Integrating decision making in the agricultural sector into ecohydrological simulations: the GLOWA-Danube approach

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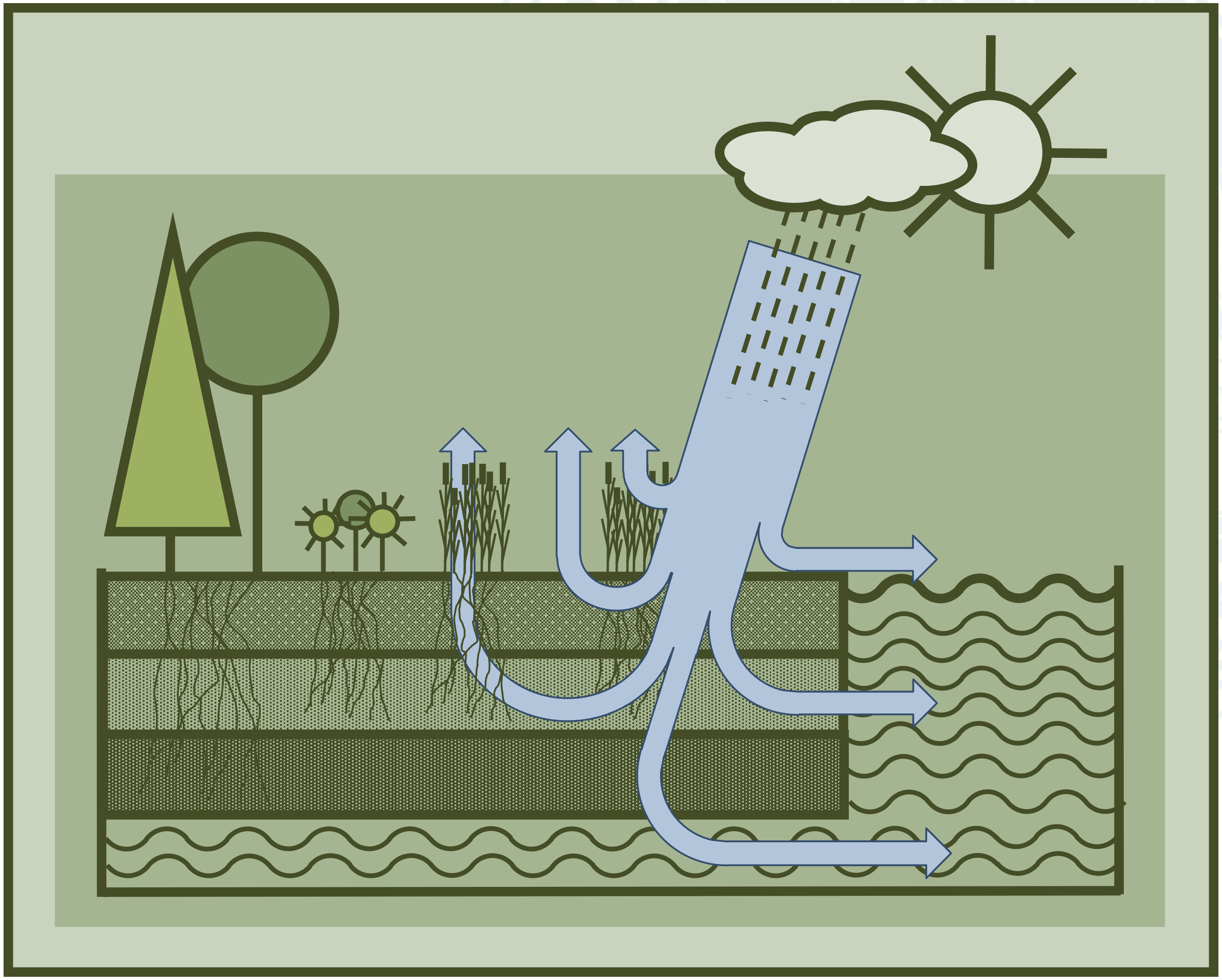
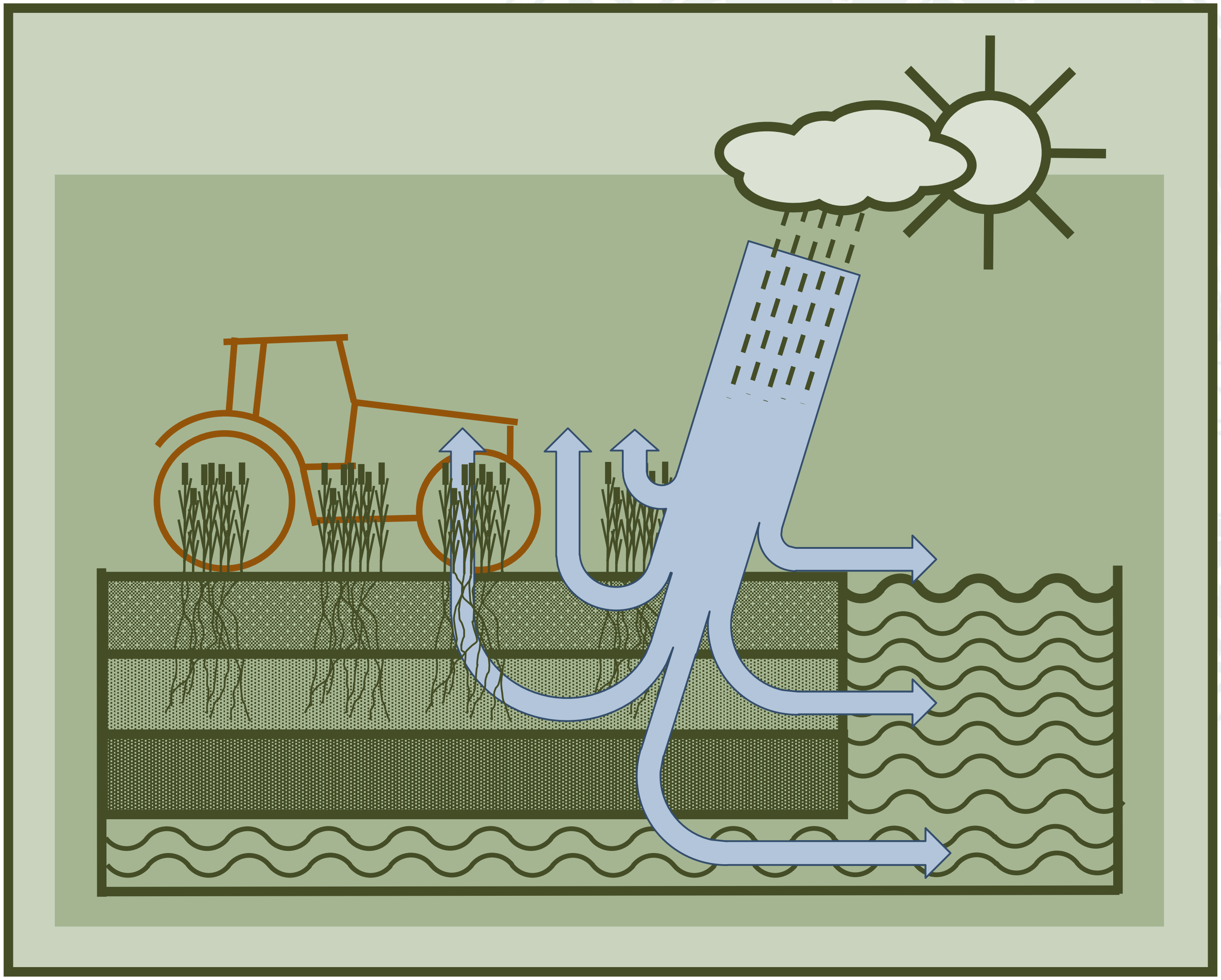
Water and vegetation



