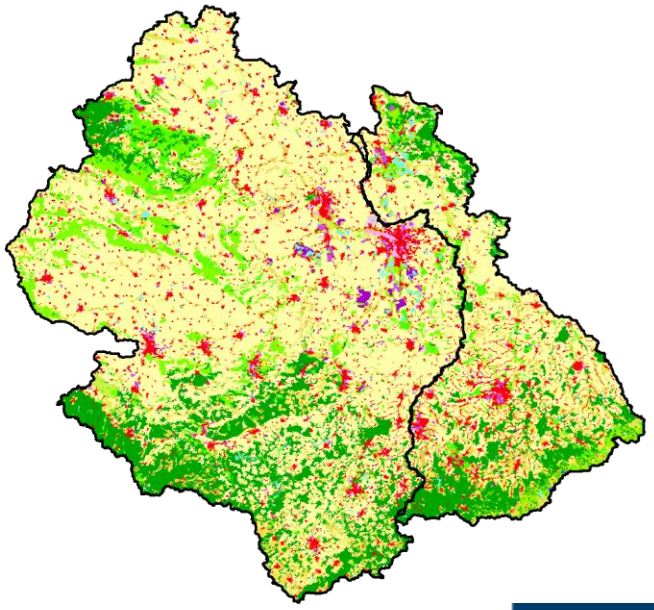
Which parameter complexity is required for a sound simulation of agricultural river basins?

Investigating SWAT model sensitivity to agricultural land cover and crop rotation parameterizations



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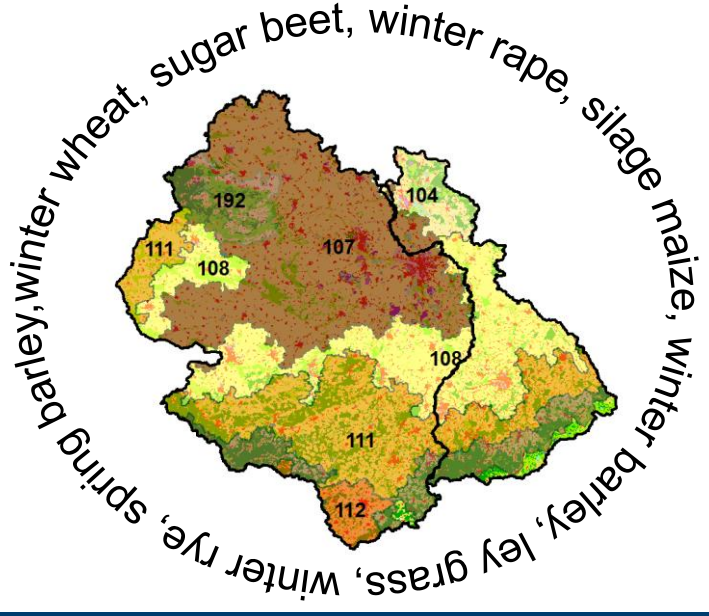

Felix Witing, Martin Volk

2013 International SWAT Conference
Paul Sabatier University, Toulouse, 17. - 19.07.2013

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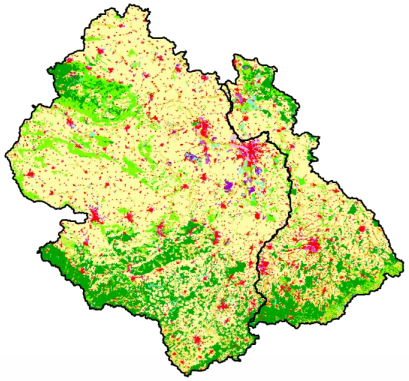
Motivation

Agricultural land:

- Very high Input (N, P, management practices)
- Highly complex & dynamic system (cultivated crops, crop rotations, management practices..)

