Universität für Bodenkultur Wien
University of Natural Resources
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Der Wissenschaftsfonds.

Linking an ABM to SWAT to determine the impacts of future changes to surface water quality

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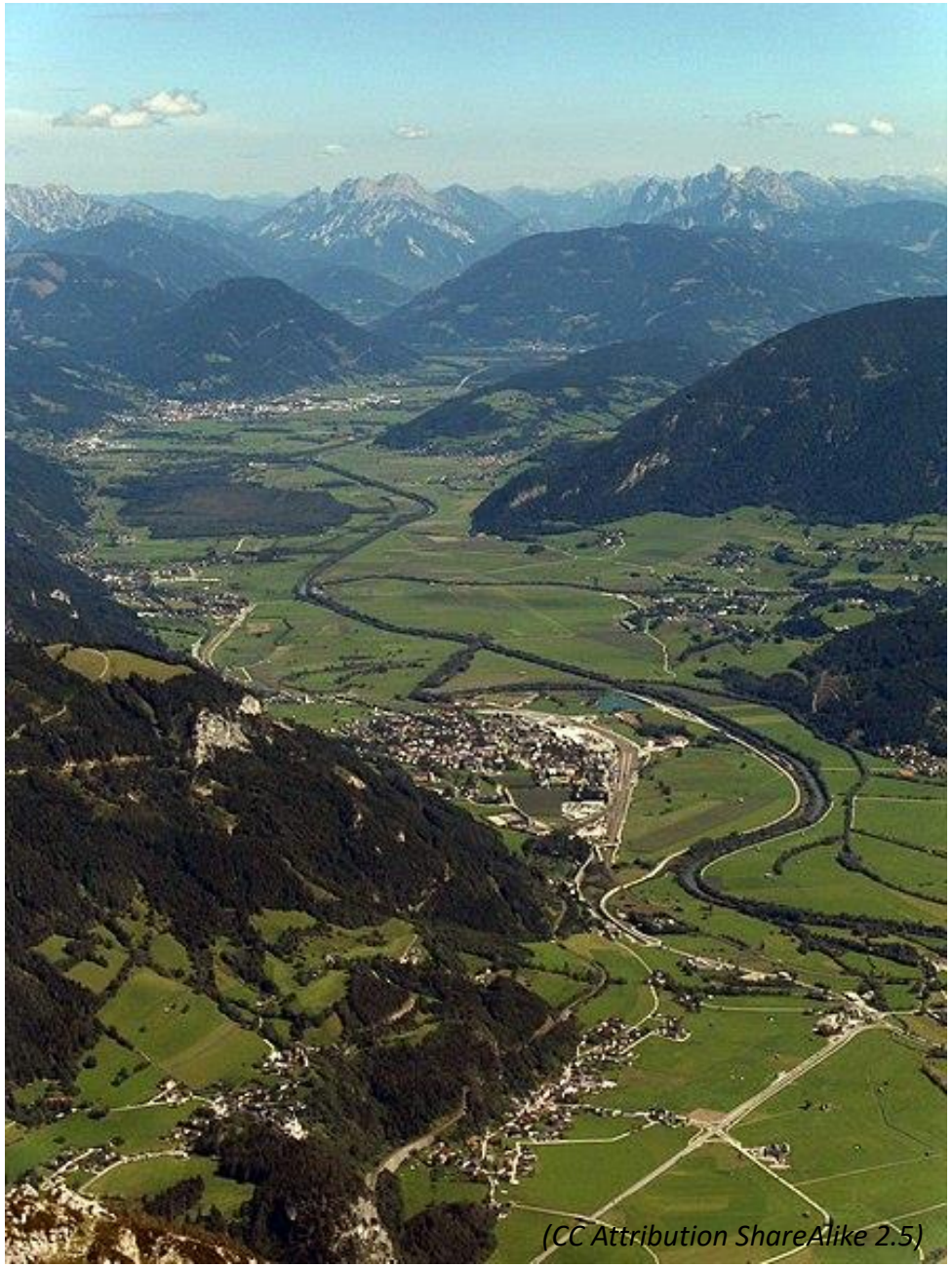


SWAT Soil & Water Assessment Tool

Session B4: Environmental Applications
June 28, 2023 Conference in Aarhus, Denmark

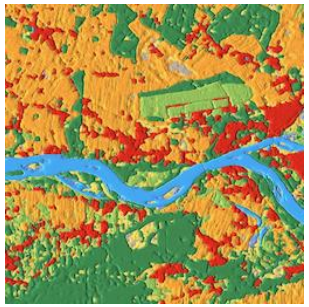
Introduction

- Field management practices are imperative to simulate the changes to soil water and nitrogen transport
  - Quantity of N losses
  - Timing of N losses
  - Spatial analysis of N losses
- Farmers are the key decision makers
- Simulating agricultural land management requires knowledge of decisions related to the crop types, fertillzation type and amount, seeding/harvesting dates, and annual changes in crop rotations

Objectives

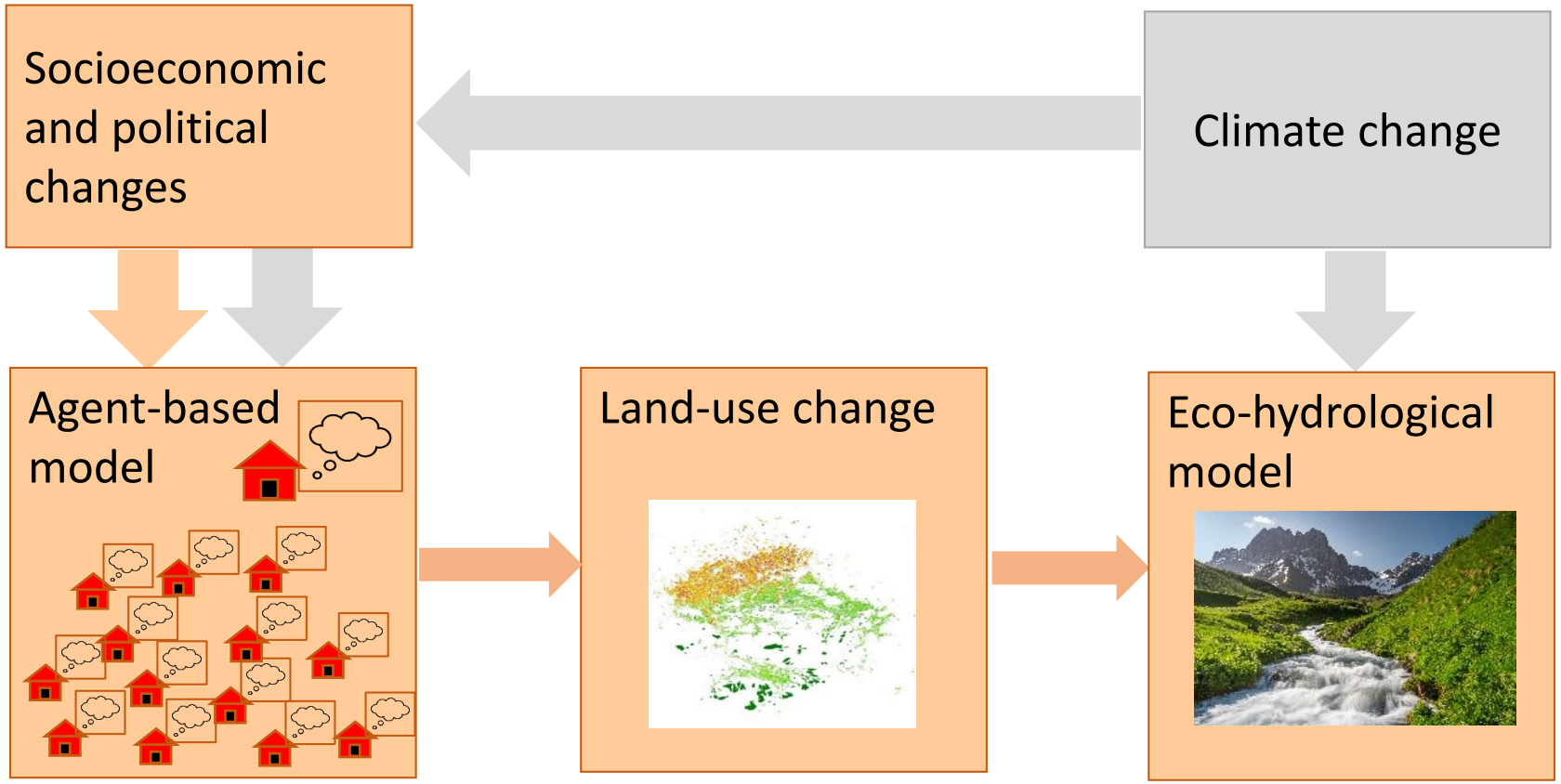
1. Develop methodology to implement farmers decision regarding the spatial distribution of annual crops including their management practices in a large watershed.
   - Input into a hydrological model
2. Quantify the simulated variables related to the water balance, plant growth and nitrogen losses
   - Future agricultural land use & future climate simulations