Water and vegetation

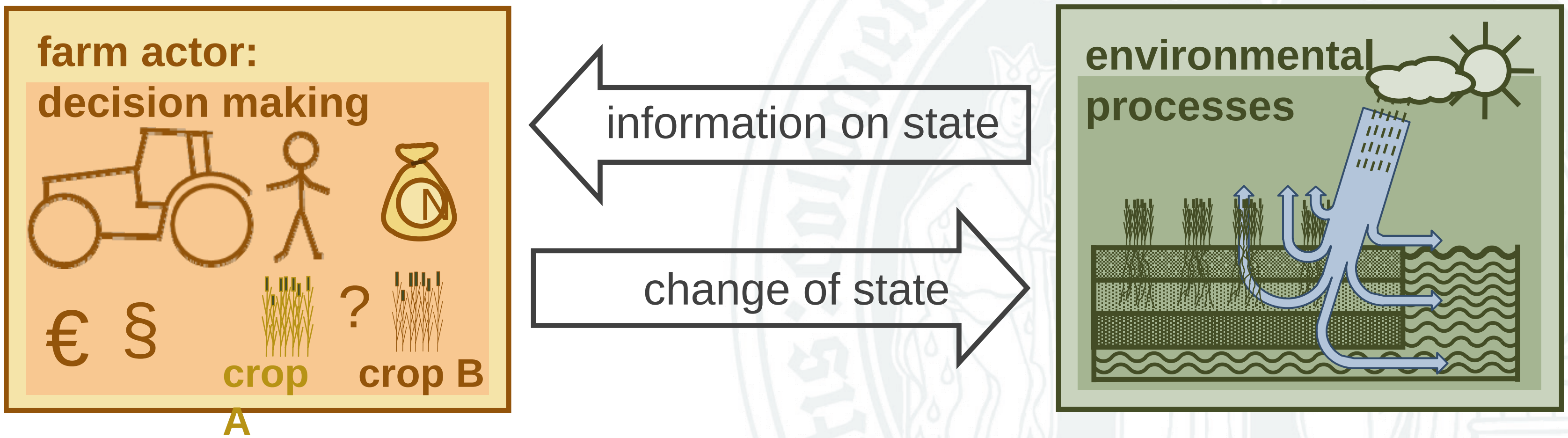


GLOWA-Danube and the DANUBIA simulation system

DANUBIA simulation system: dynamically coupled models

Integrative Techniques, Scenarios and Strategies for the Future of Water in the Upper Danube Basin