SWAT model



Input

- Generally lack of data
- Need for generalization

Output

- Various & complex effects on different levels

- Most important output-source for non-point source pollution (e.g. N, P, sediments)

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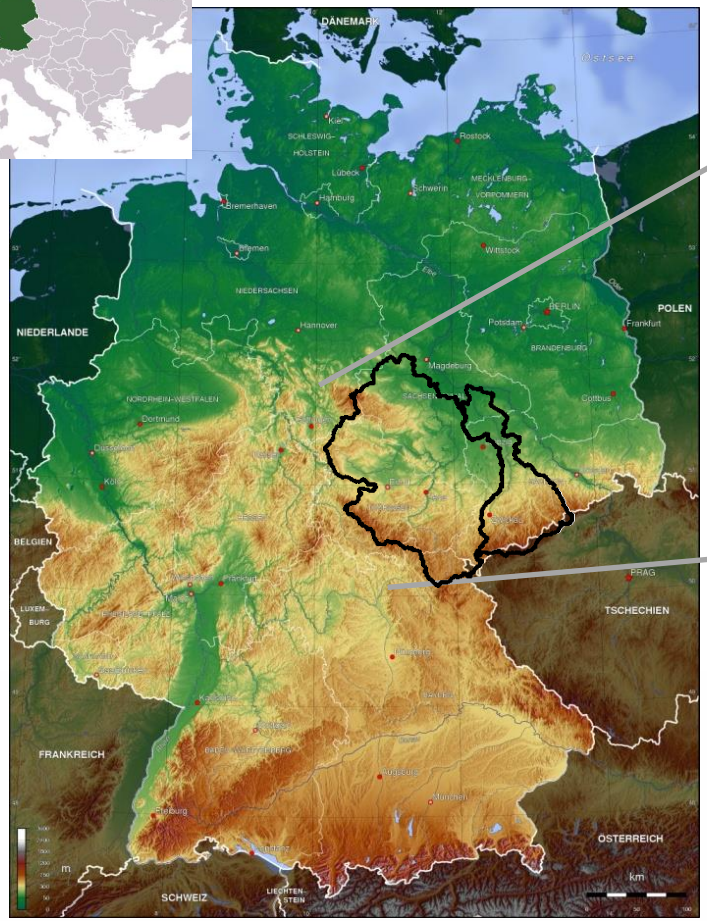
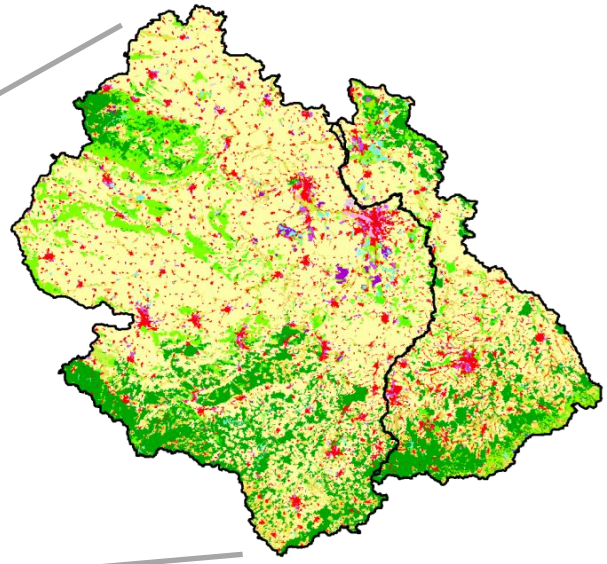
Objective

- Develop a strategy for the spatial & temporal parameterization of agricultural land cover in SWAT

Study Area

Saale & Mulde catchment area :



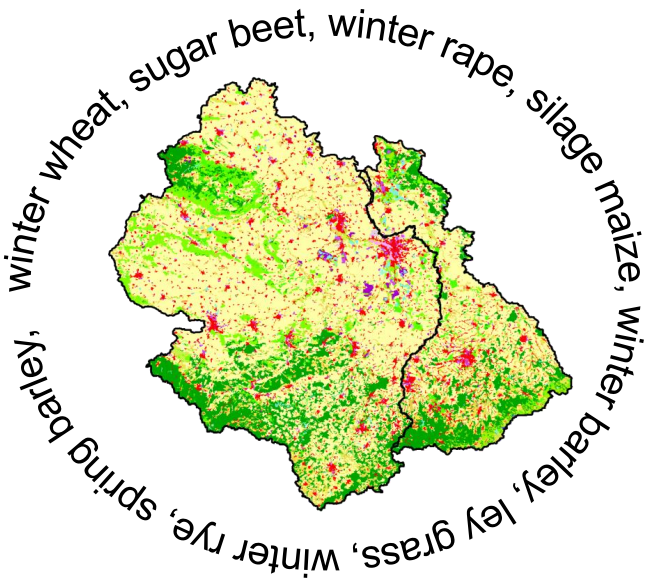


Very heterogeneous landscape:

- **Area:** ~ 31.000 km²
- **Precipitation:** <350 to >1300 mm/a
- **Elevation:** 55 to >1200m
- **Soils:** Loess (partly black) soils, sandy soils, residual soils
- **Agricultural land:** >60%

Important steps for cropland parameterization

1. Develop a **regional differentiation** of management systems (esp. in large catchments)
2. Develop a **'typical' management for every crop**:
   - Management operations
   - Management details (fertilizers, tillage systems..)
   - Management timing
3. **Spatial distribution of crops** according to the crop-cultivation statistic / areal share of each crop (e.g. using HRU-Split)
4. **Implementation of crop rotations**:
   - Develop a strategy for generalization of crop rotations applied in the catchment



	[%]	Average N-Demand [kg/ha]
Winter wheat	36	190
Winter rape	20	200
Winter barley	12	140
Silage maize	10	190
Spring barley	8	110
Ley grass	5	250
Winter rye	5	120
Sugar beet	4	170

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Crop rotation sensitivity of SWAT

Why is it important to include (realistic!) crop rotations into your model?

Modeling effects of crop-rotations (HRU-level)

- Example analysis:
  - Winter Wheat cultivation, differing preceding crop:

Year of simulation	1	Winter wheat	Winter Rape	Sugar beet
	2	**Winter wheat**	**Winter wheat**	**Winter wheat**

- Identical HRU:
  identical soil, slope, climate, same year of model run, etc.
- Identical management of the individual crops
- Different crop-rotations

- Analyzing output.hru + output.sol

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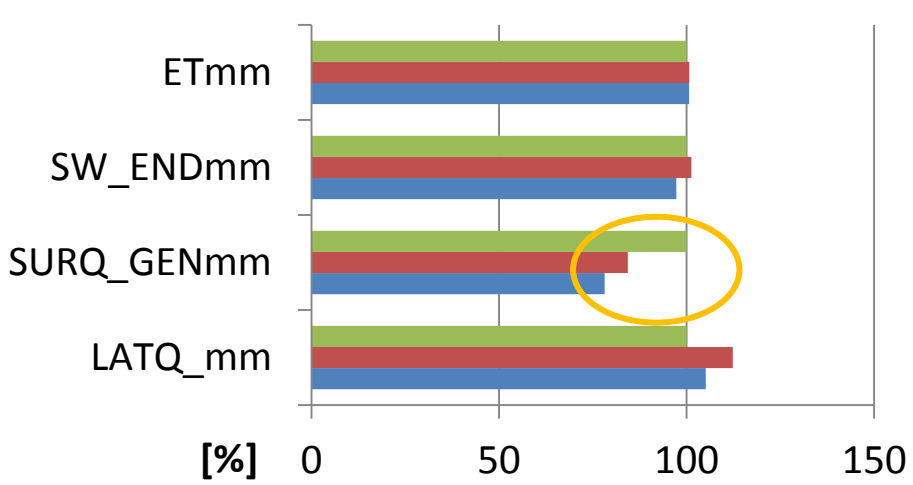
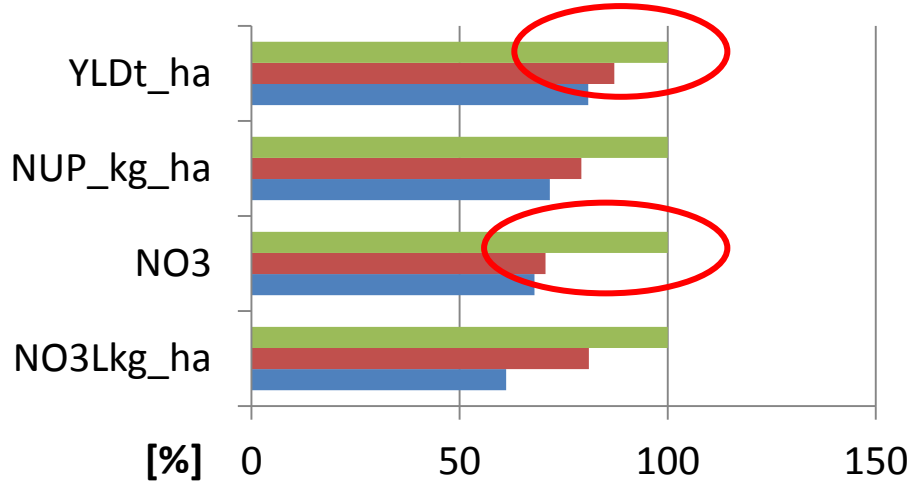
Modeling effects of crop-rotations (HRU-level)