Outcome: Determine future land use and management practices that achieve sustainable farming practices (lowest N losses) under changing conditions.



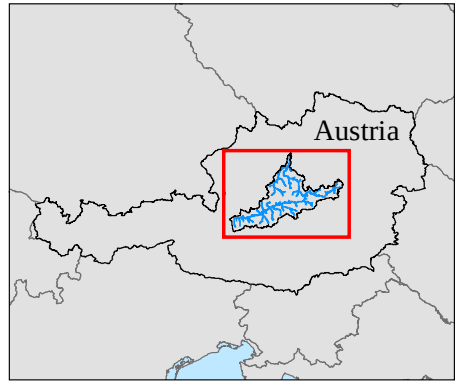
Framework

- A modelling framework that bridges the social and natural sciences
  - An ABM called SECLAND was non-dynamically coupled to the eco-hydrological model SWAT
  - Determine sustainable cropping practices that concurrently maintain or increase yields and reduce N in the environment



Study region
Enns catchment

Area: 6106 km^2
Elevation: 1750 to 254 m.a.s.l.
Avg. precipitation: 1412 mm
Avg. temperture: -5 to +18^{o}C



Land cover classes

CORN CLVR GRAP SGBT WATR
FESI FESC WWHT SOYB WETL
CANP FRST ORCD URML

Coordinate System: MGI Austria Lambert
Projection: Lambert Conformal Conic
Datum: MGI

0 7 14 21 km
1 cm = 7 km

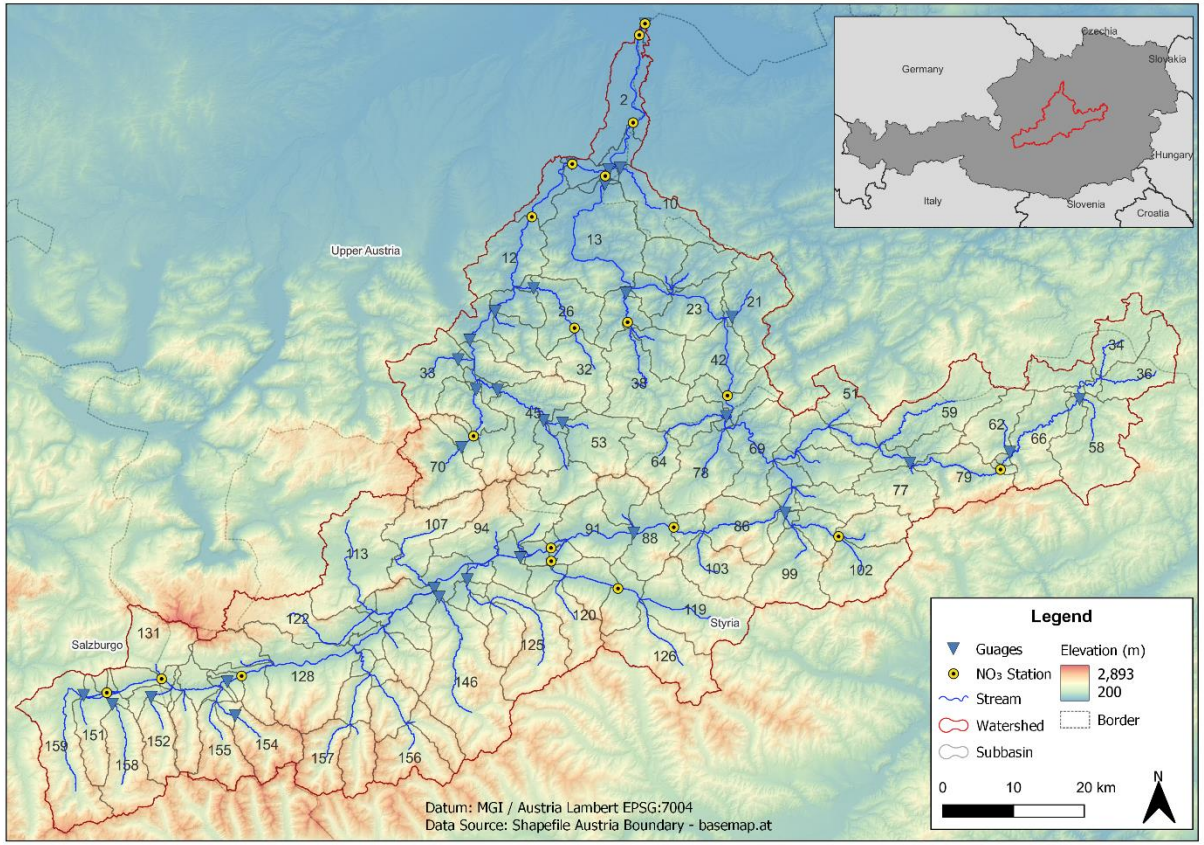
Legend code: CORN: corn; FESI: pasture intensive; CANP: winter oilseed; CLVR: fieldforage
FESC: pasture extensivet; FRST: forest; GRAP: vineyard; WWHT: cereals; ORCD: orchards;
SGBT: root crops; SOYB: soybean; URML: urban areas; WATR: water; WETL: wetlands