Coupled models in the DANUBIA simulation system



<u>agroeconomic actor model</u>

regional economic production

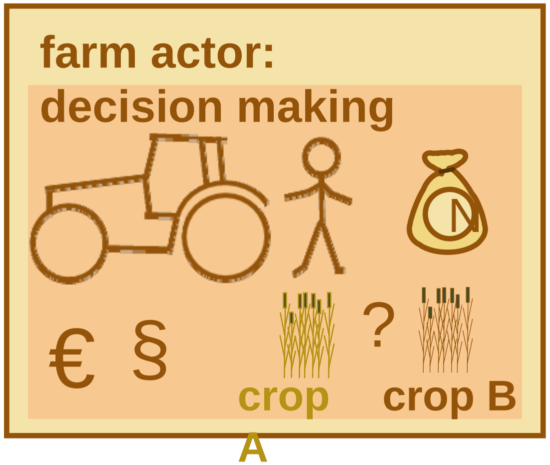
actor-based crop management

<u>ecohydrological models</u>

physically based process models

cycles of $H_2$0, C, N, energy

The regional economic production model (ACRE)



<u>decisions on acreage of crops (land use)</u>

Henseler et al. 2009, Agric. Syst. 100:31

→annual plan **for a district** (acreage of crops, number of livestock)

•maximizes gross margin (income)

basis for decision-making:

•prices

•subsidies

•yield expectations (from past experience)

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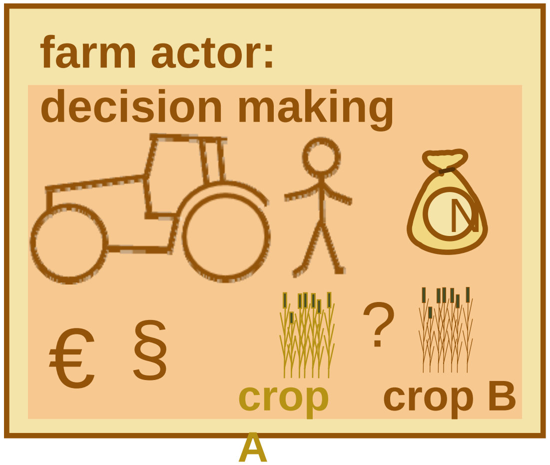
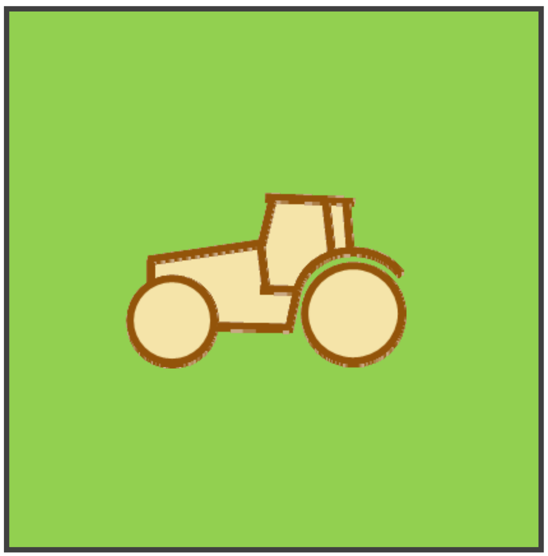
The actor-based cultivation model (DeepFarming)



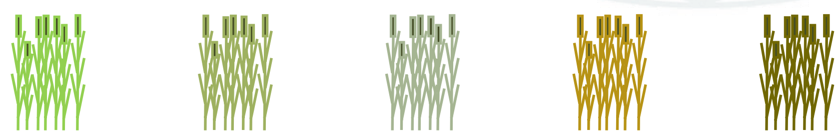


<u>decisions on daily management activities</u>

developed by: Krimly, Apfelbeck, Henseler, Huigen, Dabbert, Universität Hohenheim

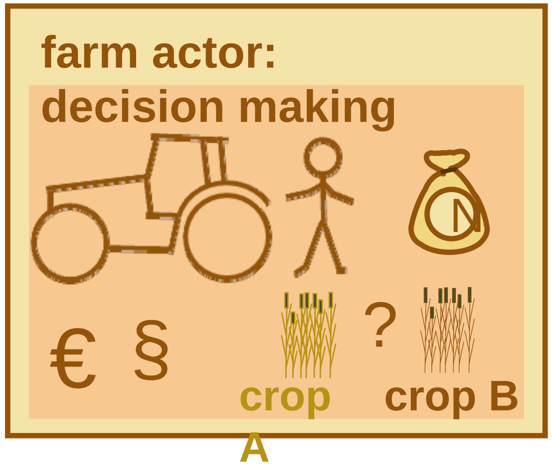
→ annual plan **for a specific pixel**

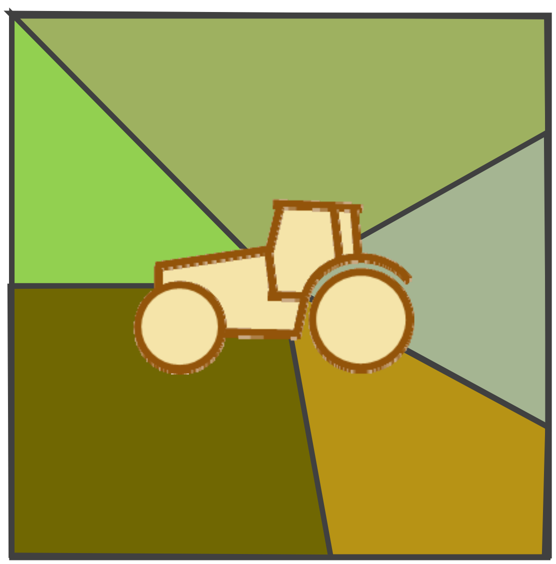
- one actor per pixel (1 km²)
- 28 farm systems



crop A crop B crop C crop D crop E …

The actor-based cultivation model (DeepFarming)