Winter wheat (Ww) growing season:
Impact of the preceding crop on the output of 1 HRU:

Hydrology



Crop yield, Nitrogen



Ww Preceding crop: Winter Rape | Winter wheat | Sugar beet

→ More N in the soil after winter rape
→ Better yield of winter wheat after winter rape
→ But also more nitrate leaching

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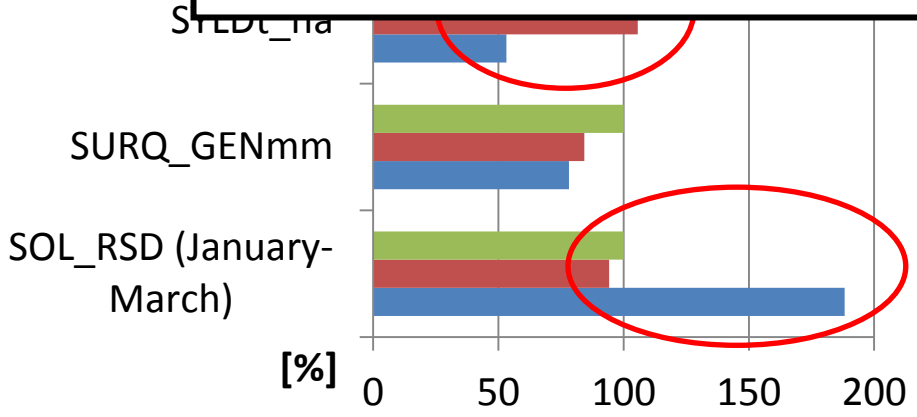
Modeling effects of crop-rotations (HRU-level)

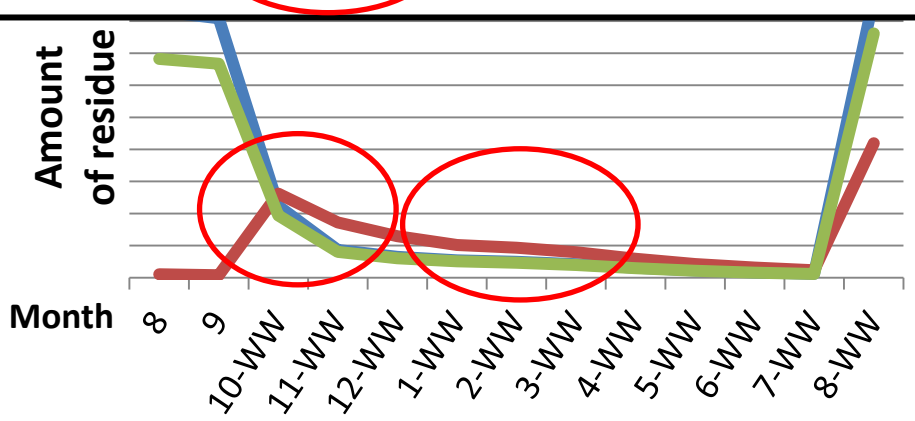
Winter wheat (Ww) growing season:

Impact of the preceding crop on the output of 1 HRU:

Sediments, Residue

$$C_{USLE} = \exp\left(\left[\ln(0.8) - \ln(C_{USLE,mn})\right] \cdot \exp\left[-0.00115 \cdot rsd_{surf}\right] + \ln[C_{USLE,mn}]\right) \quad 4{:}1.1.10$$





Ww Preceding crop: Winter Rape | Winter wheat | Sugar beet

Harvest Date: 10.08. | 10.08. | 05.10.

→ Sediment yield is strongly influenced by amount of residue

→ Late harvest of sugar beet limits residue decay

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Using realistic crop rotations can be essential for capturing the right model dynamics.

