Dynamic land use change in SWAT+ with Scenario Decision Tables

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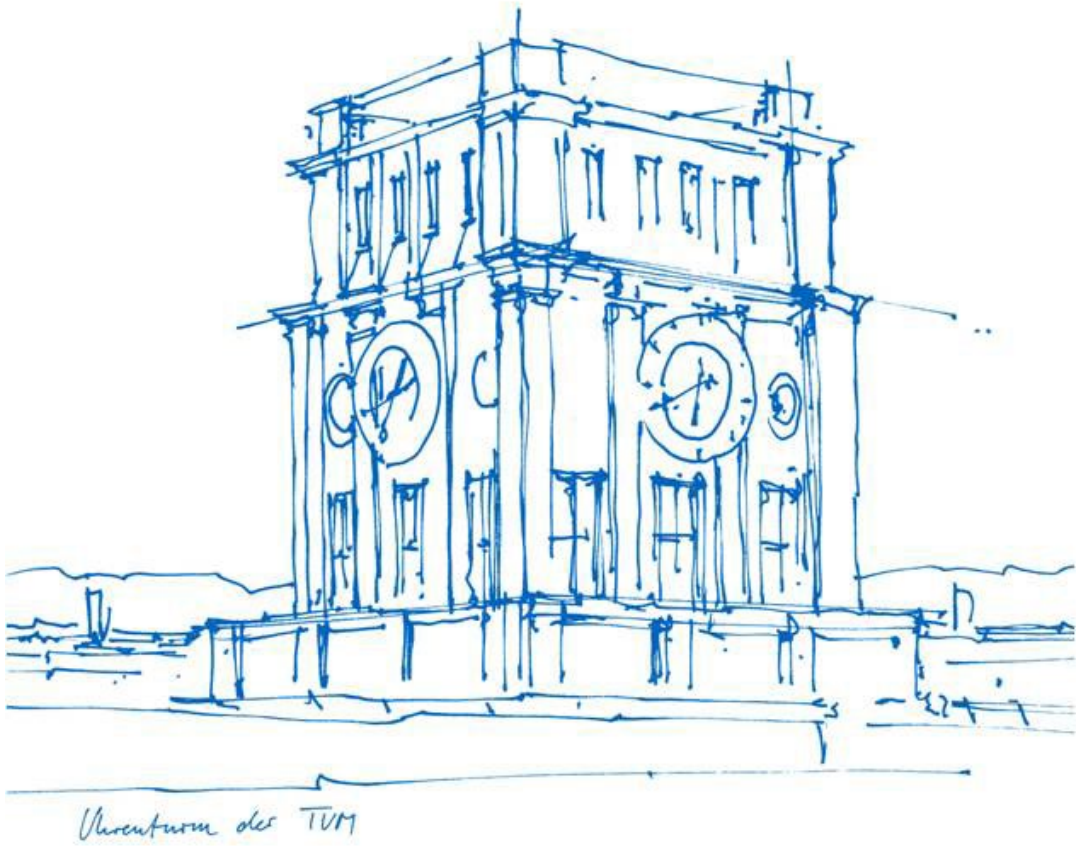