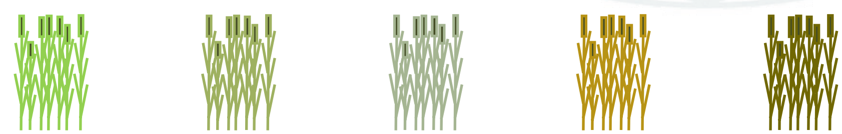


allocation of acreage to crops

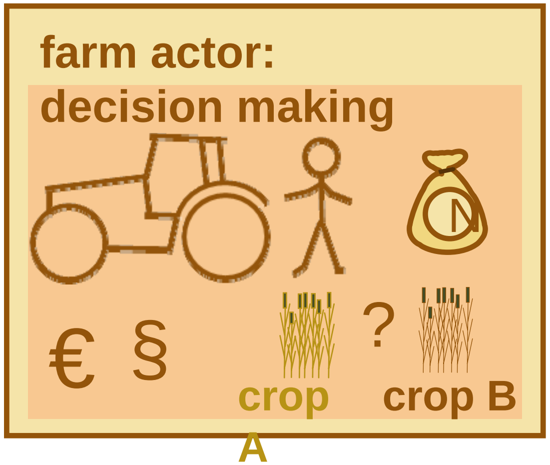
•tries to implement plan set up by ACRE

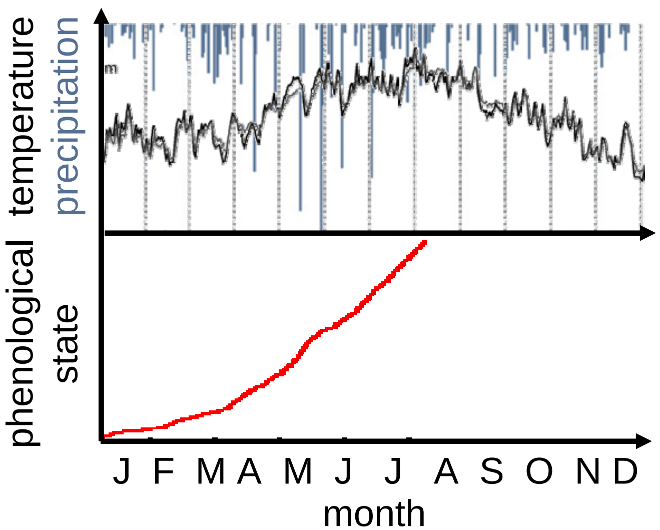
•restrictions:

- crop rotation
- feedstuff production



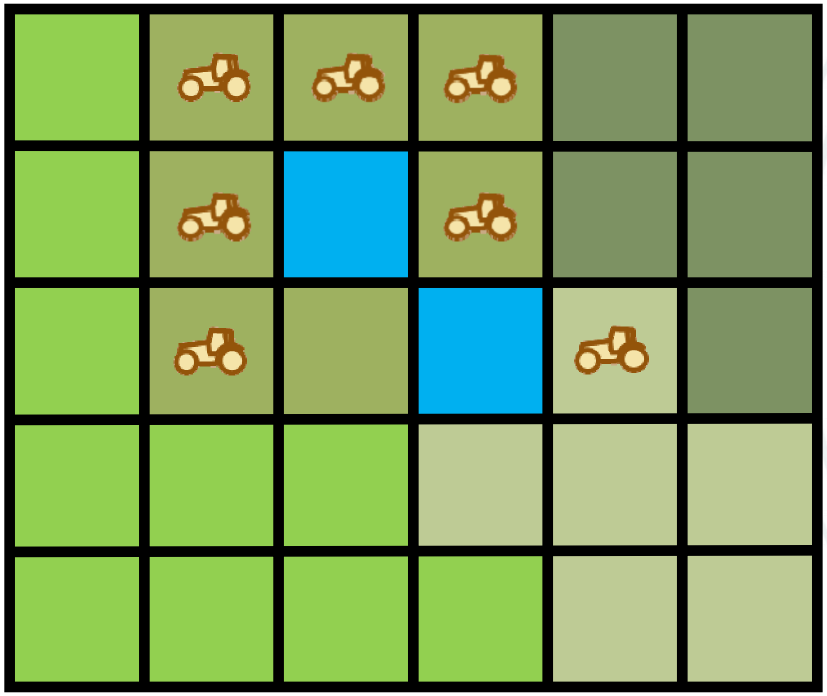
The actor-based cultivation model (DeepFarming)





- decisions on timing of sowing, harvesting, fertilization
- decision on amount of fertilizer (N)
- decision on irrigation (Geisenheim method)