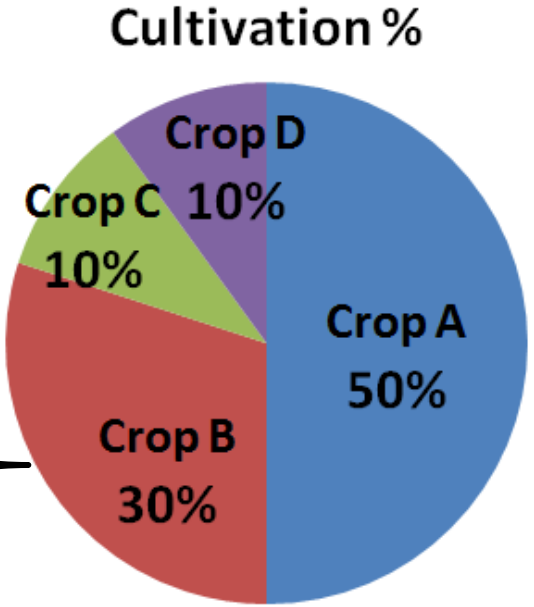
What do we have to consider when choosing crop rotations for the implementation into our SWAT-model?

Selection & Combination of crop rotations

Imaginary setup:

- 3 different crops, known cultivation statistic
- using actually practiced crop-rotations for HRU-Split

	[%] / Year of simulation	1		2		3
HRU 1	33%	Crop A	→	Crop B	→	Crop C
HRU 2	33%	Crop B	→	Crop C	→	Crop A
HRU 3	33%	Crop C	→	Crop A	→	Crop B
...						
HRU 4	(50%)	Crop A	→	Crop D		
HRU 5	(50%)	Crop D	→	Crop A		



Depending on the number of rotations taken into account:

- increasing amount of HRUs
- decreasing failure in the areal share of the crops

Selection & combination of crop-rotations

How do we choose suitable crop rotations?
Objective: realistic, but as less complex as possible

Expert knowledge, environmental state offices, Stakeholder..

Pool of crop rotations
(regionally differentiated & actually practiced)

Choose necessary complexity (e.g. 1 – 4 crop rotations) according to the simulation demands

Combing all crop rotations with each other and **calculate average error** to actual cultivation statistic

Choose crop-rotation-combination, with the least average error

In our approach :

Pool size:
> 100 differentiated by farm type

Short crop rotations get a better weighting

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Selection & combination of crop-rotations

Example for 1 management area:

Statistic:

	[%]	Error [%]
Winter wheat	36.2	2.2
Winter rape	20.4	1.2
Winter barley	12.5	0.0
Silage maize	9.6	1.3
Spring barley	7.6	2.6
Ley grass	4.9	0.8
Winter rye	4.9	0.1
Sugar beet	3.9	1.1

