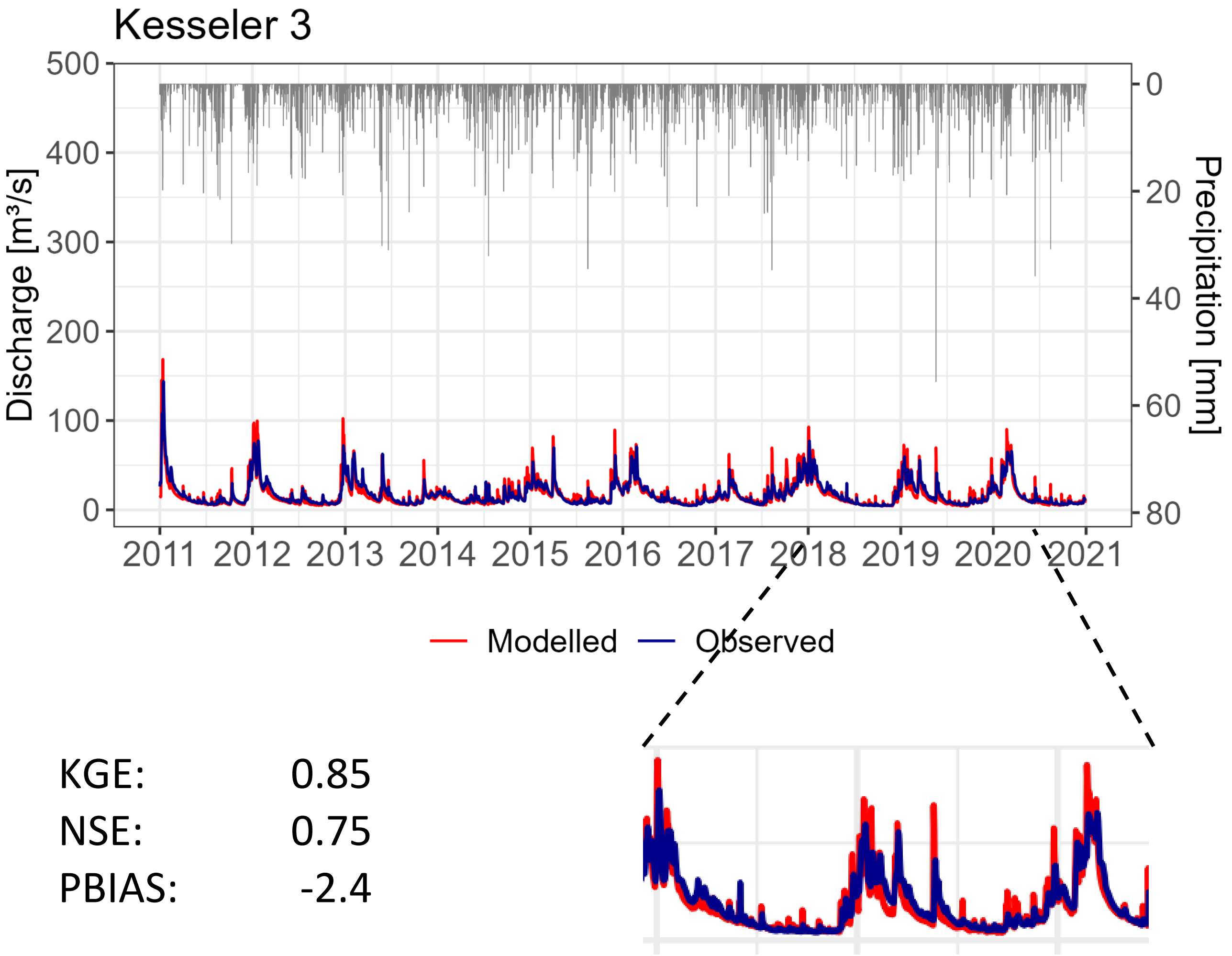
Representation of residential and commercial areas