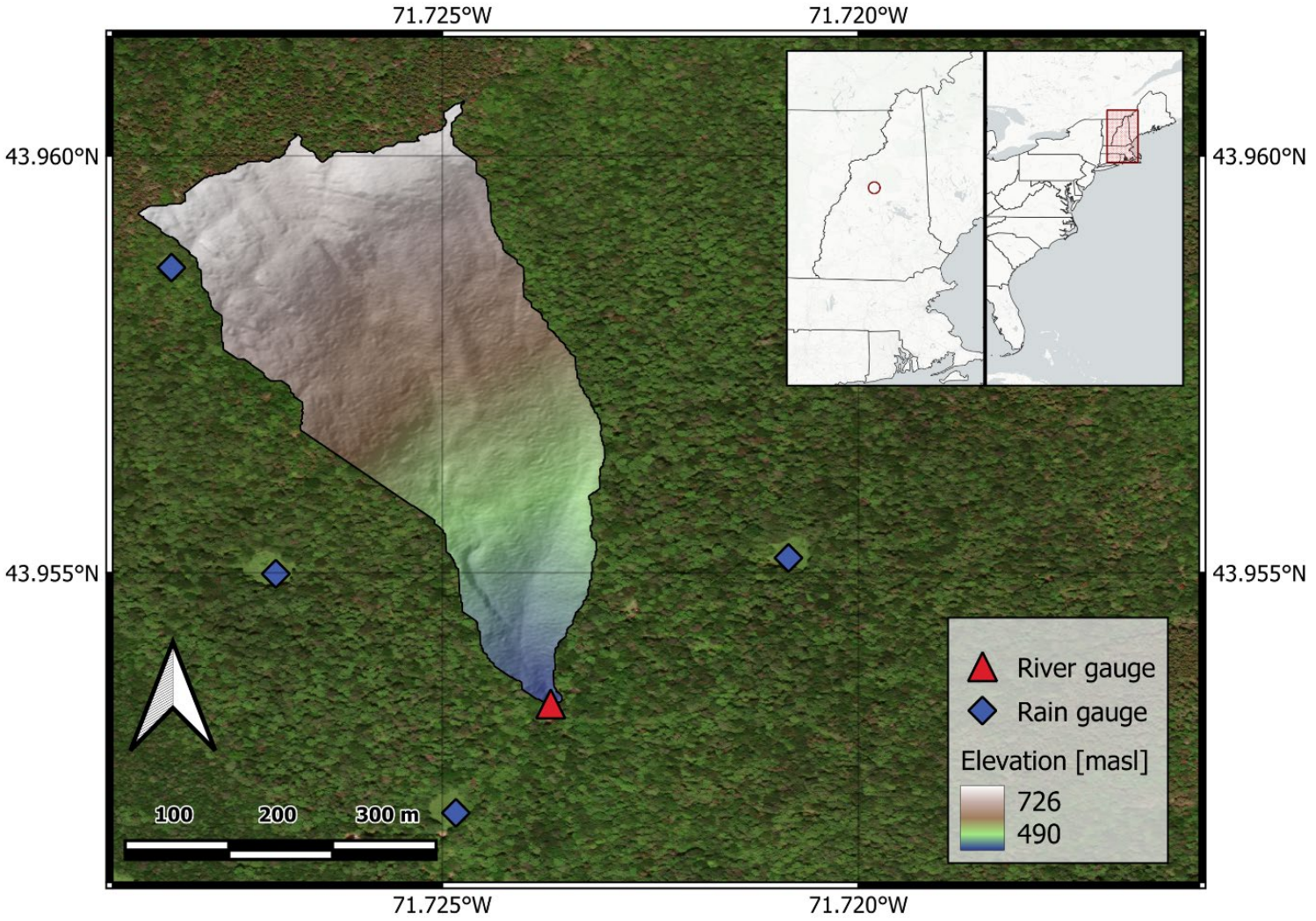
Motivation

- Land use & land cover (LULC) key component governing hydrology
- Changes in LULC potential so significantly impact water resources, flooding, and water quality
- Potential to mitigate/ enhance impacts of climate change
- Delta Approach not always sufficient
  - Static LULC information
  - Possible over-parameterization (calibration)
  - Not accounting for non-linear LULC change & potential non-linear impacts

→ Dynamic land use & land cover change

Study Area - Hubbard Brook Deforestation Experiment

- Part of Hubbard Brook Experimental Forest
- Area: 15.6 ha
- V-notch weir
- Streamflow data beginning in 1958
- Detailed precipitation & temperature data
- Deforestation experiment starting in 1966



Study Area - Hubbard Brook Deforestation Experiment

Goal:

Investigate capabilities of SWAT+ for LULC change impact assessments

Start measurements

Deforestation & herbicide application

Natural regeneration of forest

1956 1966 1969 1976

Sensitivity Analysis/ Calibration

Evaluation

Model Setup – Land use

Before devegetation:
→ FRSD_MAT
→ Deciduous forest

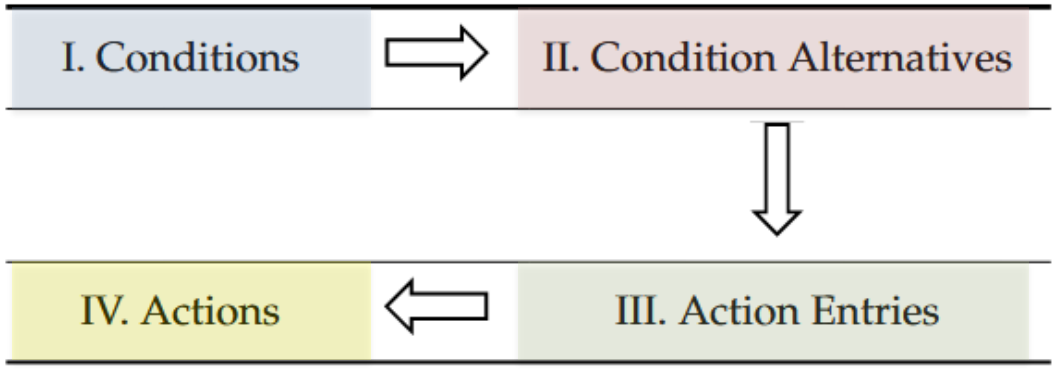
During devegetation
→ BARN
→ Sparsely vegetated

After devegetation
→ FRSD_NEW
→ Deciduous forest (new growth)

Model Setup – Scen decision table

Decision table setup:

- 4 Quadrants:
  - Conditions
  - Condition Alternatives
  - Action Entries/ Outcomes
  - Actions



DTBL_NAME	CONDS	ALTS	ACTS					
forest_to_barn	2	1	1					
COND_VAR	OBJ	OBJ_NUMB	LIM_VAR	LIM_OP	LIM_CONST	ALT1		
jday	null	0	null	-	1	=		
year_cal	null	0	null	-	1966	=		
ACT_TYP	OBJ	OBJ_NUM	ACT_NAME	ACT_OPTION	CONST	CONST2	FILE_POINTER	OUT1
lu_change	hru	0	frsd_to_barn	null	0	0	barn_lum	y

Model Setup – Scen decision table

- Treatment:
  - All woody vegetation cut between 18 Nov. and 31 Dec. 1965
  - Herbicides applied during growing season (1966-1968)

- Two tables needed
  1. In 1966 from forest to bare
  2. In 1969 (1970) from bare to new growth forest