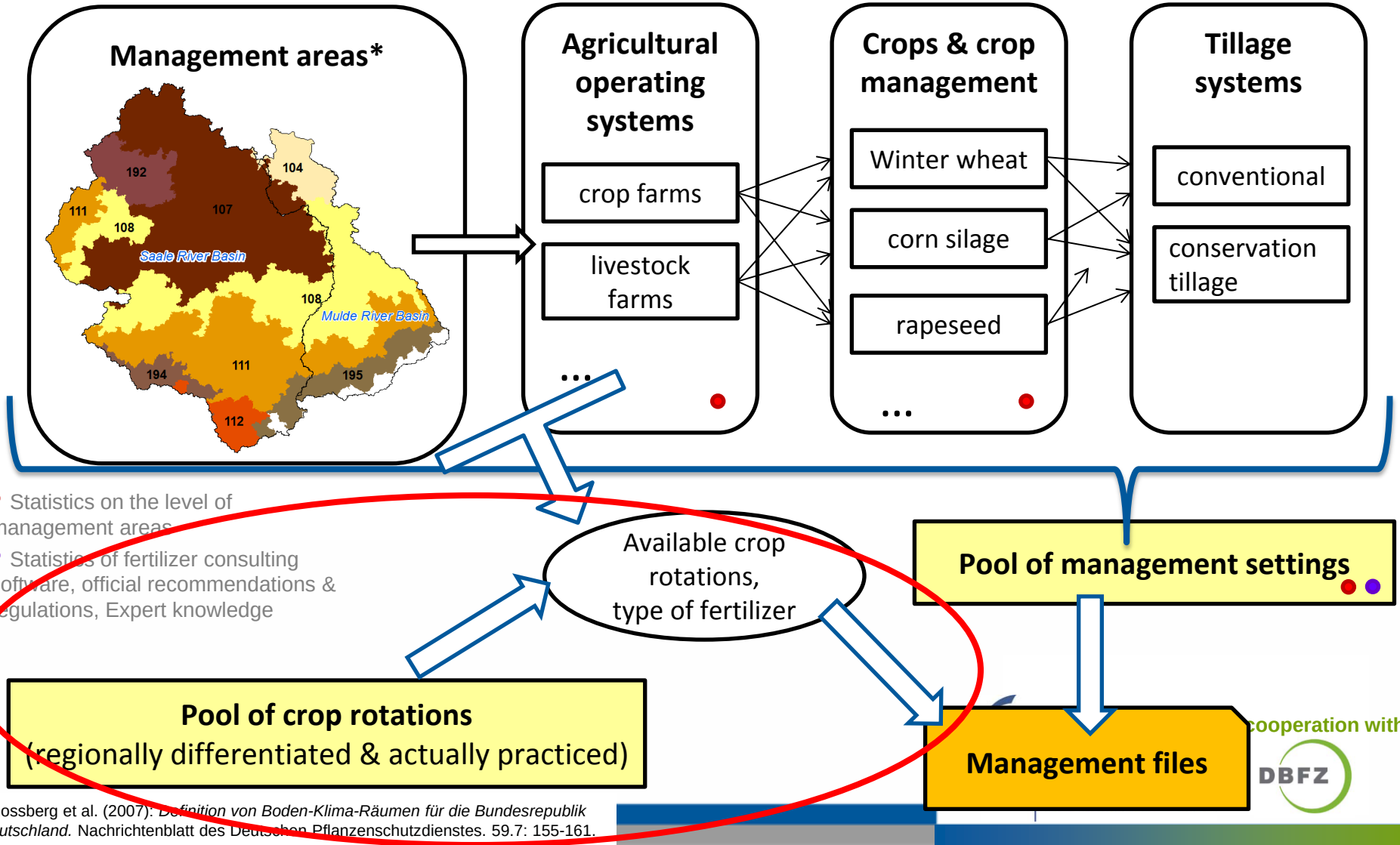
Selected crop rotations:

[1,] Winter rape [2,] Winter wheat [3,] Winter wheat	[1,] Silage maize [2,] Winter wheat [3,] Winter barley
[1,] Sugar beet [2,] Winter wheat [3,] Spring barley [4,] Winter rape [5,] Winter rye	[1,] Winter wheat [2,] Ley grass [3,] Winter rape [4,] Winter wheat [5,] Winter barley [6,] Winter rape

→ Afterwards: bringing crop rotations & management for every crop together for *.mgt parameterization of HRUs

Short Digression

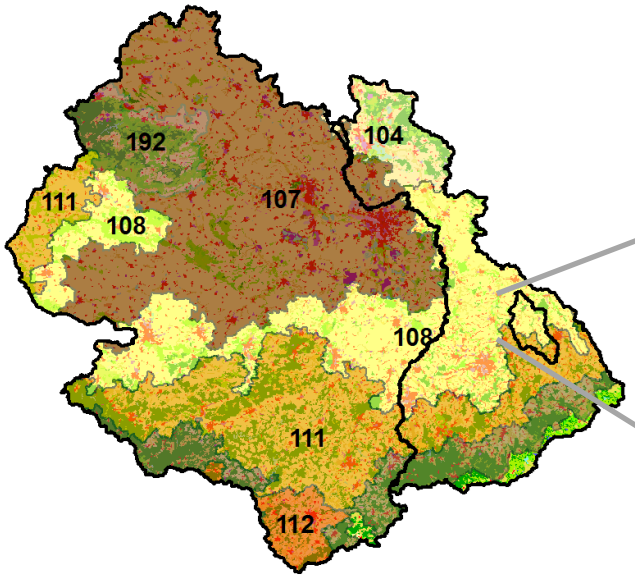
General strategy on cropland parameterization