Initialization



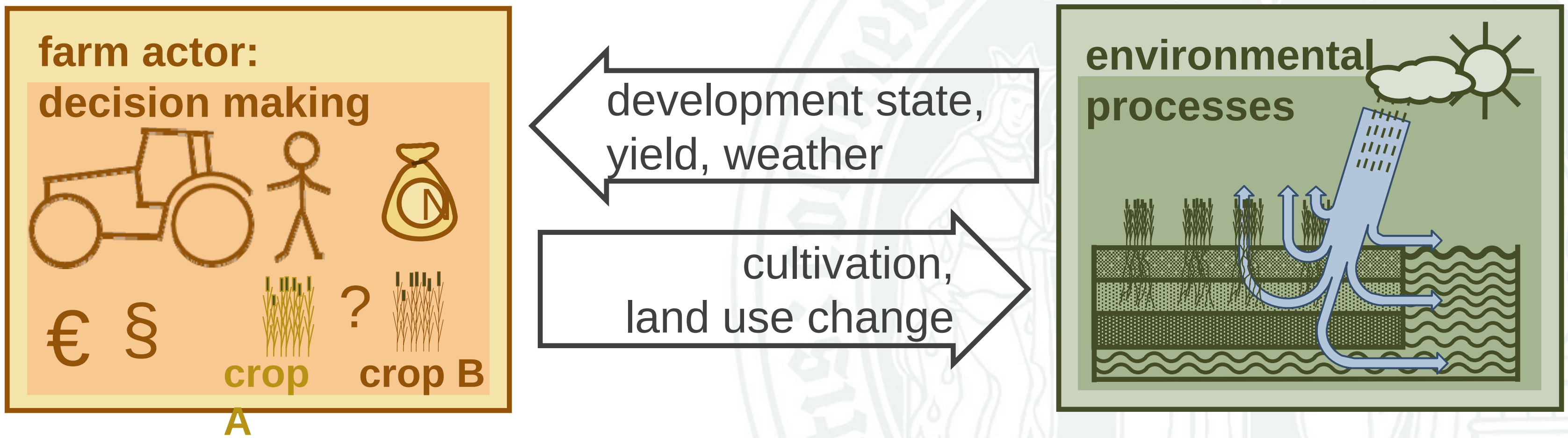
Allocation of suitable farm systems to specific pixels.

basis for decision-making:

•spatially explicit map of suitability for arable farming

•statistics on farm systems in the district

GLOWA-Danube scenarios



socioeconomic aspects

legal/political framework

market prices

environmental aspects

weather/climate

atmospheric CO_2 concentration

GLOWA-Danube scenarios

climate trend	climate variant	societal scenario	optional intervention
IPCC regional	*baseline*	*baseline*	*e.g. intensification of irrigation*
REMO regional	*5 warm winters*	*open competition*	*e.g. energy crops*
MM5 regional	*5 hot summers*	*public welfare*	*etc.*
extrapolation	*5 dry years*		

GLOWA-Danube scenarios

baseline	• continuation of current societal conditions • „business as usual“ • agro-economy: CAP (2013) does not change
open competition	• more materialistic, hedonistic society • less emphasize of collective responsibility • agro-economy: all subsidies abolished
public welfare	• claim for orientation towards public welfare in politics and economy • focus on collective responsibility and sustainability