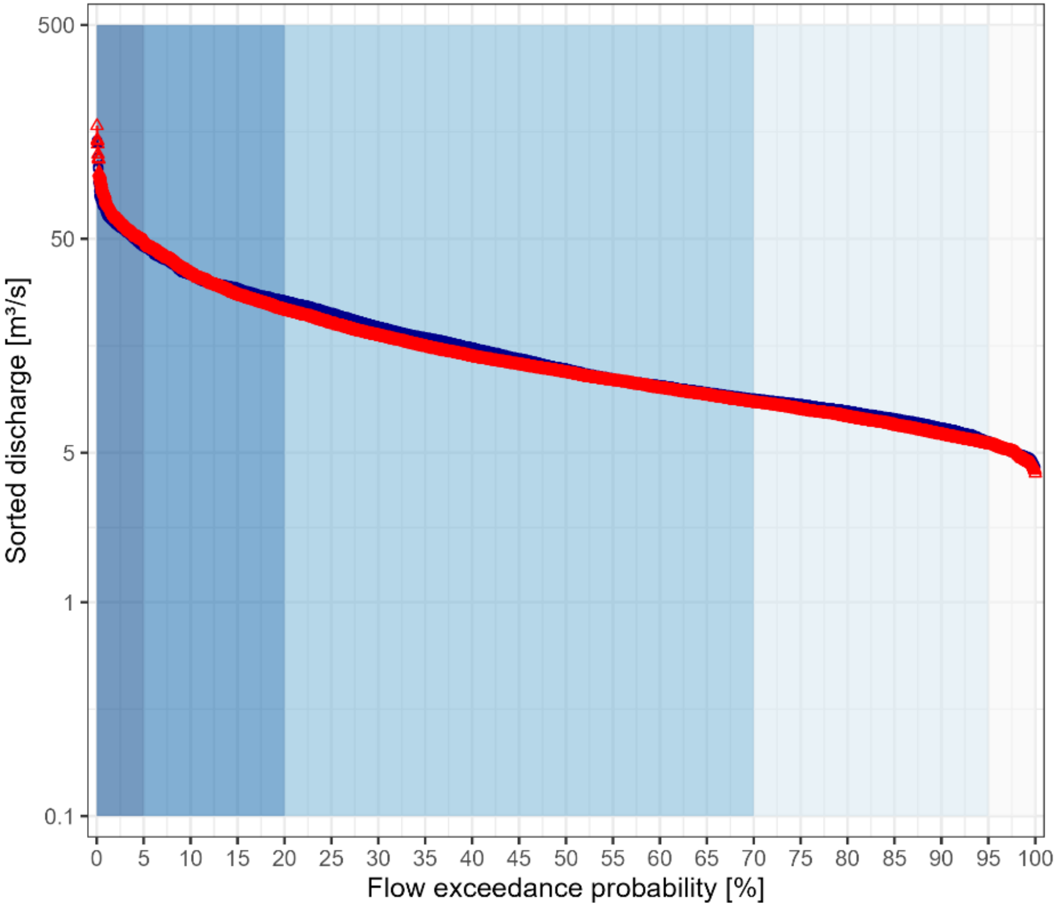
10 m raster product 2018 by the European Environment Agency (EEA, 2020)

Average imperviousness in the Upper Lippe catchment	
Residential – Medium Density	Commercial (Industry, Commerce, Transport)
46 %	58 %