Methodology: hydrological model **SWAT**

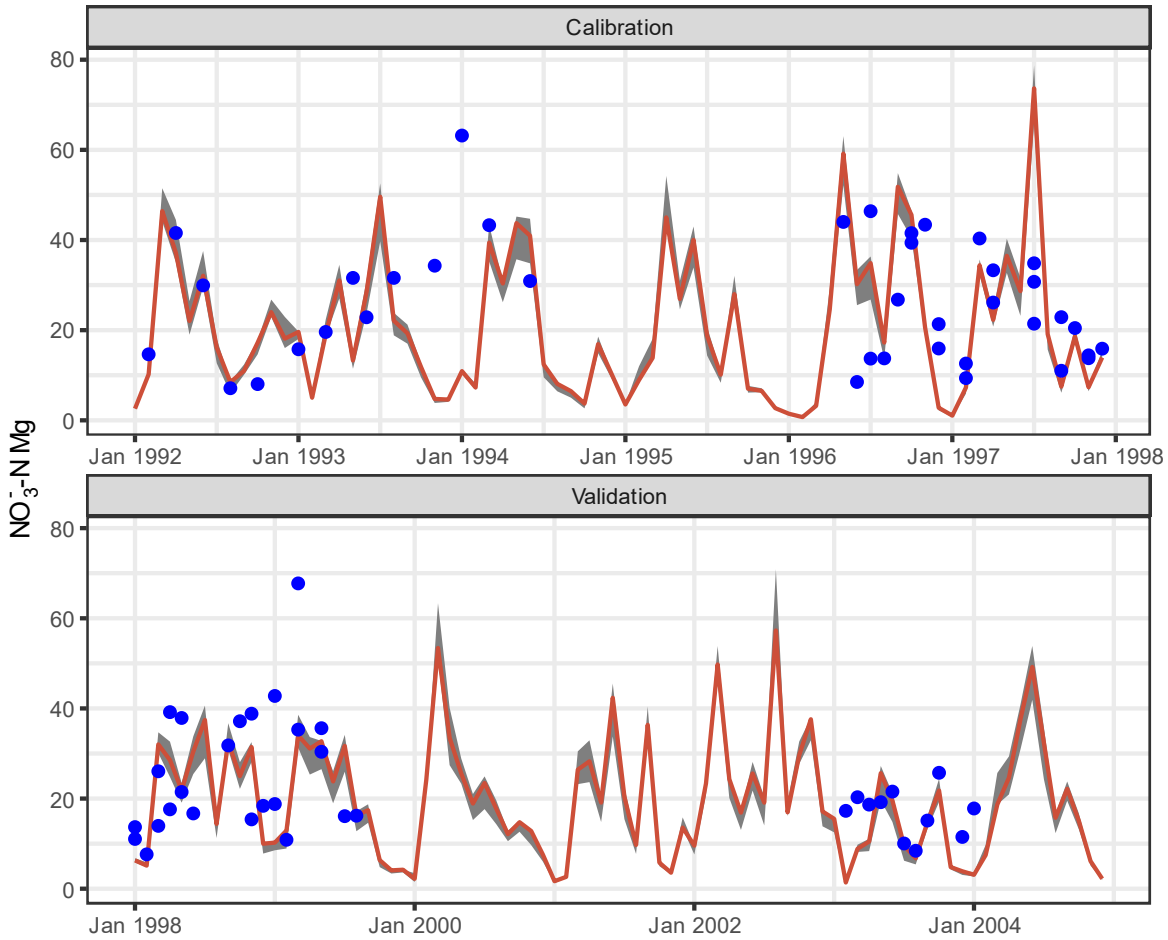
- ArcSWAT 2012 version 2012.10_2.19, rev. 627
- Catchment divided into sub-basins and into HRUs
- Smallest unit is based on HRU
- Spatial representation of land use
- Simulation time step: daily
- Simulation period: 30 years

Calibrated variables at multiple gauges simultaneously:

- ❑ **Water balance components**
- ❑ **Nitrogen concentrations in stream**
- ❑ **Crop yields**



SWAT model performance for discharge and nitrate



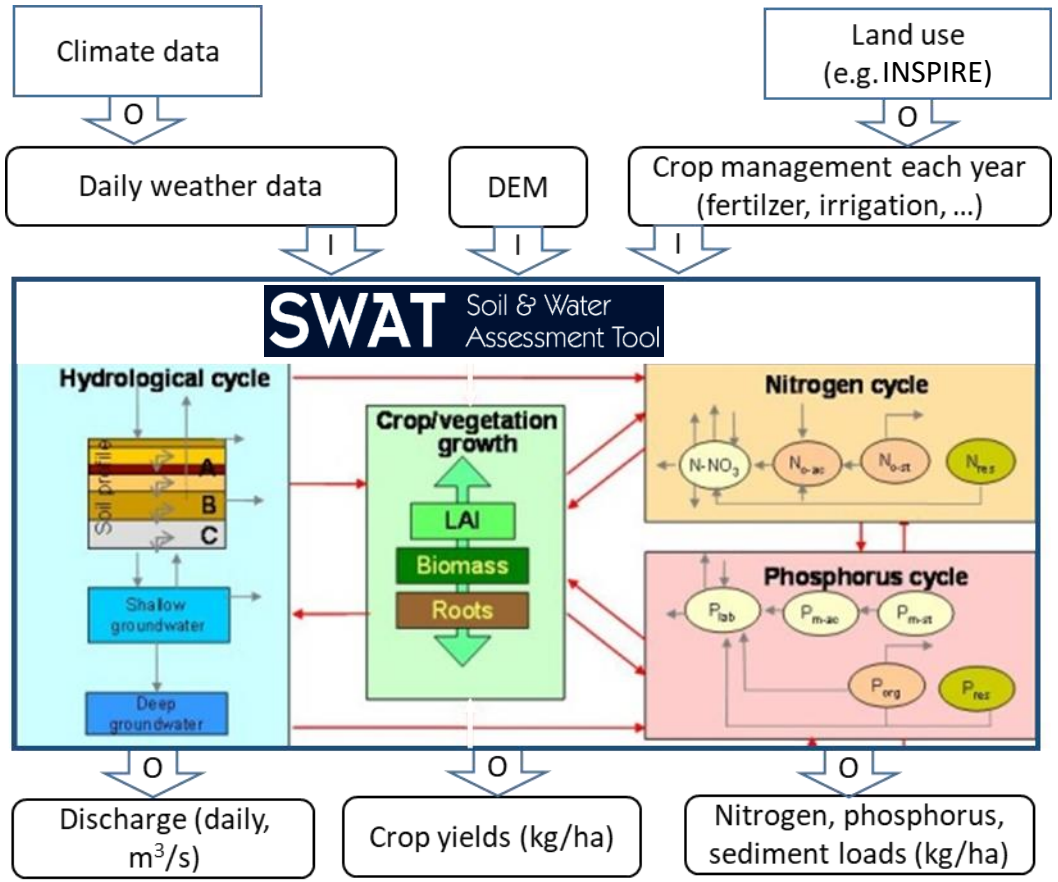
sub. 6	daily	period	years	KGE	p-bias
Q	Calibration	1981-2005	25	0.69	-21
Q	Validation	2006-2018	13	0.67	-21

sub. 1	daily	period	years	KGE	p-bias
NO_3^--N	Calibration	1991-1998	8	0.45	-16
NO_3^--N	Validation	1998-2004	7	0.55	-22

Crop yields simulated with SWAT

	Avg. yield (Mg/ha)	SGBT	CORN	WWHT	CLVR	CANP
Reference	**LU0**	13	8	5	7	3
	measured	50-60	8-11	4-6	7-8	3