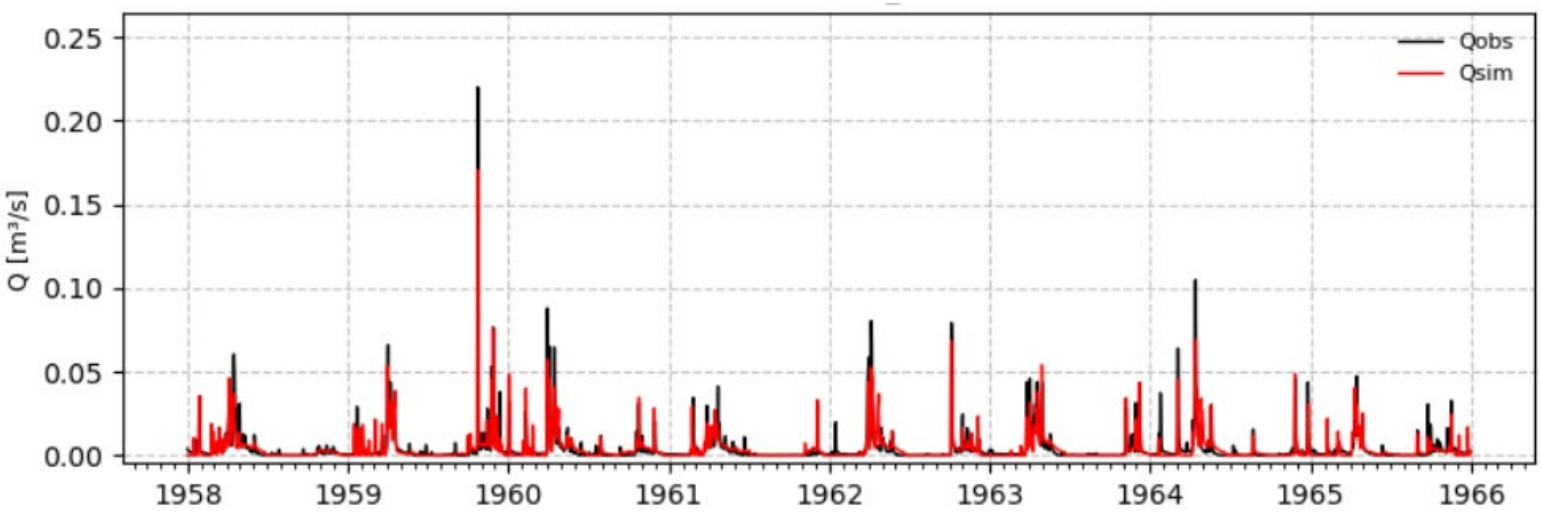
scen_lu.dtl

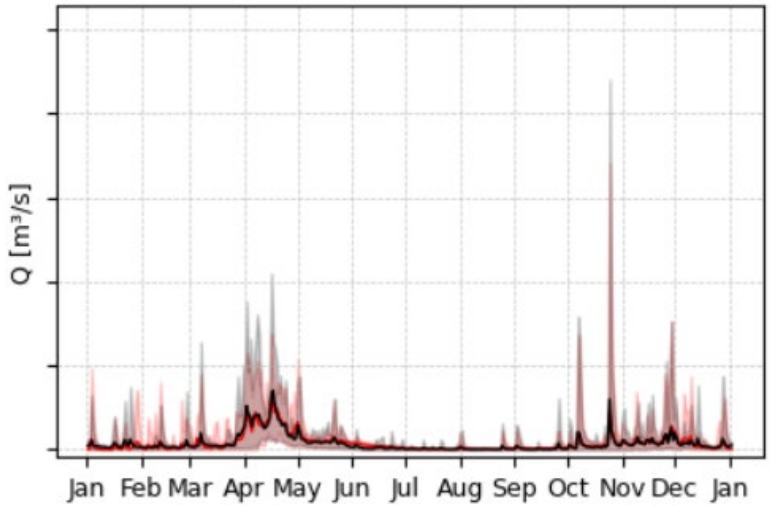
```
scen_dtl Generated by L.Alcamo on 20.01.2025
2

      DTBL_NAME         CONDS       ALTS       ACTS
 forest_to_barn           2          1          1
COND_VAR     OBJ       OBJ_NUMB  LIM_VAR     LIM_OP  LIM_CONST  ALT1
 jday        null      0         null        -       1          =
 year_cal    null      0         null        -       1966       =
 ACT_TYP      OBJ      OBJ_NUM   ACT_NAME     ACT_OPTION CONST  CONST2 FILE_POINTER  OUT1
 lu_change   hru       0         frsd_to_barn  null       0      0      barn_lum      y

      DTBL_NAME         CONDS       ALTS       ACTS
 barn_to_forest           3          1          1
COND_VAR     OBJ       OBJ_NUMB  LIM_VAR     LIM_OP  LIM_CONST  ALT1
 jday        null      0         null        -       1          =
 year_cal    null      0         null        -       1970       =
 land_use    hru       0         barn_lum    -       0          =
ACT_TYP      OBJ       OBJ_NUM   ACT_NAME     ACT_OPTION CONST  CONST2 FILE_POINTER  OUT1
 lu_change   hru       0         barn_to_frsd  null       0      0      frsd_new_lum  y
```

Normal text file | length : 1,126 lines : 20 | Ln : 1 Col : 4 Pos : 4 | Windows (CR LF) | UTF-8 | INS