Model performance in the investigation period

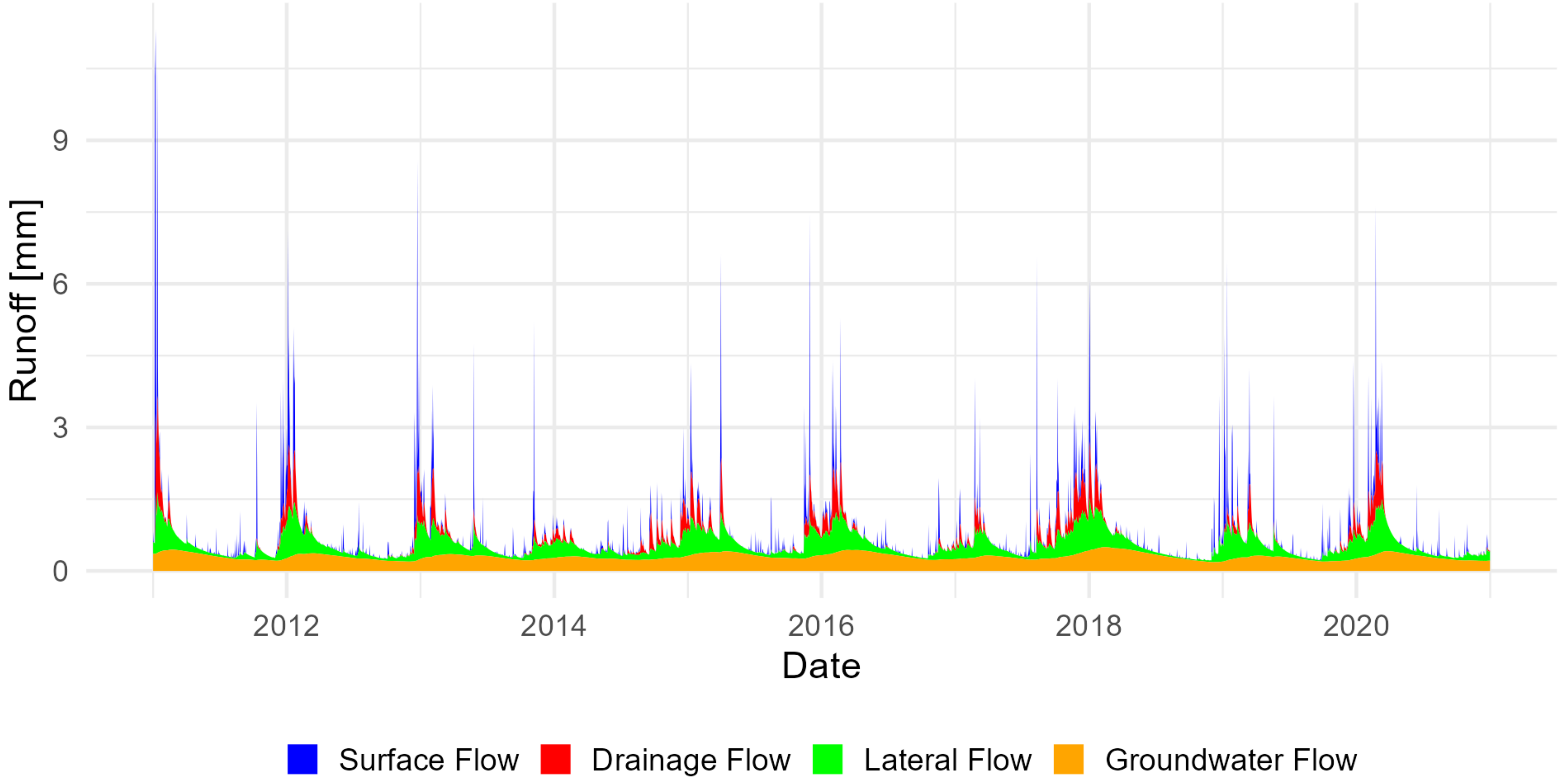


KGE: 0.85
NSE: 0.75
PBIAS: -2.4

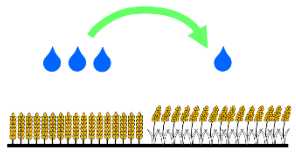
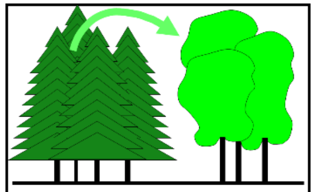
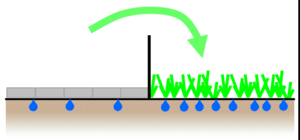


Segmentation of the flow duration curve based on: Pfannerstill et al. 2014

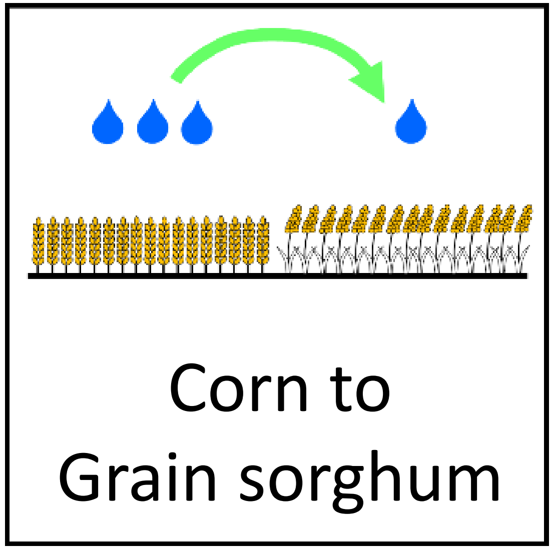
Analysis of runoff components on the catchment scale