Input and management data per HRU

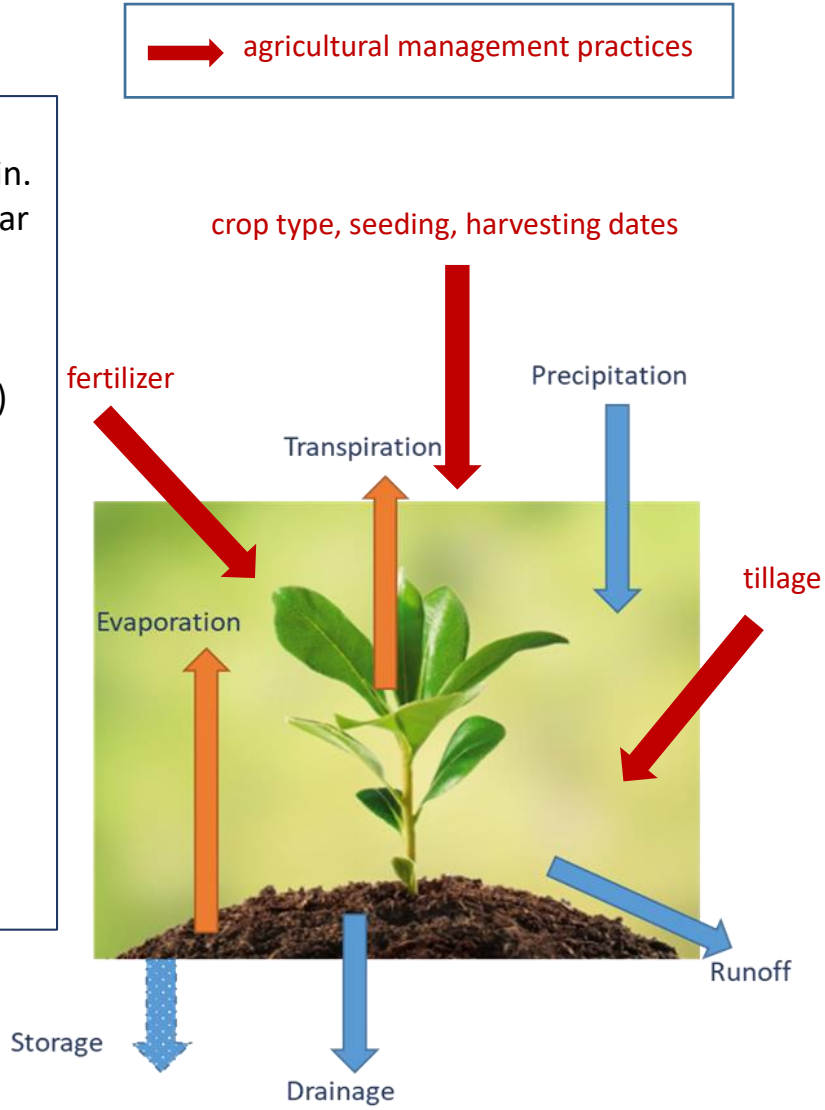


INPUT DATA:

- Daily climate (precipitation, min. & max. temperature, wind, solar radiation)
- Digital elevation map
- Soil map
- Land use map (incl. crop types)
- Agricultural management practices (seeding date, ploughing type and dates, fertilizer application date and amount, harvest date).

CALIBRATION DATA:

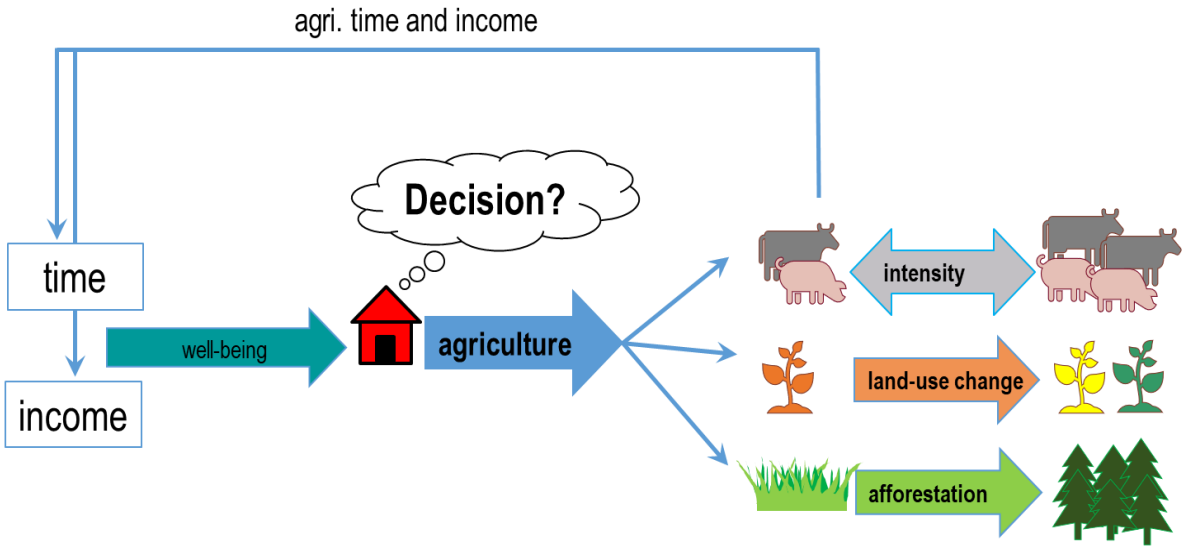
- Daily discharge rates
- In-stream nutrient concentrations
- Yields of crops



Methodology: Future land use scenarios
SECLAND

SECLAND is used to evaluate the impacts of changing socio-economic (prices, subsidies) and climate (extreme events) conditions on farmers' decision-making

- The farm agents (3059) seek well-being: a satisfying balance between income and workload.
- Their farming type and farming style influences their management decisions to improve or maintain their satisfaction.
- Management decisions affect land-use intensity, cultivated crop types, land abandonment, afforestation



Egger et al. (2022) Using the SECLAND model to project future land-use until 2050 under climate and socioeconomic change in the LTSER region Eisenwurzen (Austria). Ecological Economics, 201, 107559

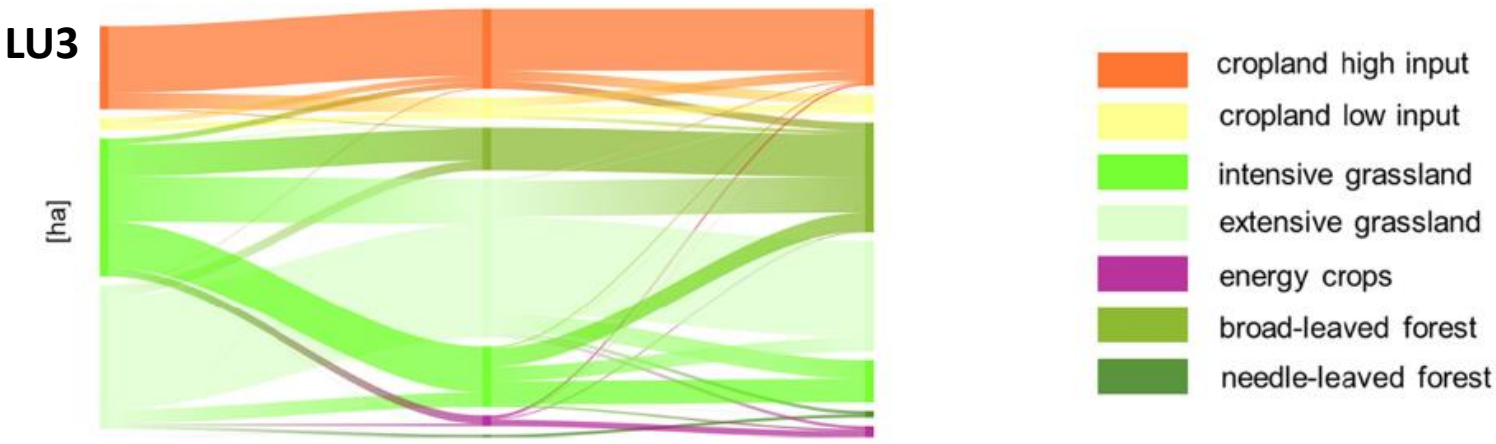
Methodology: Future land use scenarios
SECLAND

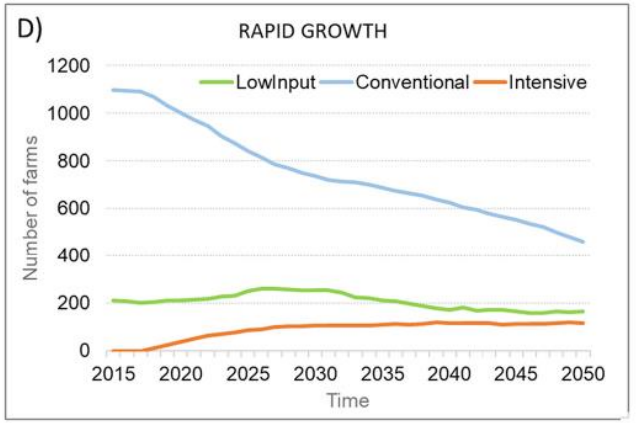
Scenarios of land use change:

Business-as-usual (LU1): the continuation of current development trajectories with constant subsidies and moderate impacts of climate change.