Sensitivity Analysis & Calibration

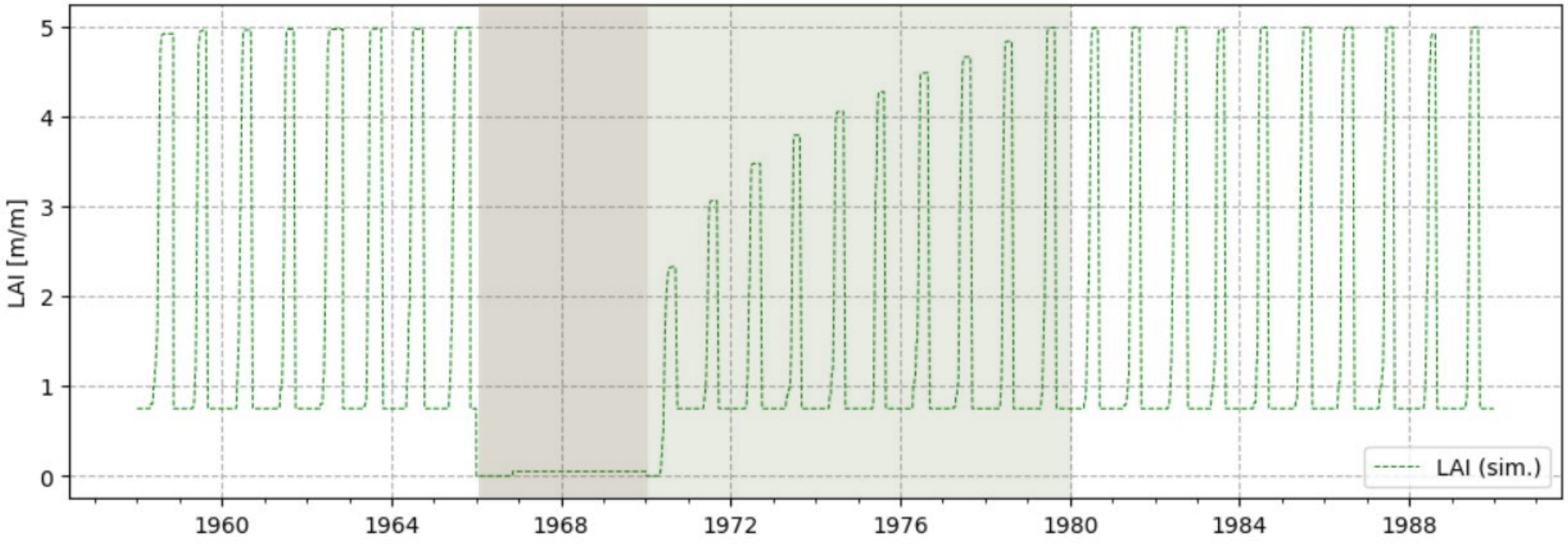
- Timeframe: 1956-65
- Discharge at outlet
- 12 sensitive parameters chosen
  - Including 5 snow parameters
- Calibration:
  - NSE = 0.74
  - KGE = 0.83
  - PBIAS = 0.45 %





Day of the year plot

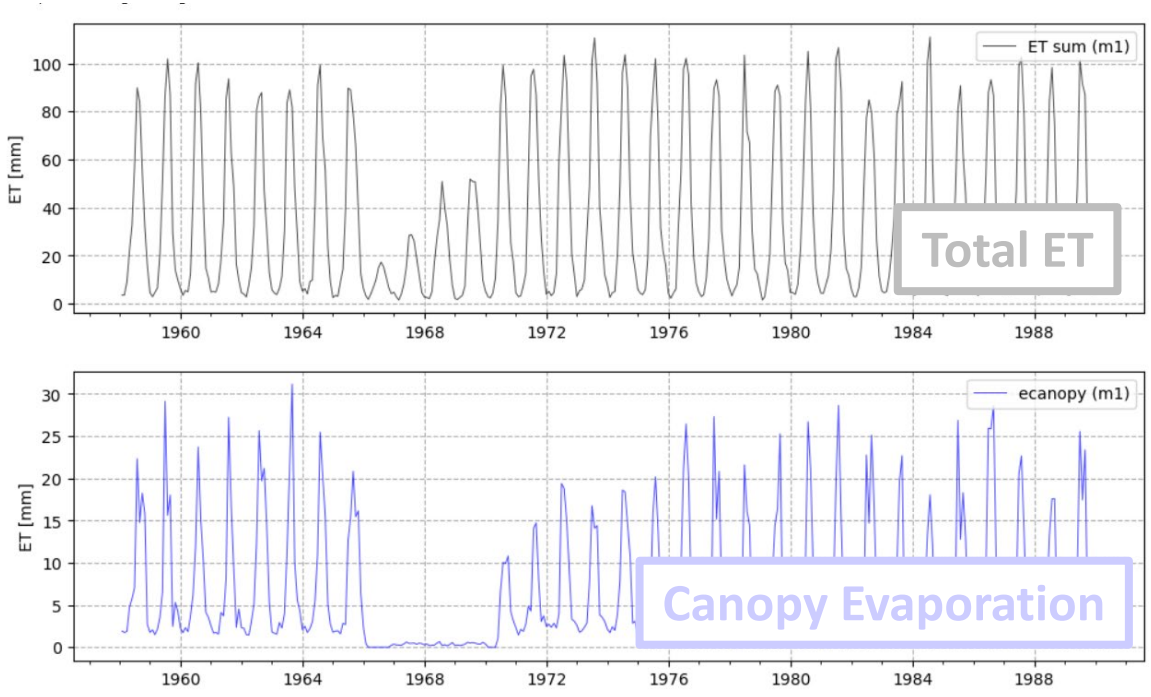
Results – Validation (LAI)