Effect of agroeconomic decision making: example

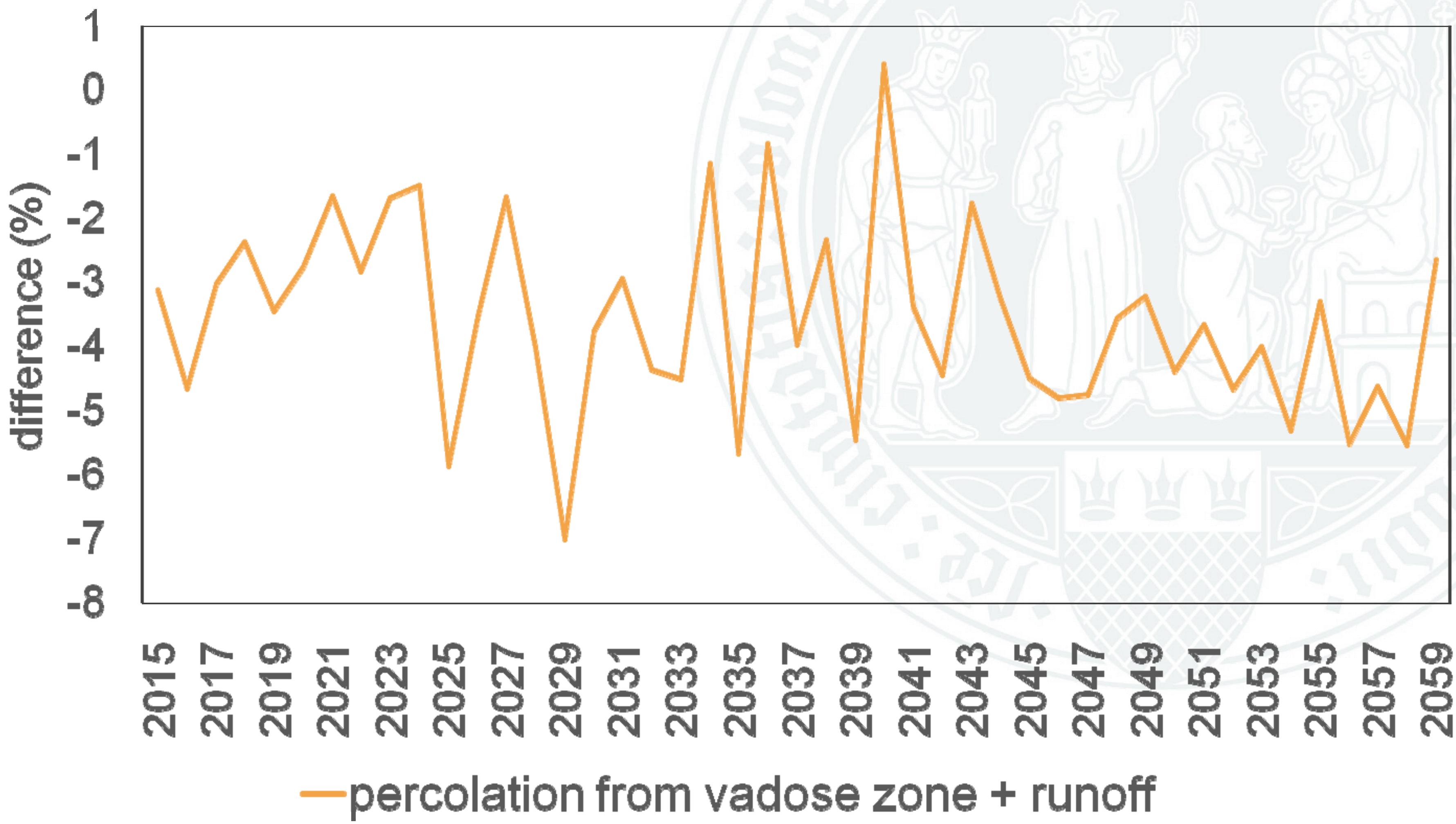
Source: GLOWA-Danube

District Günzburg in the Upper Danube catchment

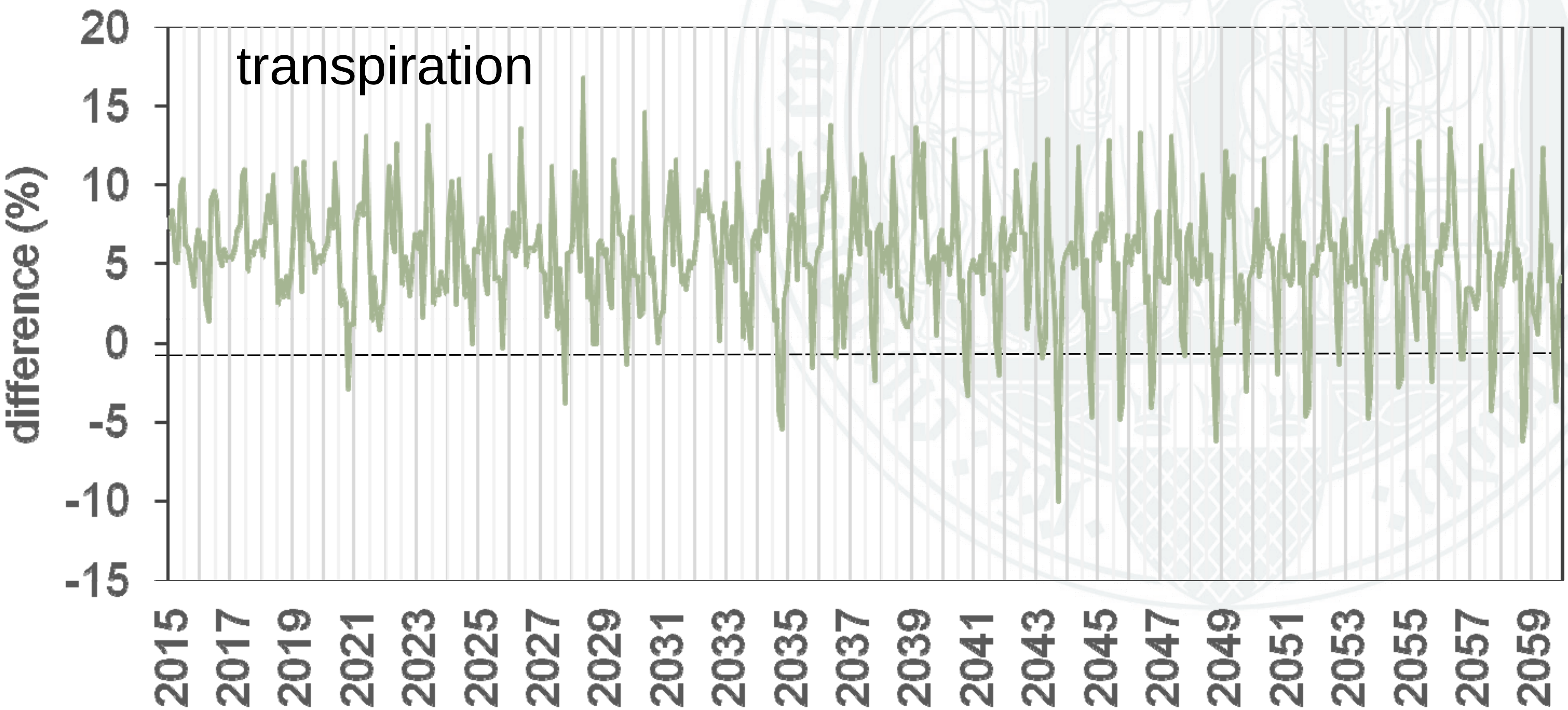
Scenario:
REMO baseline
open competition

Results compared to continuation of land use and cultivation activities from 1995.