Sustainabilty (LU2): a considerable increase in farm subsidies are used as a steering mechanism to achieve sustainability goals. This describes high societal market intervention to achieve climate goals and thus, low climate change impacts.

Rapid Growth (LU3): the development of a society that forgoes controlling intervention and abolishes all subsidies by 2050 to focus on free market competition, which is associated with a stronger climate change impacts





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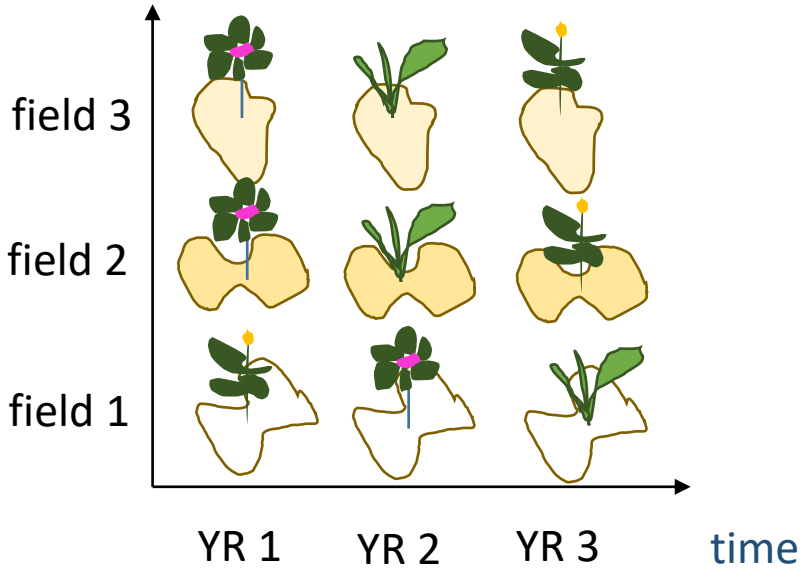
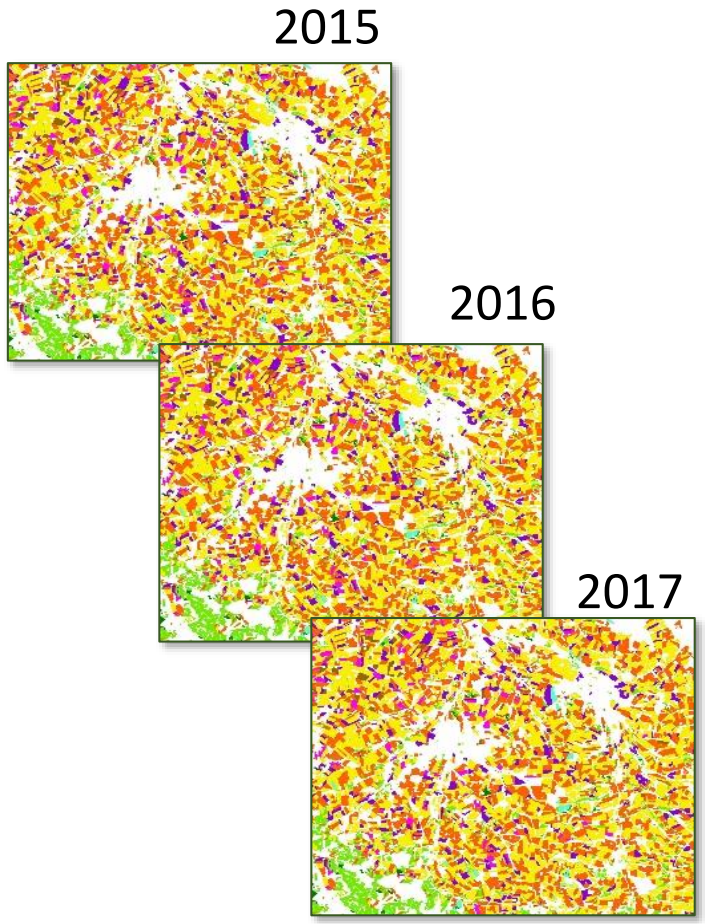
Methodology: Future land use scenarios
Land use maps

- SECLAND output is annual spatially distributed field level data
  - Depicts spatial distribution of crops
  - Based on farmer decisions in the region

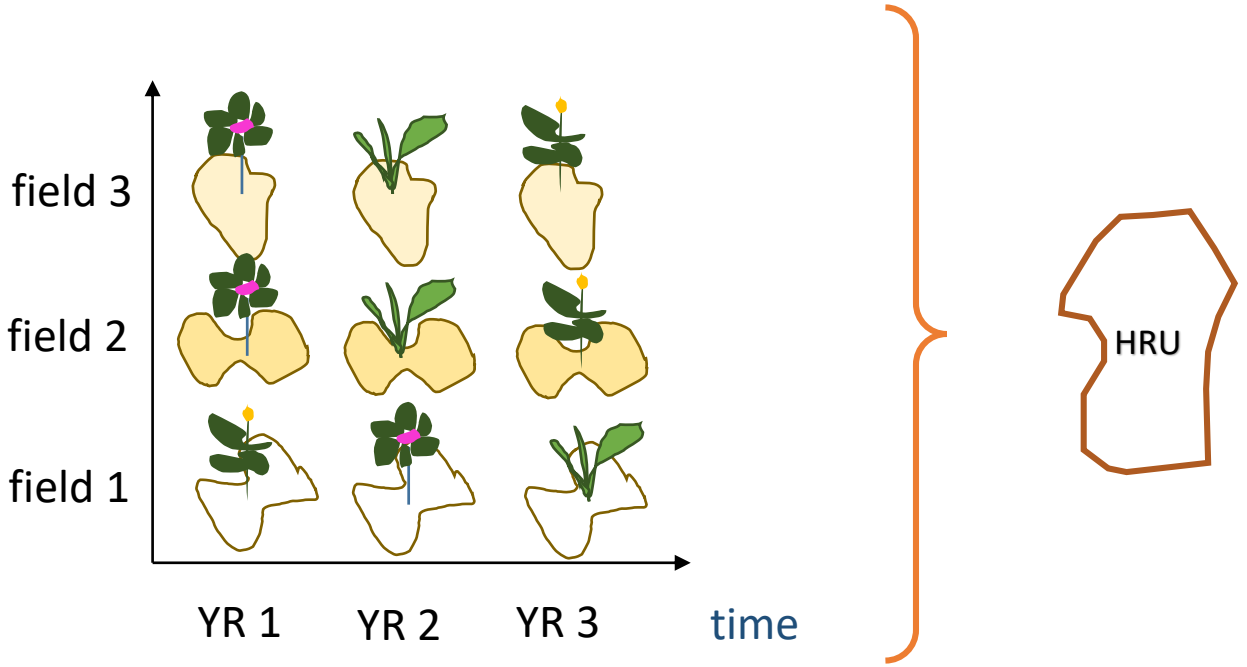




Methodology: Future land use scenarios
Land use maps

- SWAT land use change takes place at the HRU level

➢ The interface between SECLAND and SWAT is the annually, spatially-explicit land-use map



For details on joining the ABM with SWAT:
Poster #19 Lima et al.