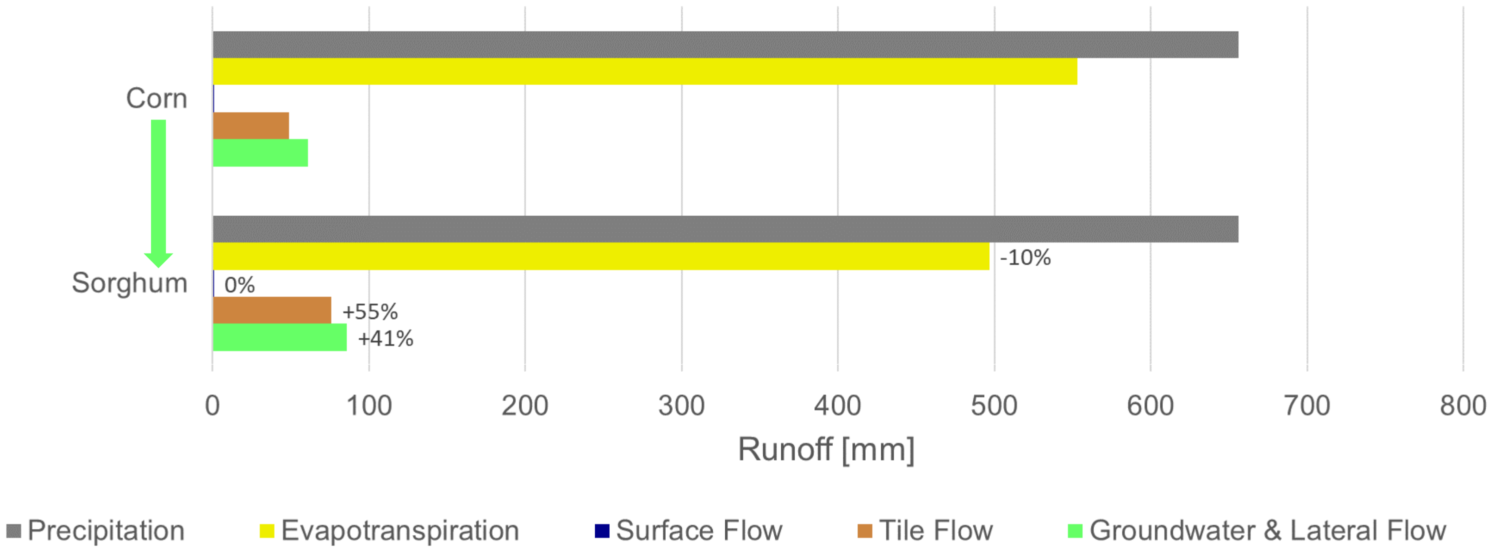


Modelling of an alternative landuse scenario

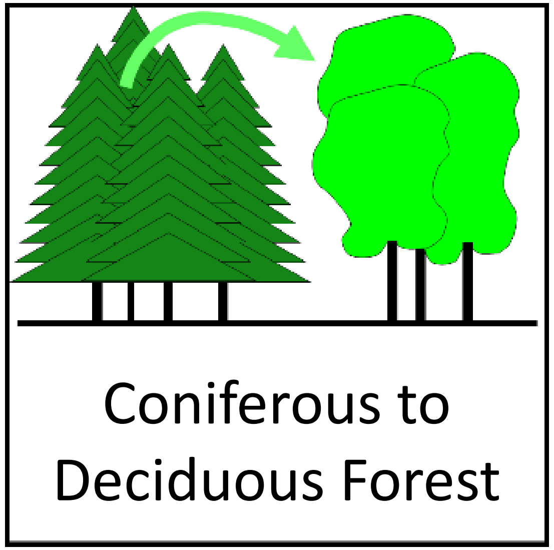
	Adaption of crops	Adaption of forest composition	Adaptation of residential and commercial areas
	 Corn to Grain sorghum	 Coniferous to Deciduous Forest	 Reduction of Imperviousness
Area	Silage Corn: 212 km^2 Corn: 124 km^2	Spruce: 125 km^2 Pine: 49 km^2	Residential: 143 km^2 Commercial: 38 km^2
Share of the catchment	17 %	9 %	9 %
Measure	Replacement of corn *(Zea mais L.)* with sorghum *(Sorghum bicolor)* in crop rotations	Change dominant tree species from coniferous to deciduous depending on site properties	greening roofs and rainwater cisterns with infiltration options
SWAT + (v 60.5.4) implementation	landuse.lum, management.sch, plant.ini	landuse.lum, plant.ini	adjust FRAC_DC_IMP in urban.urb

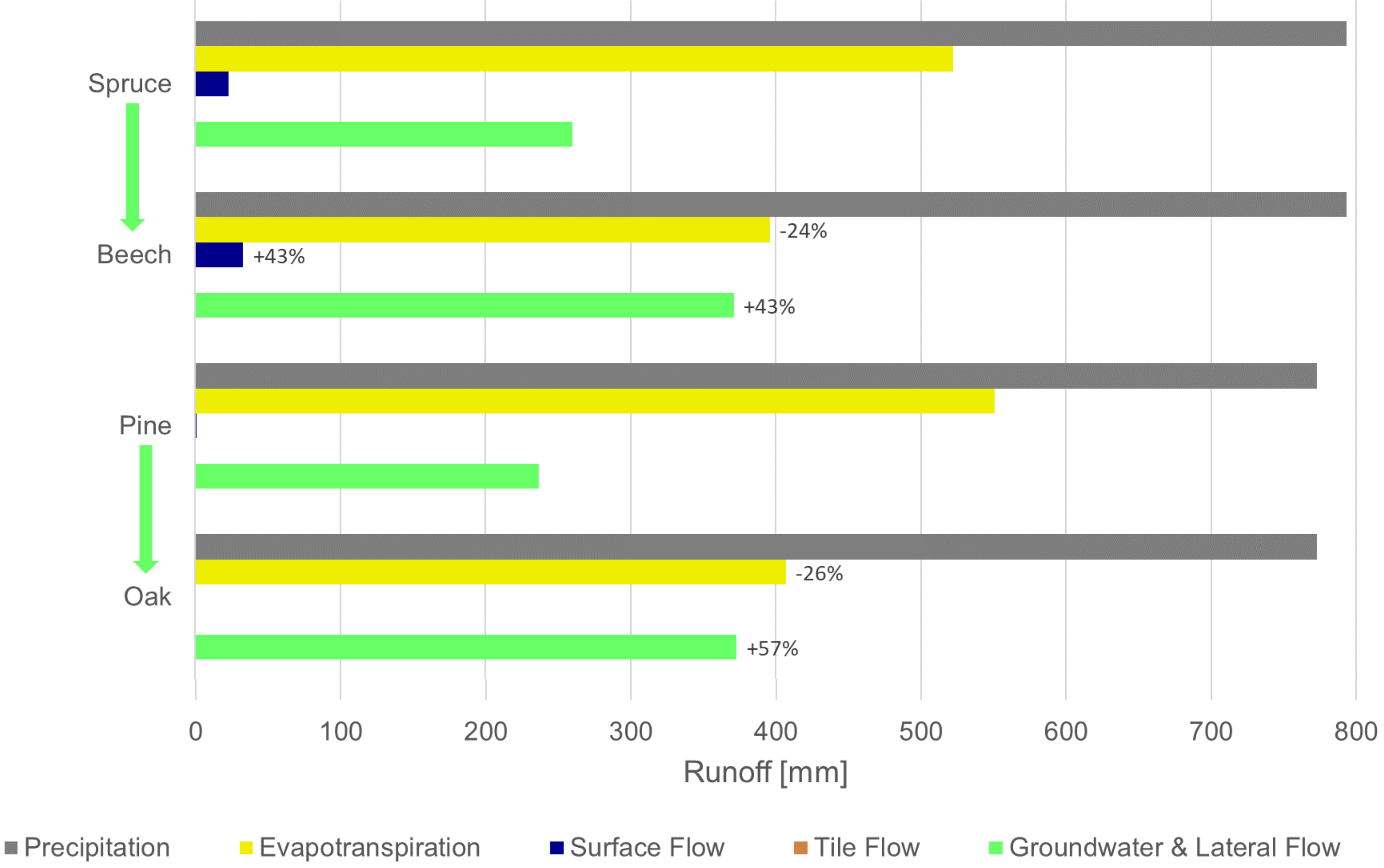
Modelled water balance results for crop adaptation