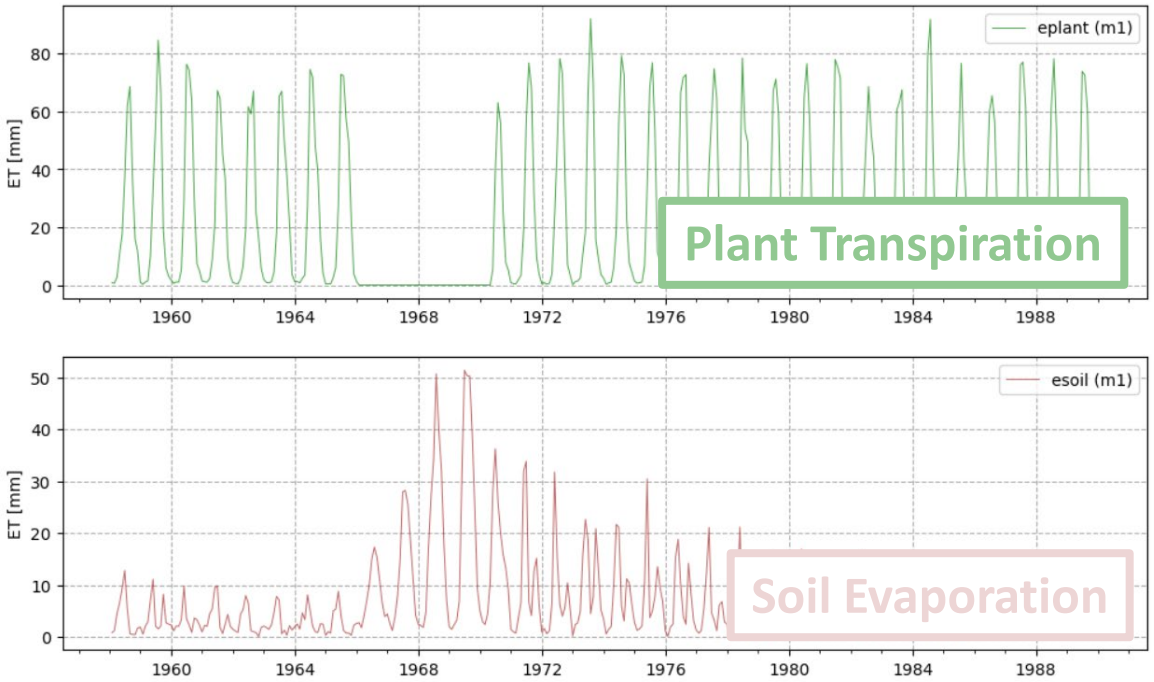


Devegetation

Regrowth
(10 years to maturity)

Results – Validation (ET)





- Soil evaporation increases during devegetation due to residue decomposition
- Quick recovery of ET after devegetation

Model Setup – Scenarios

- With dynamic LULC change

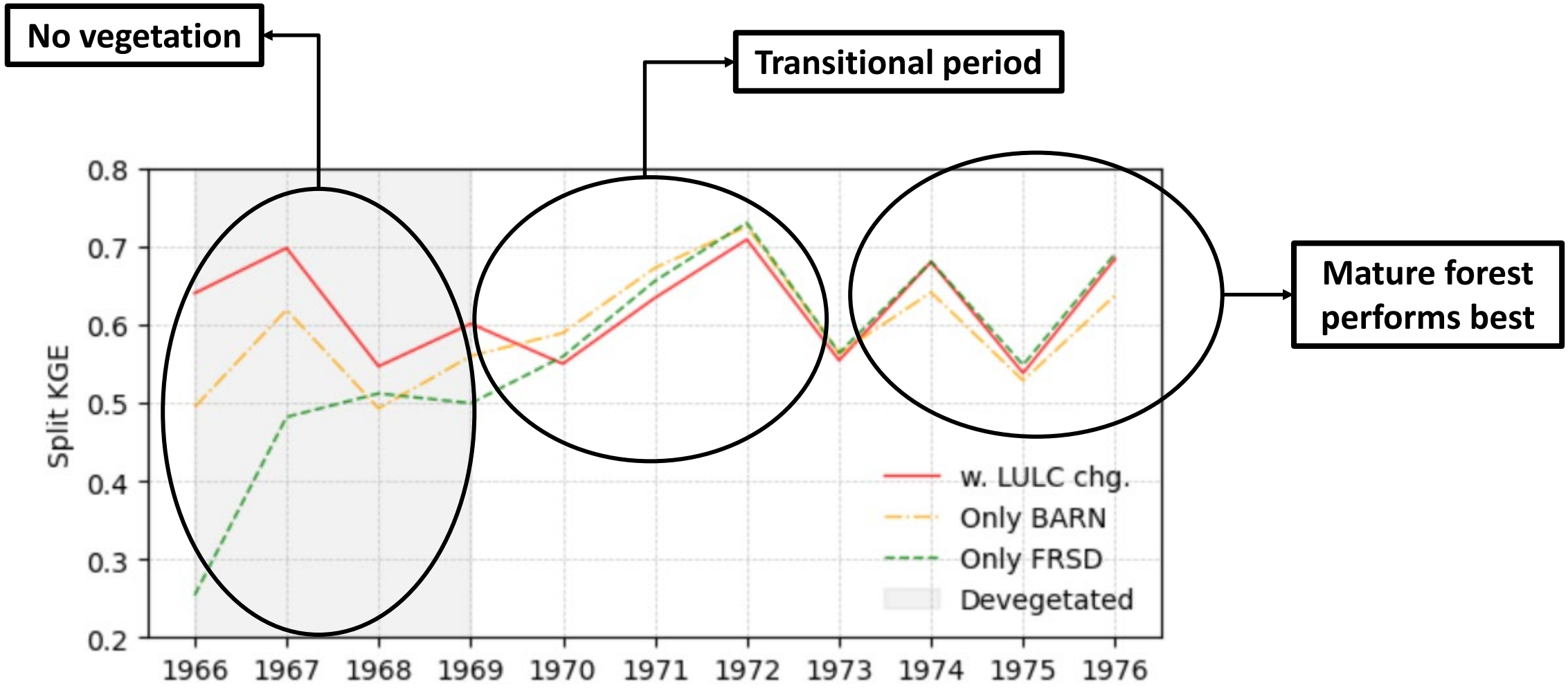
- No LULC change

  (Only forest)

- Constant LULC change

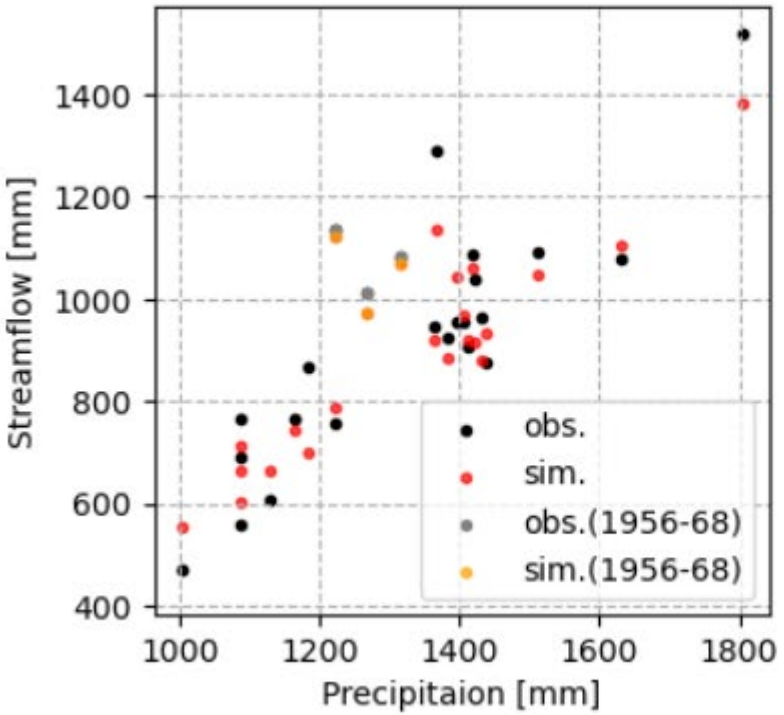
  (Only sparse vegetation)