Future crop management in LU1 – LU3

- In the future land use scenarios, *ÖPUL* (Austrian agro-environmental program) 2023 regulations were respected
- Summer crops that are normally seeded in April were planted 7-10 days earlier
- SWATfarmR (Schürz 2022) used for management practices

Crop type	SWAT code	Plant Date		Harvest Date		Mineral N	Organic N	Total N
		from	to	from	to			kg/ha
Grain & silage corn	CORN	14 Apr	3-May	8- Sep	5-Oct	160		**160**
Legumes	SOYB	10-Apr	10-May	20-Jul	15-Aug	60		**60**
Winter grains	WWHT	01-Oct	29-Oct	20-Jul	10-Aug	145	5	**150**
Tuber crops	SGBT	20-Mar	05-Apr	05-Oct	25-Oct	130		**130**
Winter rapeseed	CANP	27 July	10-Sep	20-Jul	10-Aug	150	10	**160**
Vineyards	GRAP			10-Sep	30-Sep	13	5	**17**
Orchards	ORCH			20-Aug	15-Sep	69	4	**73**
Pasture (BROM)	FESI					17	133	**151**
	FESC					90	90	**180**

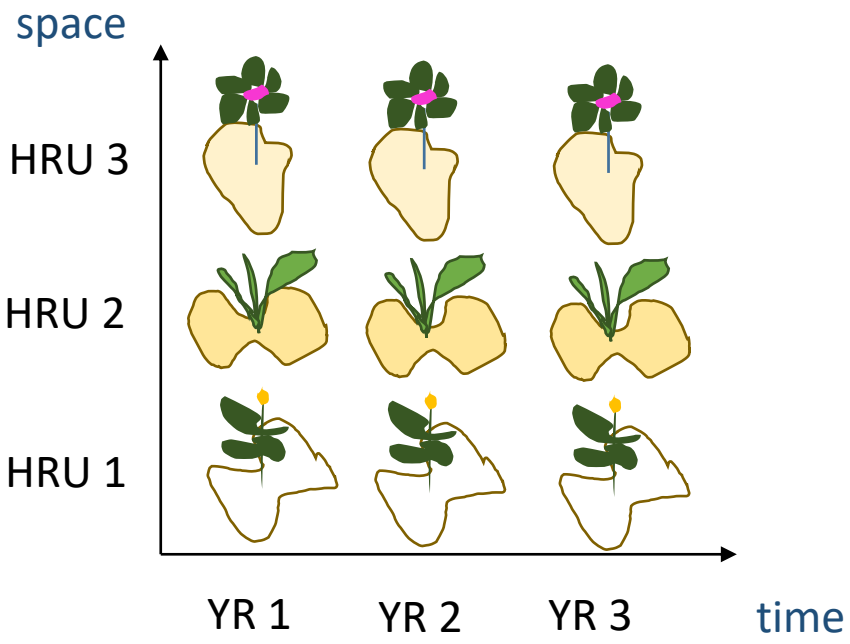
Schürz (2022) *SWATfarmR: Simple rule based scheduling of management operations in SWAT*. R package version 1.8.0, https://github.com/chrisschuerz/SWATfarmR