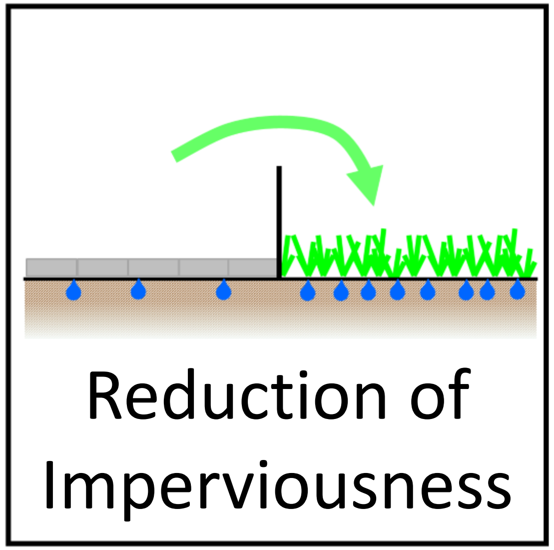


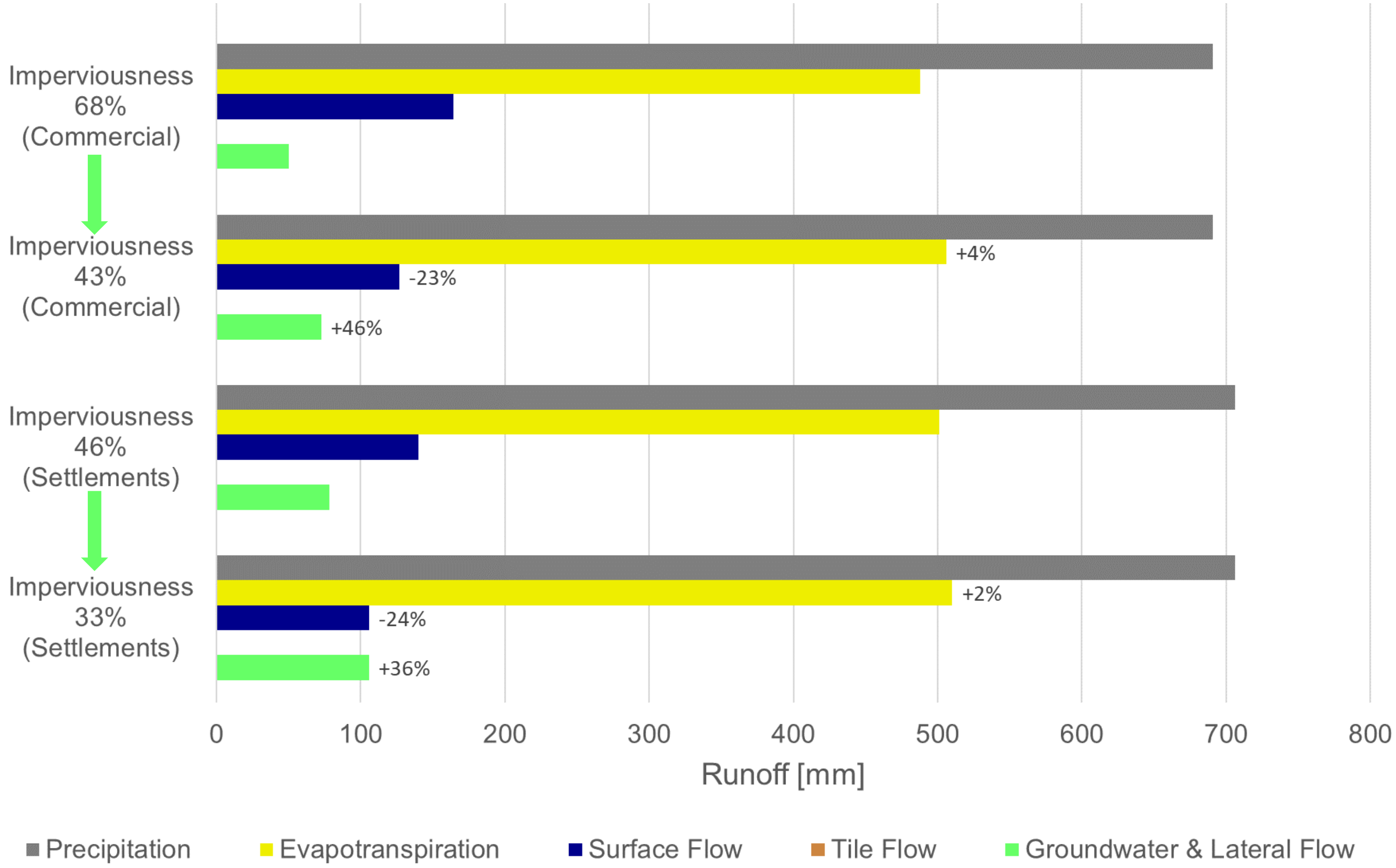
Modelled water balance components for forest composition adaptation



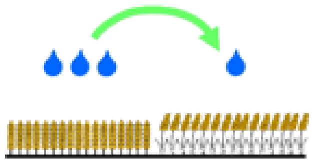
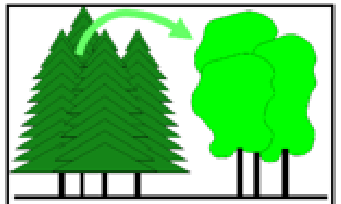
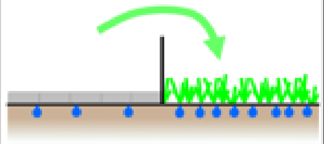


Modelled water balance results for adaptation in settlements and commercial areas





Impacts of alternative landuse on the water balance

	Adaption of Crops	Adaption of Forest Composition	Reduced Imperviousness
	 Corn to Grain sorghum	 Coniferous to Deciduous Forest	 Reduction of Imperviousness
Evapotranspiration	↓	↓	↗
Fast Runoff	↗	↗	↓
Slow Runoff	↑	↑	↑