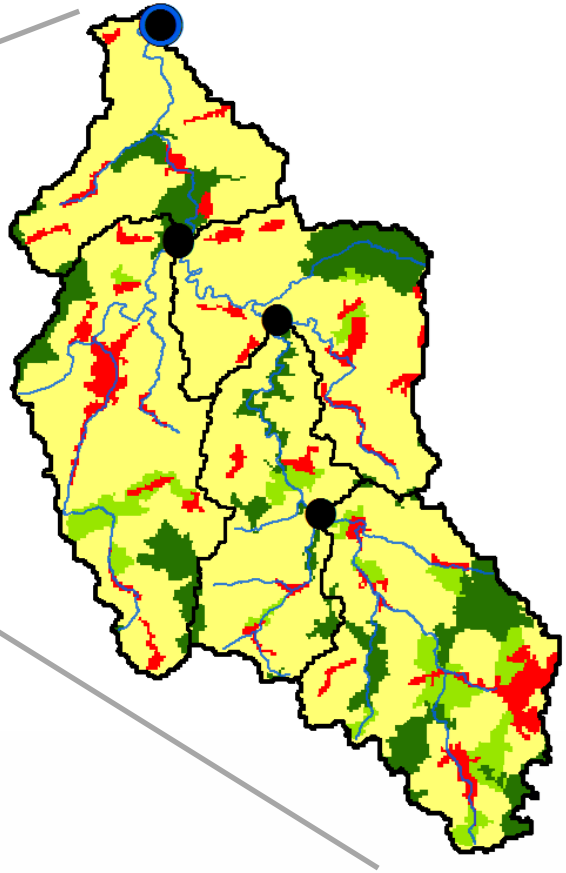


* Rossberg et al. (2007): *Definition von Boden-Klima-Räumen für die Bundesrepublik Deutschland.* Nachrichtenblatt des Deutschen Pflanzenschutzdienstes. 59.7: 155-161.

Study Area – Testing of land-cover strategies

Striegis catchment area :





- **Area:** ~ 283 km²
- **Precipitation:** 820 to 960 mm/a
- **Elevation:** 185m to 590m
- **Soils:** Loess soils, residual soils (mixed with loess)
- **Agricultural land:** 74%

Modeling effects of crop rotations

Strategy	1	2	3
Correct cultivation statistic in every year of simulation	**yes**	no	**yes**
Use of realistic crop rotations	no	**yes**	**yes**

Strategy 1: HRU-Split using crop-cultivation statistics, No use of crop-rotations

Strategy 2: use of **1** realistic crop rotation, but due to that: variations from the actual cultivation statistic

Strategy 3: **4** realistic crop rotations are combined

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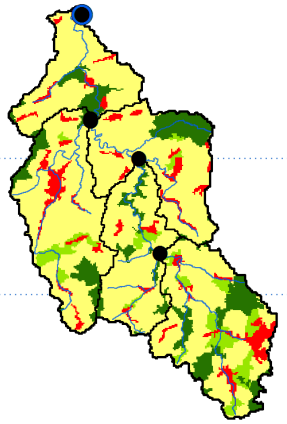
Modeling: Basin-level comparison of strategies

Strategy	1	2	3
Correct **cultivation statistic** in every year of simulation	**yes**	no	**yes**
Realistic **crop rotation**	no	**yes**	**yes**
Total **N Applied [%]**	- 2	- 9	100

Same management of individual crops, differing rotations & cultivation statistics



	1	2	3
	yes	no	**yes**
	no	**yes**	**yes**
Hydrology (Surf-Q, GW-Q, ET, etc.) **[%]**	+/- 1	+/- 1	100
Upland **Sediment** Yield **[%]**	+17	+39	100
Total **N Loss [%]**	+ 7	- 2	100
Nitrate Leached **[%]**	+ 3	- 10	100
Average crop-yield **[%]**	- 3	- 5	100

Input → **SWAT model** → Output

Uncalibrated models; upland statistics, before in-stream processes

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Conclusion

- SWAT has an high sensitivity regarding crop rotations. Especially, with regard to sediments, crop yield & nutrient cycles.

- It is complex to account for crop rotations and cultivation statistics at the same time during SWAT-model setup, but we showed a possible strategy of dealing with that.

- If the purpose of modeling is analyzing the catchments hydrology, than crop rotations seem not that important.

Outlook

- Investigate the effect of the different strategies in large catchments (Saale & Mulde).

- Investigate the effect of the different strategies model calibration and management scenarios.

Thank you!!