Results comparing

LU0

SWAT

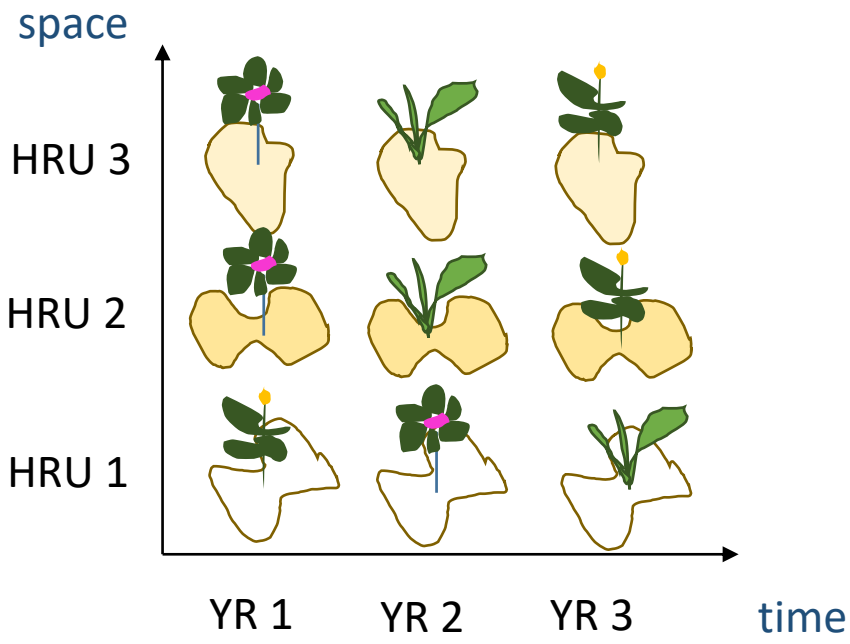
Period: 1981-2017



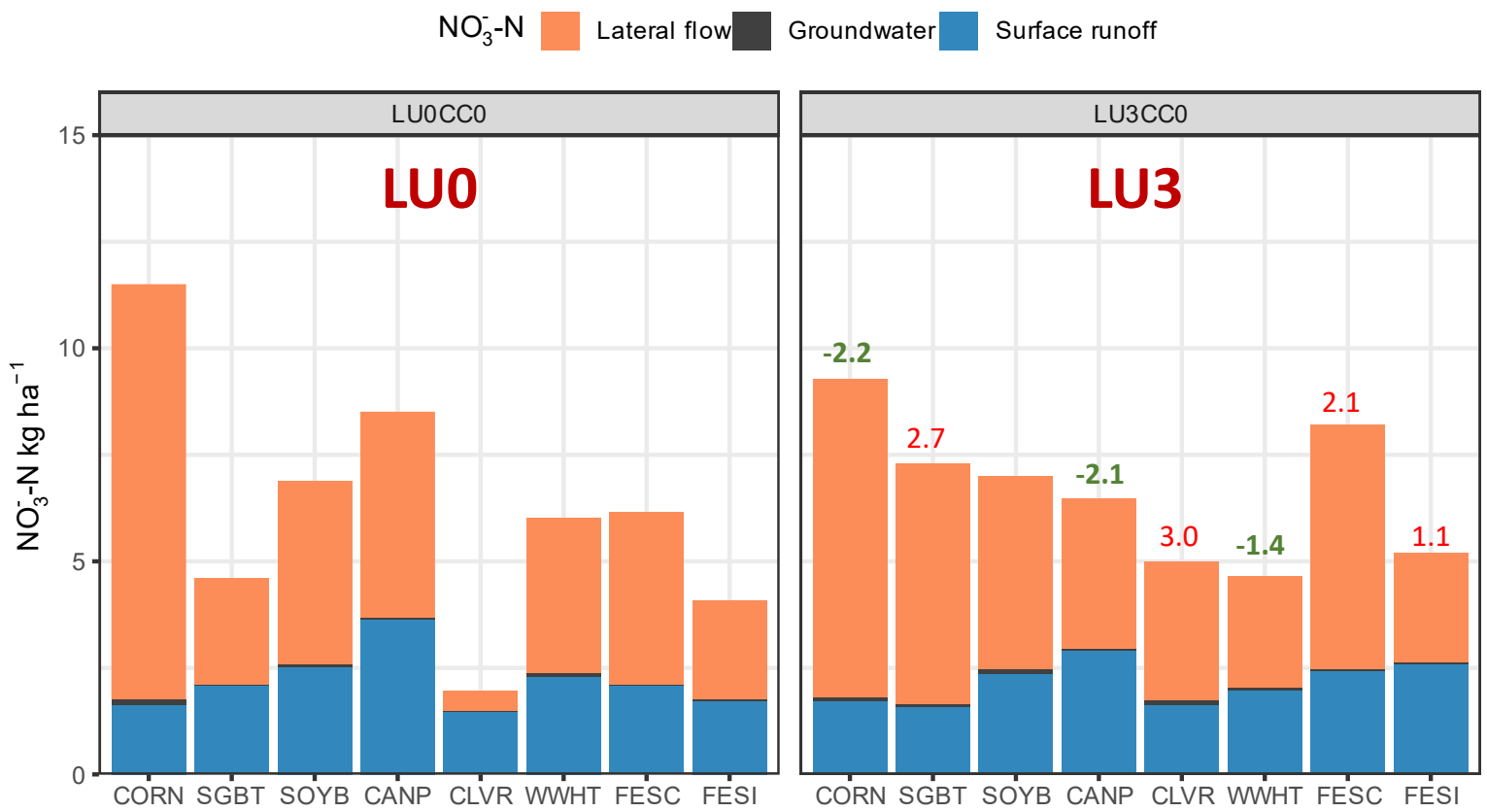
LU3

SWAT + SECLAND

Period 2015-2050



Results
NO_3^--N loads per HRU for each crop



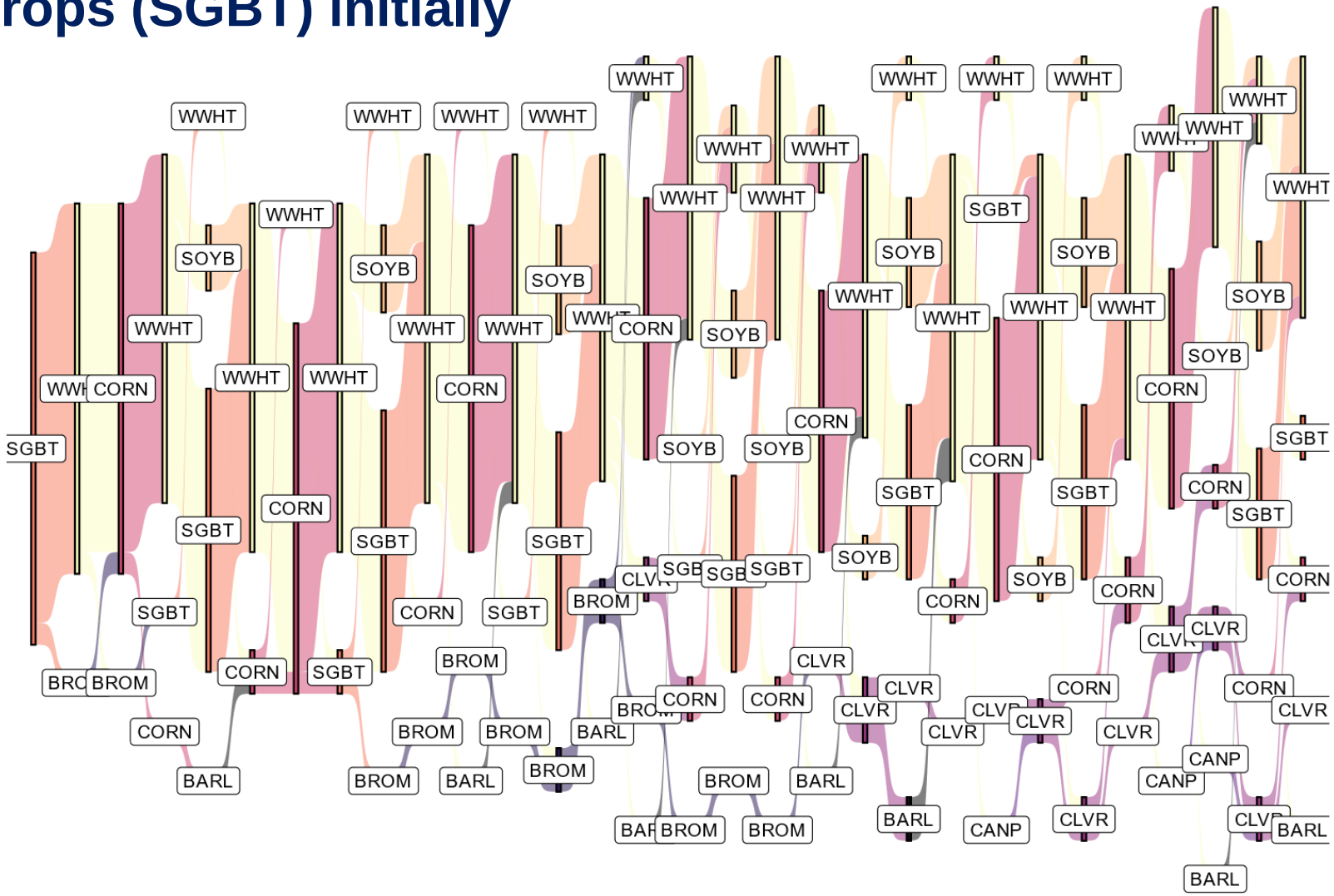
In LU3, CLVR and SGBT > +2.5 kg /ha

In LU3, CORN and CANP > -2 kg /ha

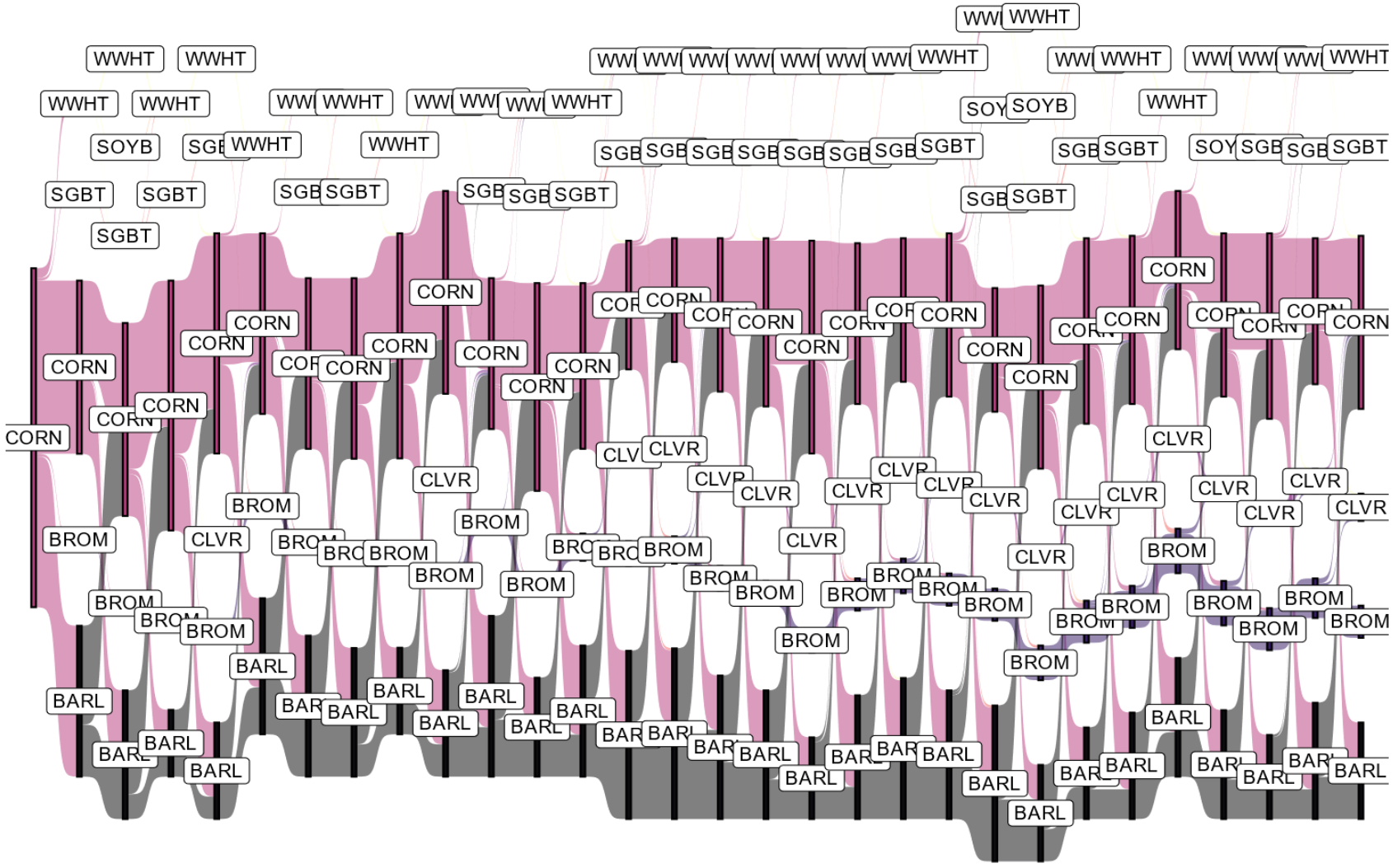
Amount and type of fertilzer applied are critical