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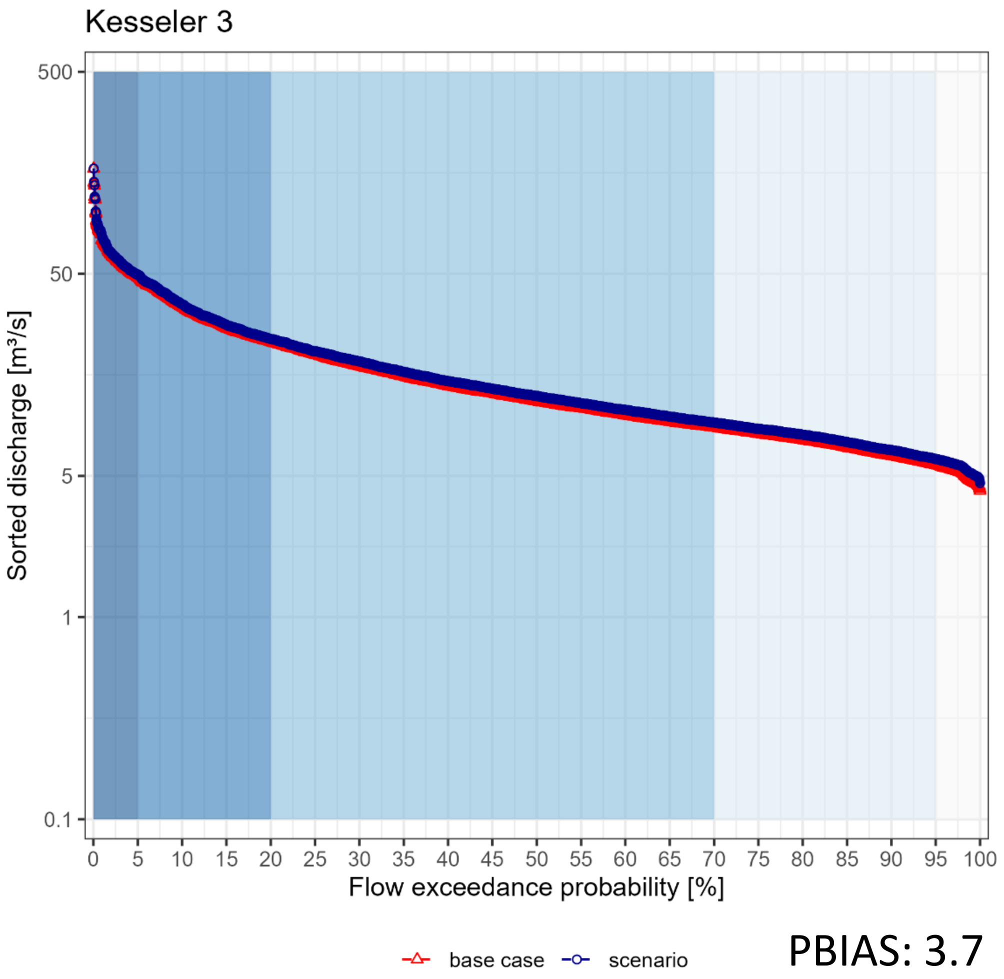