Results – Scenario Analysis

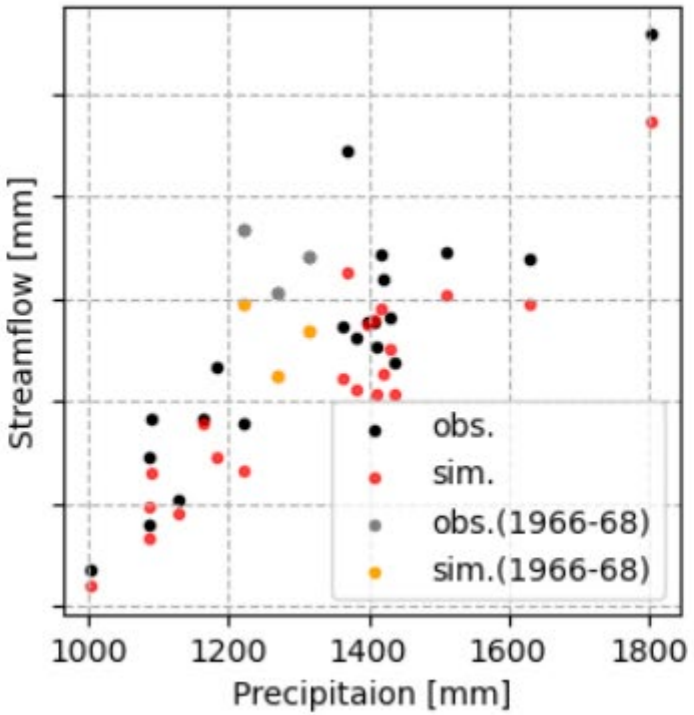


Results – Scenario Analysis

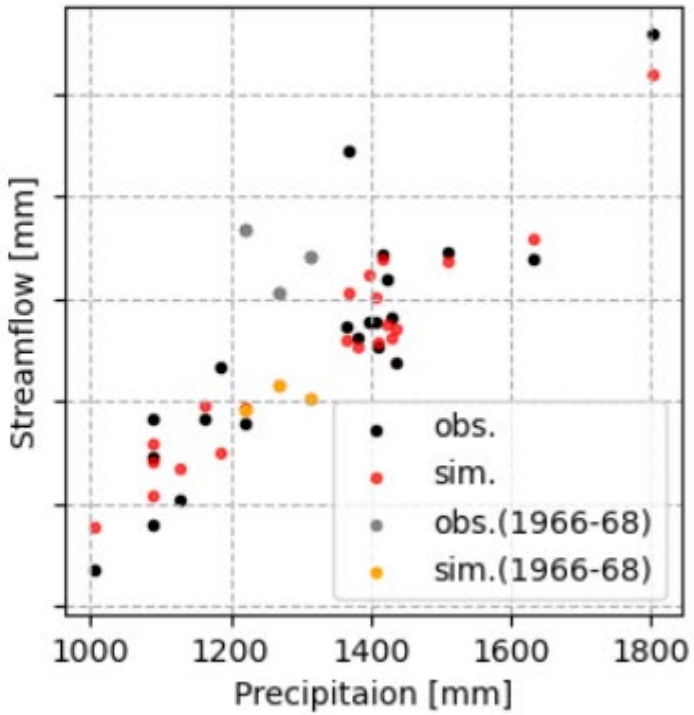
with LULC change



only “BARN“

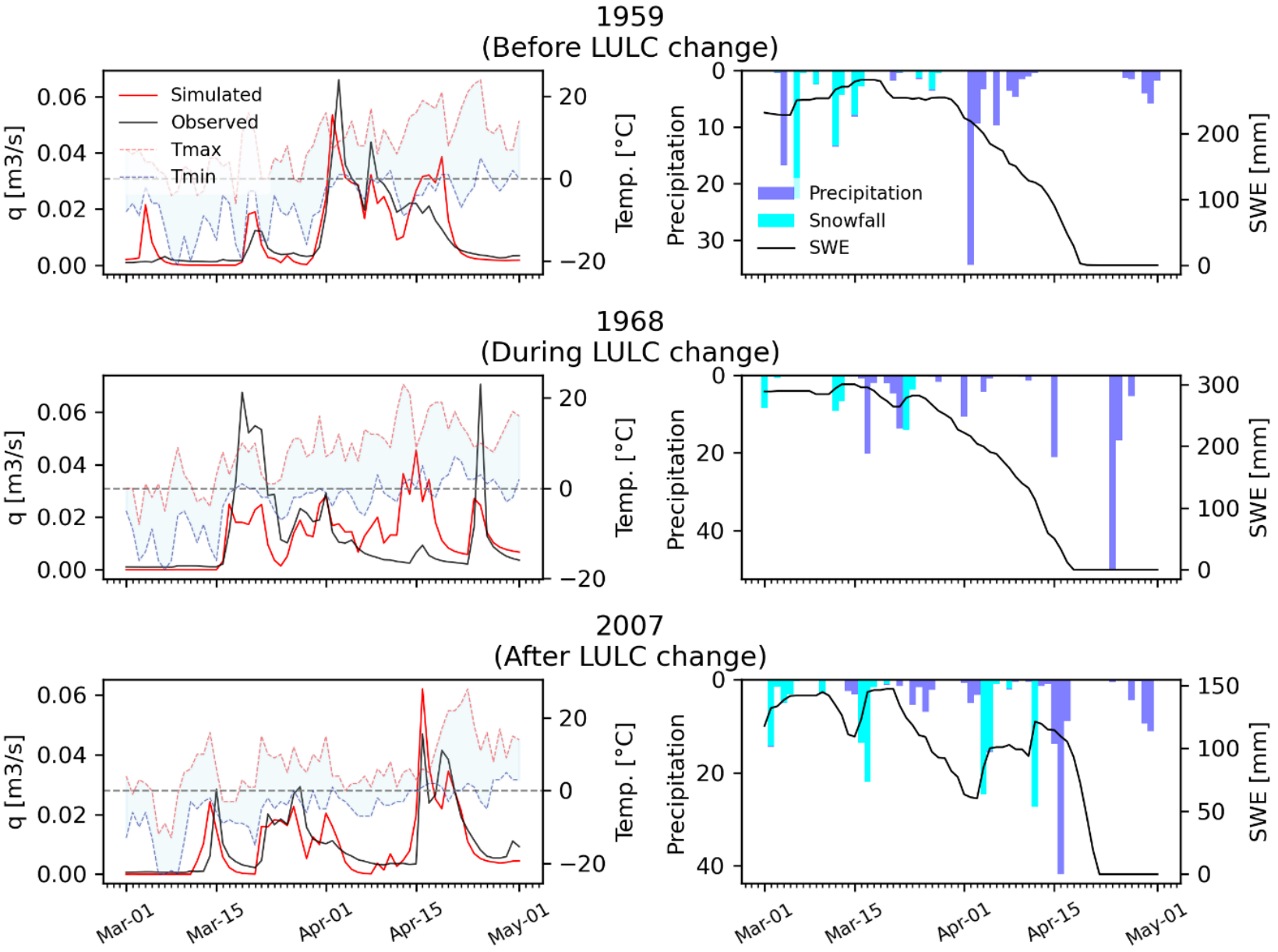


only “FRSD“



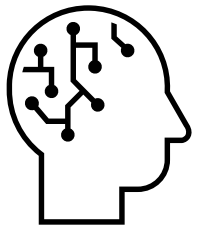
Results – Snow

- During devegetated period (1966-68)
- NSE = 0.55 (only, why?)
- Snow parameters are constant!
- van Meerveld and Seibert, 2024:
  - High sublimation rates in canopy
  - Melt rates generally higher in open areas
- No adaptations to sublimation, melt rates or ground temperature