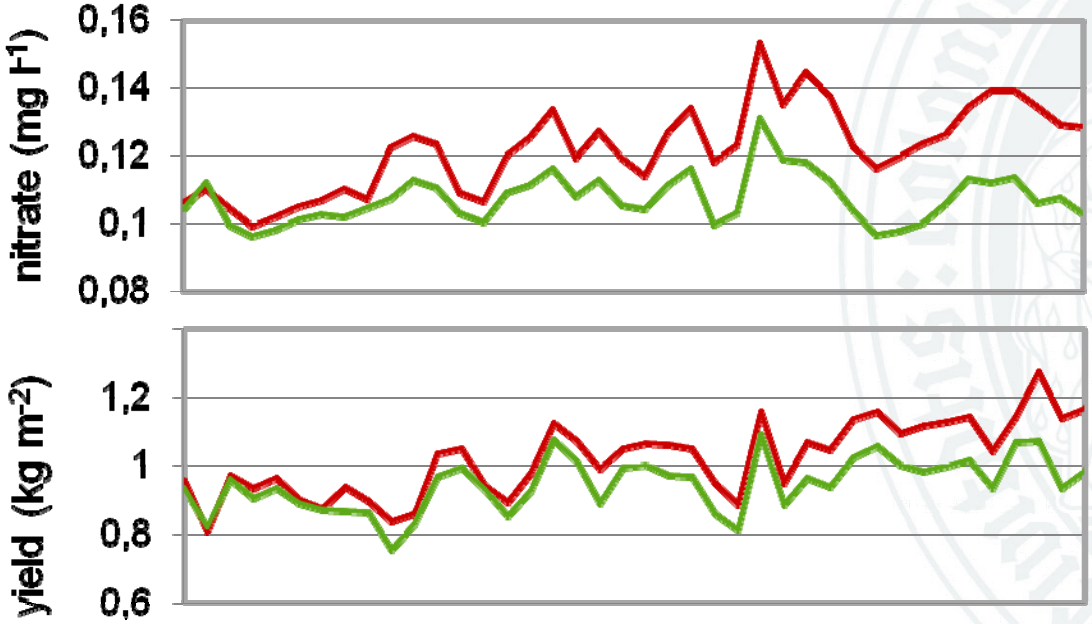
Effect of agroeconomic decision making: example



Effect of agroeconomic decision making: example



model application: results



+14 %

+8 %

deviation from *static*

— *dynamic* — *static*

Data requirement

- **expert knowledge/literature**: periods for cultivation activities, fertilizer amounts
- **regional statistical data** (regional authorities): crops, yields, livestock, price for drinking water
- **statistical yearbook**: market prices
- **CAP, national and regional regulations**: subsidies, restrictions
- **land use map** in accordance with statistics for a base year
- **map of suitability for arable farming** (based on topography, LVZ/EMZ, farmer interviews)

→ mostly generally available data

→ DANUBIA is generally applicable to the Rhine catchment

Main challenges

- establishing a common terminology of naturals sciences and economic sciences
- preparation of data from environmental models at the interface to models of decision making
- adjustment of decision making process to results of crop growth model
- development of a land use change scheme capable of dealing with changing acreages per crop
- coupling models with differing timesteps (day vs. hour)
- combination of models working on different spatial categories (political vs. hydrological)

How are (inter-)national socioeconomic developments translated into developments in water use by the sector?

Translation happens implicitly within DANUBIA.

The development has to be described as (scenario-) assumptions on the development of market, political framework and climatic conditions.

How does the sector anticipate on future changes in water availability and water requirements from the sector?

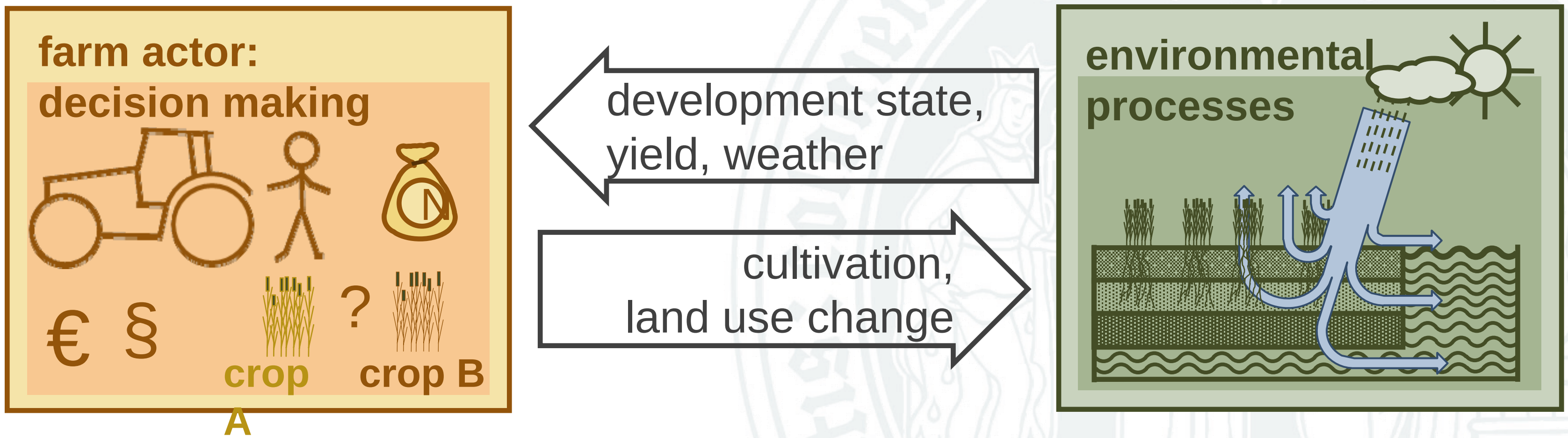
don't know

On what time horizon does the sector prepare for future changes in water availability?

short term:

Is there a temporal and/or spatial differentiation in the water use by the sector?