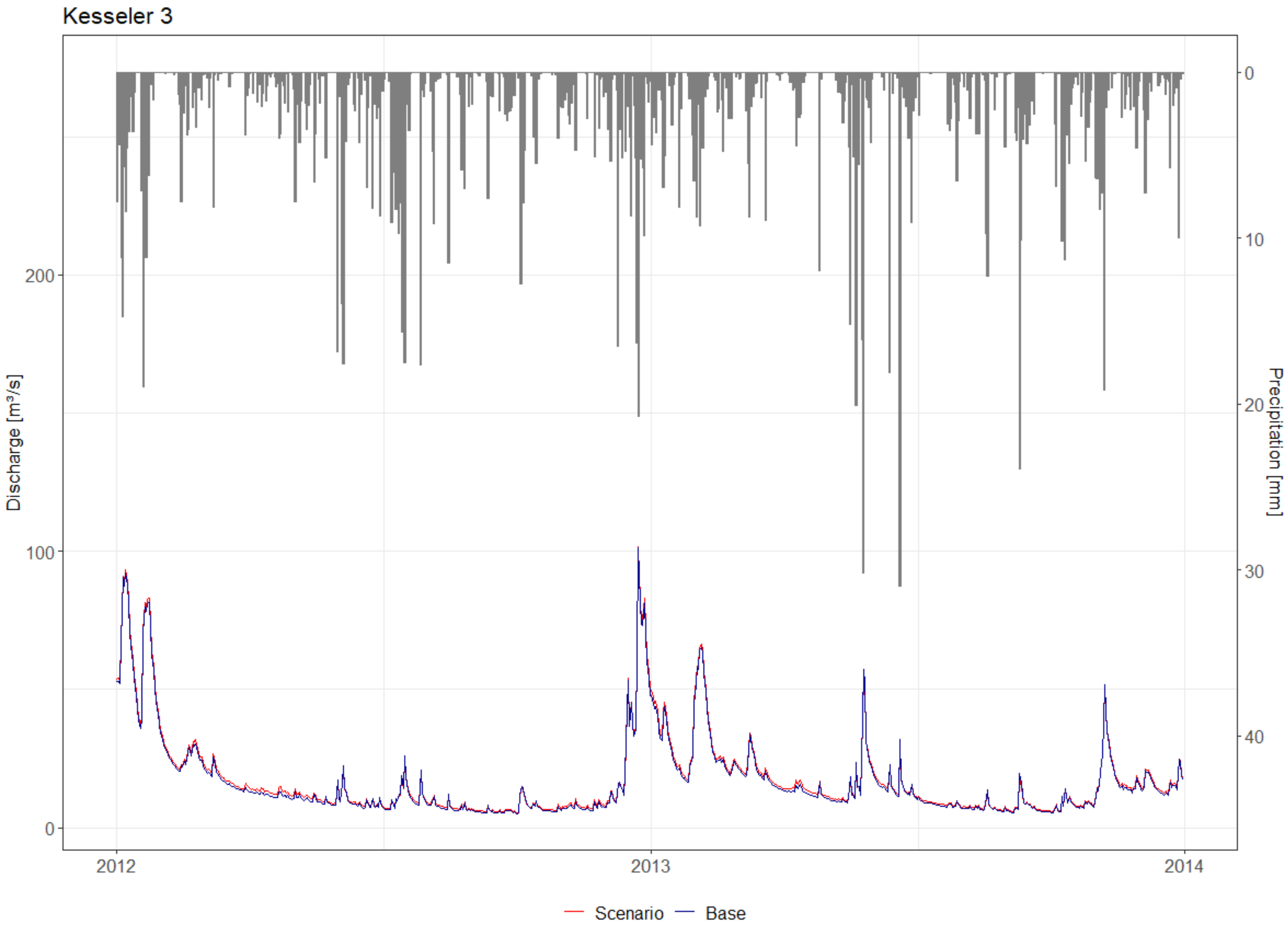
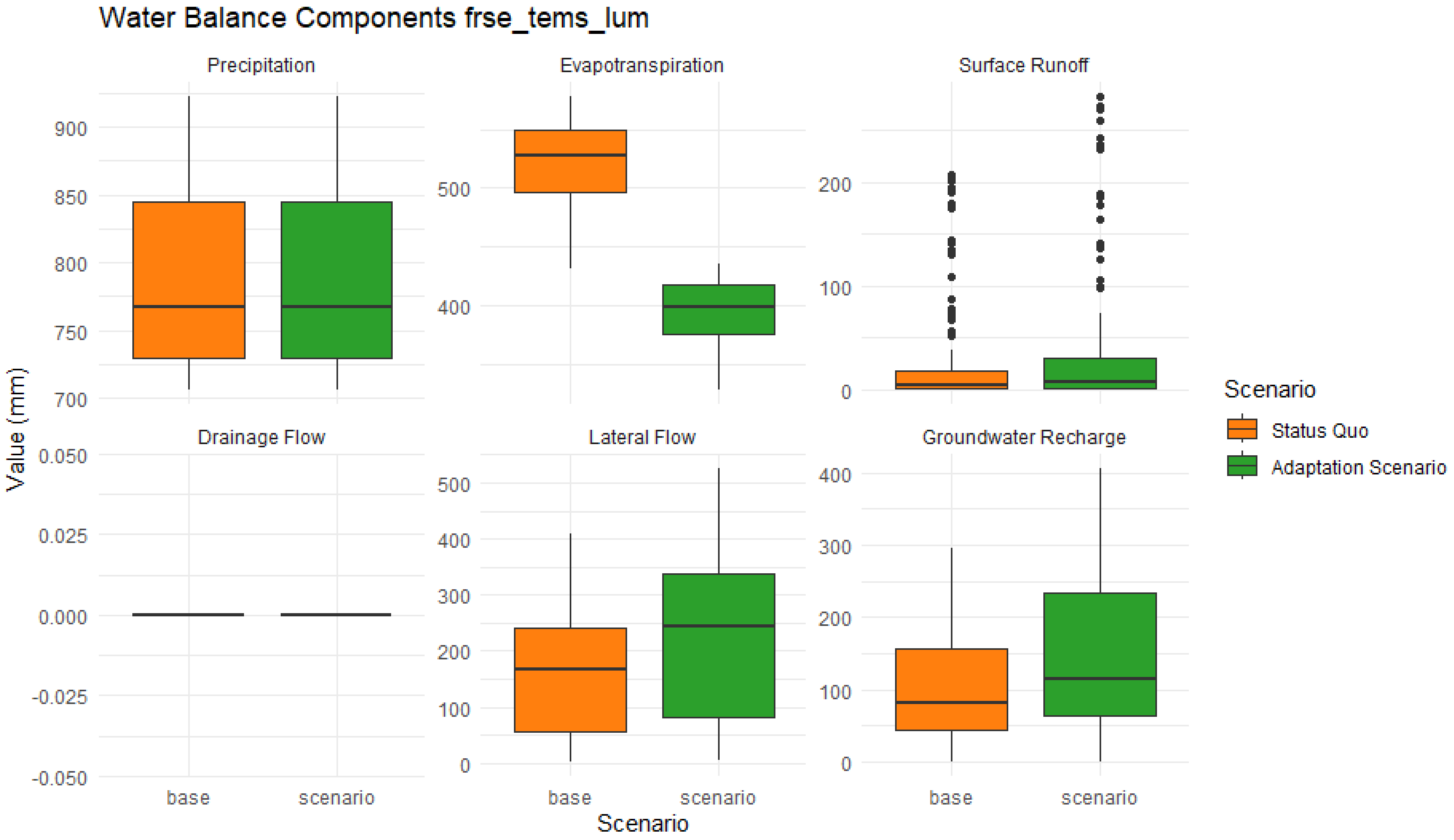
Backup Slides