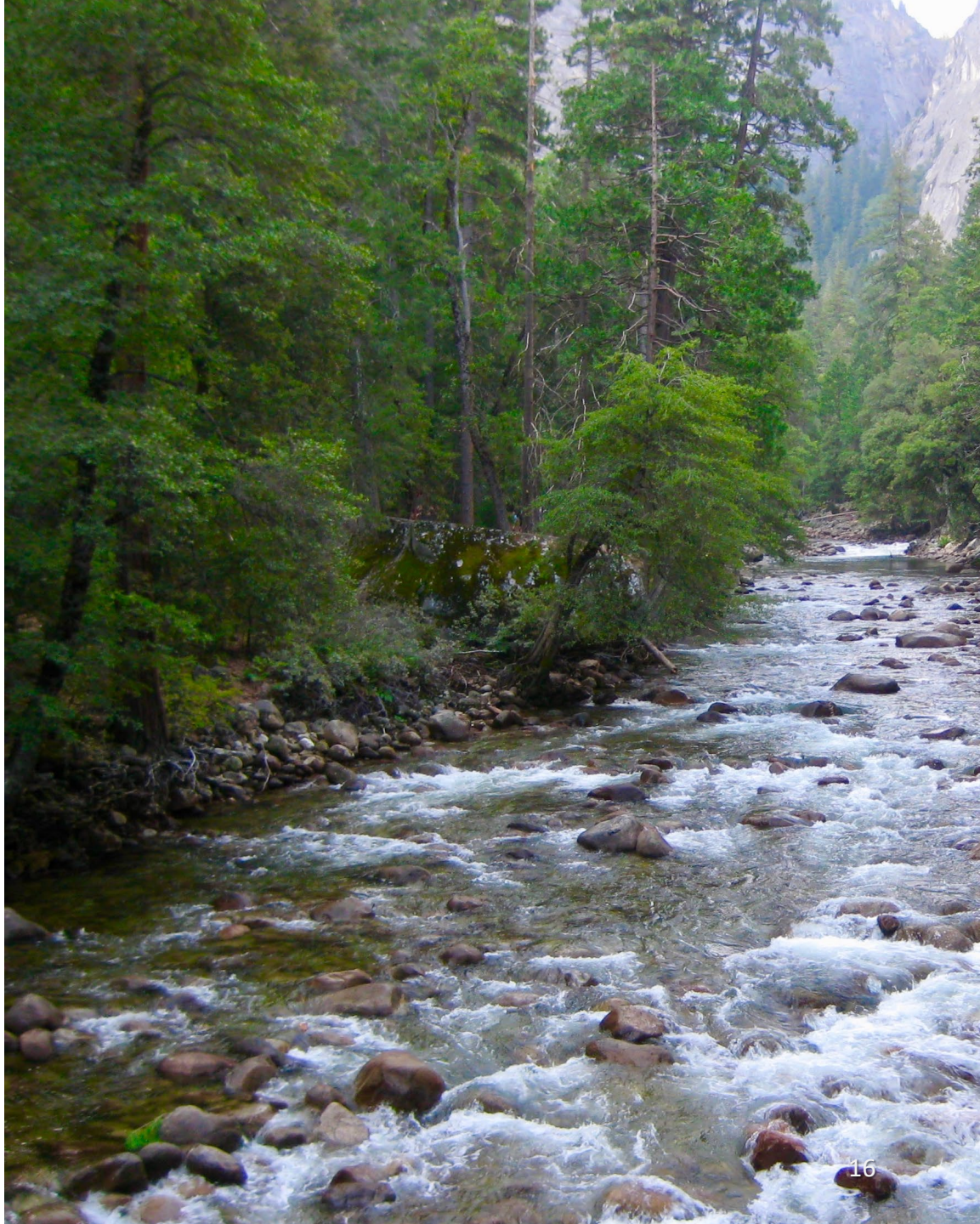
Conclusion

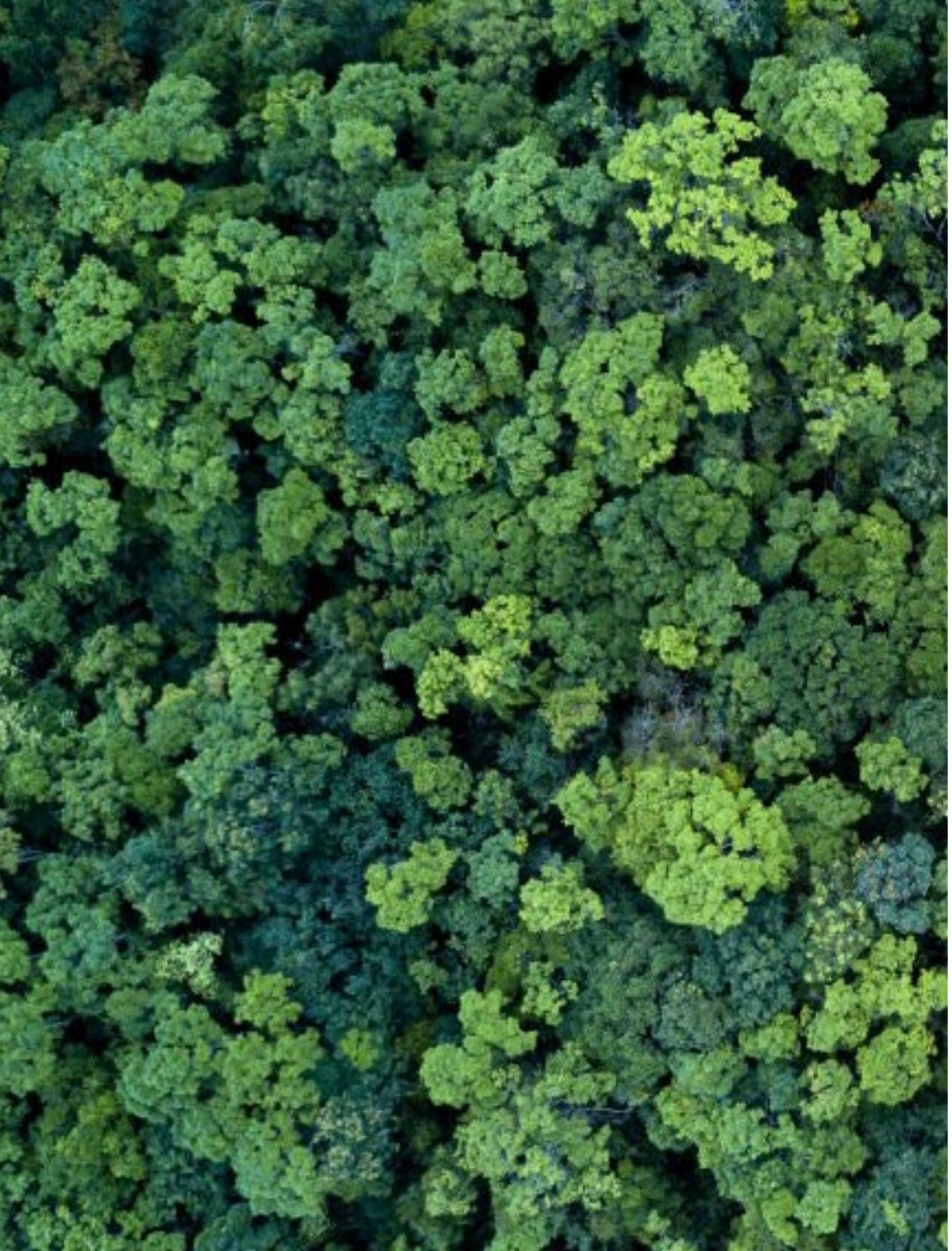
- Dynamic LULC change implemented with “scenario decision tables”
  - LAI,
  - ET and
  - Q response as expected
- Updated parameters:
  - CN2
  - Plant initialization
  - Land use management
  - Soil erosion (not investigated here)
- Application:
  - Rapid or dynamic land use changes
  - Calibration (Avoid overparameterization)



Open questions…

- How to include snow processes in dynamic LULC change?
  - Unique decision tables for snow parameters?
  - Possibly others → time varying parameters
- What forest growth processes are simulated inaccurately?
  - Biomass production
- How does residue affect soil evaporation?
  - Woody residue





Thank you for your attention!

Questions?

Contact:
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Model Setup - Adjustments

During devegetation:

- Residue cover → Reduced soil evap.
  - rsd_init = 40,000 kg/ha [plants.ini]
  - plnt_decomp = 0.001 [plants.plt]
  - rsd_decay = 0.001 [parameters.bsn]

After devegetation:

- New growth forest
  - lai_init = 0.0 [plants.ini]
  - bm_init = 20,000 kg/ha [plants.ini]
  - yrs_init = 0.0 [plants.ini]

Results – Snow

- Changes of parameters calibrated during different time frames