	Total N kg/ha
CORN	**160**
SGBT	**130**
SOYB	**60**
CANP	**160**
WWHT	**150**
FESI	**151**
FESC	**180**
CLVR	**0**

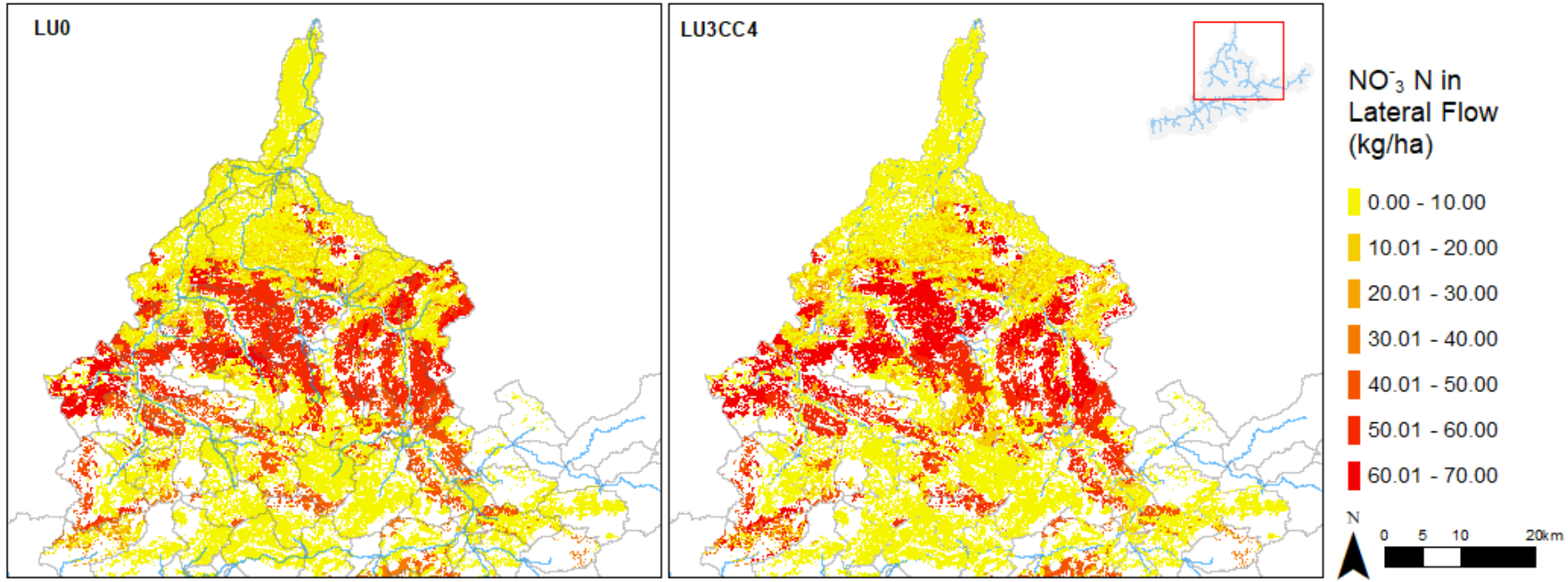
LU3 annual crops in all HRUs with tuber crops (SGBT) initially

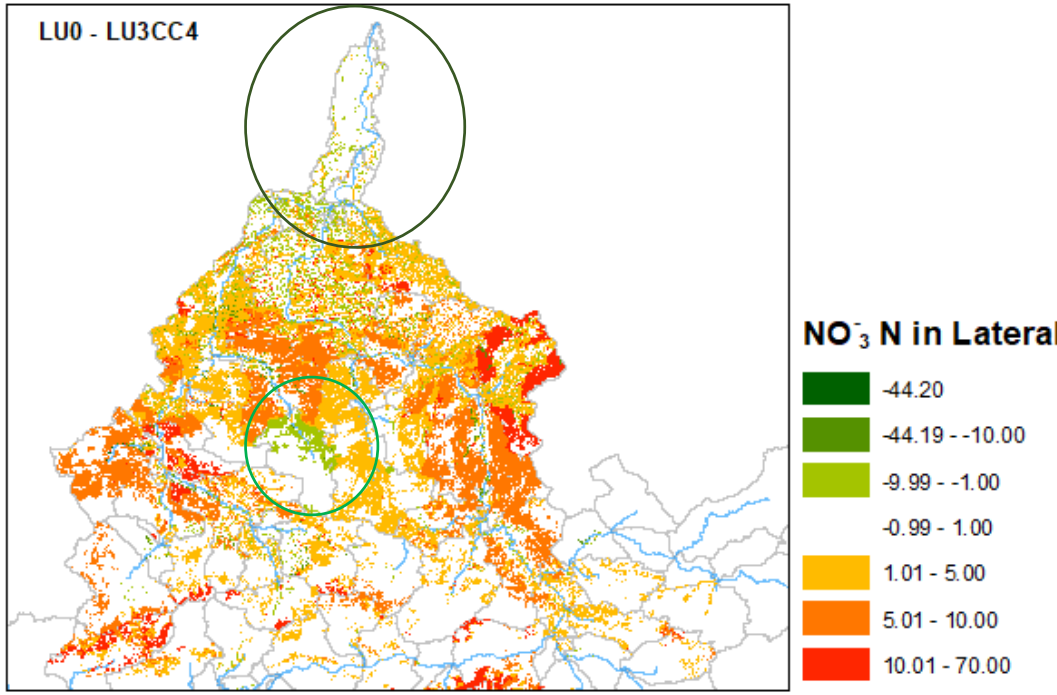


LU3 annual crops in all HRUs with maize (CORN) initially



Total NO_3^--N losses from lateral flow: land use and climate change





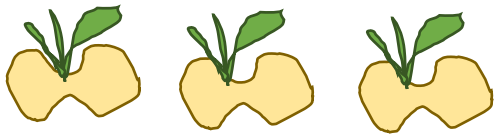
Highest loads where pasture (BROM, CLVR, FESC) were rotated instead of monoculture

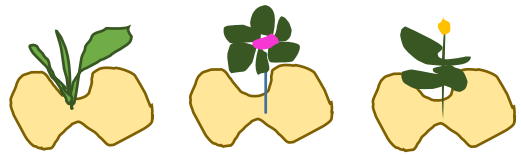
Large reductions found where maize (>20 kg ha^{-1}), and intensive pasture (>10 kg ha^{-1}) (FESI) were rotated instead of in a monocrop

Conclusions

- The ABM generated land use scenarios that were successfully integrated into the HRUs and implemented in SWAT.
- Able to identify HRUs that are sensitive to the rotation and implementation of future management practices
- The spatial hotspots of future simulated nitrogen pathways were identified in SWAT.
- Including rotations in SWAT results will reduce N losses to environment, if the crop replacing the main crop has less N fertilizer application, and if pasture is not in a rotation (replacing organic N with mineral N).

Dynamically coupling the ABM to SWAT would optimize the streamlining of the climate change scenarios into the land use scenarios.





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