Change in discharge (2011 – 2020)



PBIAS: 3.7





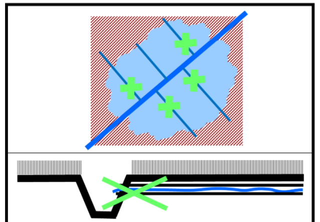
Water Balance Components frse_tems_lum
Precipitation
Evapotranspiration
Surface Runoff
Drainage Flow
Lateral Flow
Groundwater Recharge
Value (mm)
900
850
800
750
700
500
400
200
100
0
0.050
0.025
0.000
-0.025
-0.050
500
400
300
200
100
0
400
300
200
100
0
base
scenario
Scenario
Scenario
Status Quo
Adaptation Scenario

SWAT+ model calibration and validation

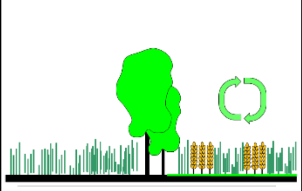
- Gauge: Kesseler 3
- Latin Hypercube Sampling (McKay et al., 2000; McKay, 1988) of 19,200 parameter sets
- **Objective function:**
  lowest RSR in the low-flow segment of the flow duration curve (0.7–1.0 flow exceedance probabilities)
- Behavioral runs with thresholds of -5 ≤ PBIAS ≤ 5 and KGE ≥ 0.5

Further research

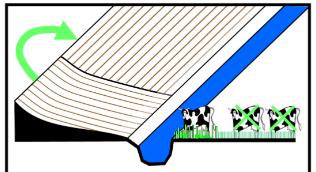
- Parameterization of management measures



Drainage management



Land management



Best management practices

- Modelling of rule-based implementation scenarios based on feasibility analyses
- Modelling and evaluation of the combined measures in regionalized climate scenarios RCP 2.6 and RCP 8.5 (German Weather Service Core Ensembles v2018)

Thank you for your attention!

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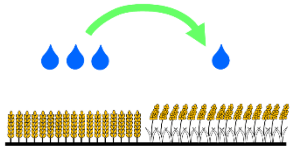
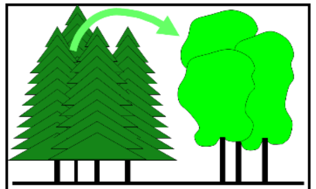
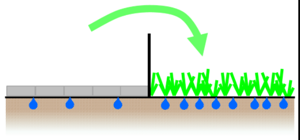
Conclusions: Changes of the runoff components from landuse-based climate resilience measures

	Adaption of Crops	Adaption of Forest Composition	Reduced Imperviousness
	 Corn to Grain sorghum	 Coniferous to Deciduous Forest	 Reduction of Imperviousness
Evapotranspiration	↓	↓	↗
Fast Runoff	↗	↗	↓
Slow Runoff	↑	↑	↑

SWAT+ model calibration and validation

- Latin Hypercube Sampling (McKay et al., 2000; McKay, 1988) of 19,200 parameter sets
- Objective function:
  best performance low-flow segment of the flow duration curve (0.7–1.0 flow exceedance probabilities)

	Calibration	Validation
Years	2007, 2018, 2004, 2013, 2005, 2014, 2010, 2003, 2019, 2015	2002, 2016, 2001, 2020, 2017, 2011, 2009, 2008, 2006, 2012
Precipication (average)	814.6076	827.4398
Precipication (standard deviation)	153.4750148	140.5080816
Kling-Gupta Efficiency (KGE, Kling et al. 2009)	0.81	0.81
Nash-Sutcliffe Efficiency (NSE, Nash et al. 1970)	0.72	0.72
Percent Bias (PBIAS, , Moriasi et al. 2007)	-0.6	5.9
Root Square Error (RSR, Moriasi et al. 2007) low flows (Yilmaz et al. (2008)	0.07	0.31
Kling-Gupta Efficiency low flows (KGElf, Garcia et al. 2017)	0.88	0.85

Parameter	Description	Change	Min	Max	Final value/adjustment
SURLAG	Surface runoff lag coefficient	absval	0.05	0.2	0.11416
CN2	Condition II curve number	abschg	-30	0	-16.02966
CN3_SWF	Soil water factor for curve number condition III	absval	0	1	0.74405
ESCO	Soil evaporation compensation coefficient	absval	0	1	0.27152
EPCO	Plant water uptake compensation coefficient	absval	0	1	0.73084
AWC	Available water capacity of the soil layer (mm H2O/mm soil)	pctchg	-50	50	38.22824
K	Saturated hydraulic conductivity of soil layer (mm H_2O/hr)	pctchg	-50	50	30.67697
LATQ_CO	Lateral flow coefficient	absval	0	1	0.88037
LAT_LEN	Average slope length for lateral subsurface flow	pctchg	-40	40	-35.47720
TILE_DTIME	Time to drain soil to field capacity (hrs)	absval	48	72	70.63843
TILE_DRAIN	Maximum drainage capacity per day (mm)	absval	10	51	50.08286
PERCO	Percolation coefficient	absval	0	1	0.92981
ALPHA	Baseflow recession constant	absval	0.001	0.2	0.00425
SP_YLD	Aquifer specific yield (m^3 H_2O/m^3)	absval	0.05	0.2	0.05172