- highly variable in both, space and time
- strongest changes due to conversion of grassland/forest into arable land or vice versa
- temporal aspects: adjustment of cultivation activities to changing climate
- irrigation may become more important



main challenges

- adjustment of decision making process to results of crop growth model
- subscale land use change scheme
- differing timesteps (day vs. hour)
- different spatial units (political vs. hydrological)

model application: scenario 2019-2058

weather scanario: IPCC A1B

→ ECHAM →REMO (Jacob et al., 2008)

stochastical weather generator (Mauser, 2009)

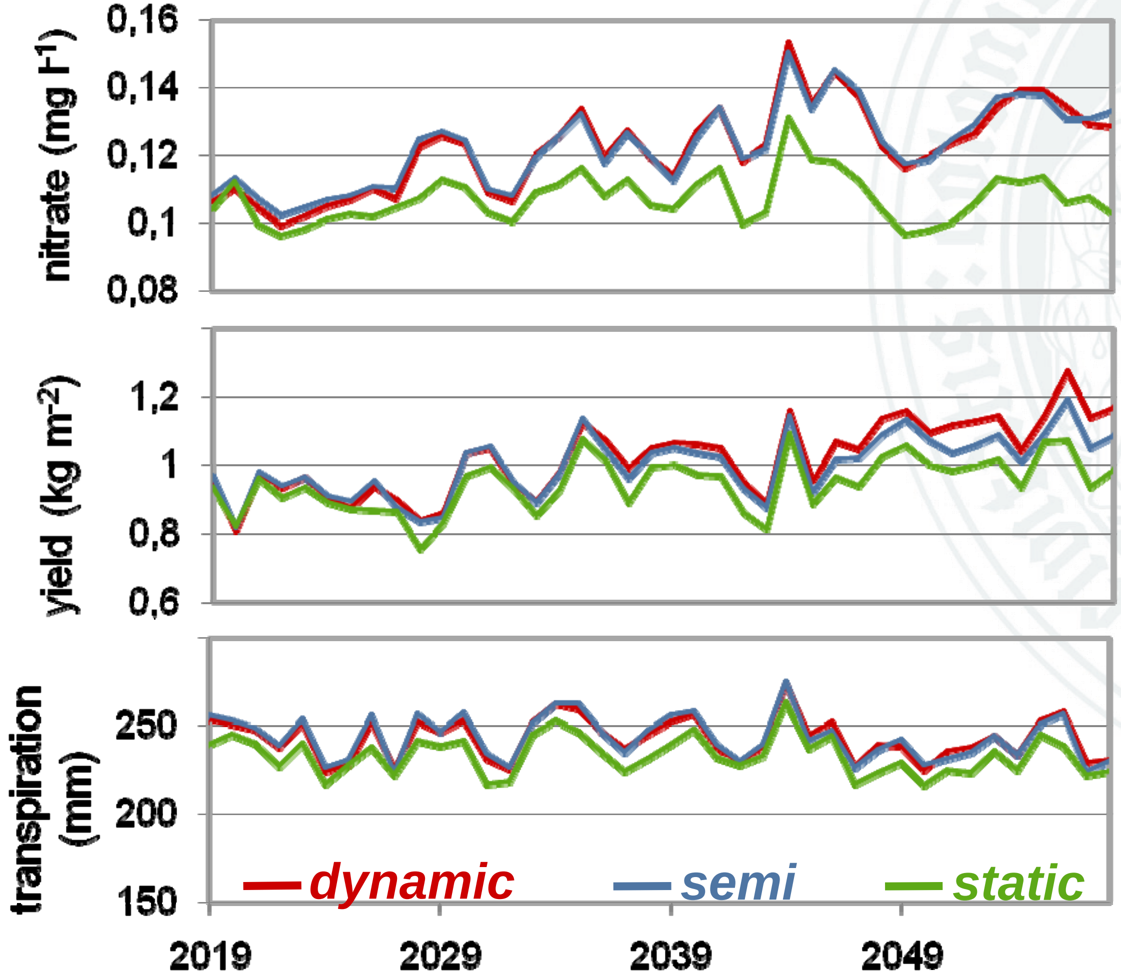
agro-economic scenario: Baseline

•conditions of the CAP (common agricultural policy of the EU) 2005-2013 throughout the scenario period

•constant market price

Jacob, D. et al. 2008, Dessau, Umweltbundesamt, Climate Change 11/08.
Mauser, W. 2009, in: Global Change Atlas, Einzugsgebiet Obere Donau. GLOWA-Danube Projekt, Münc

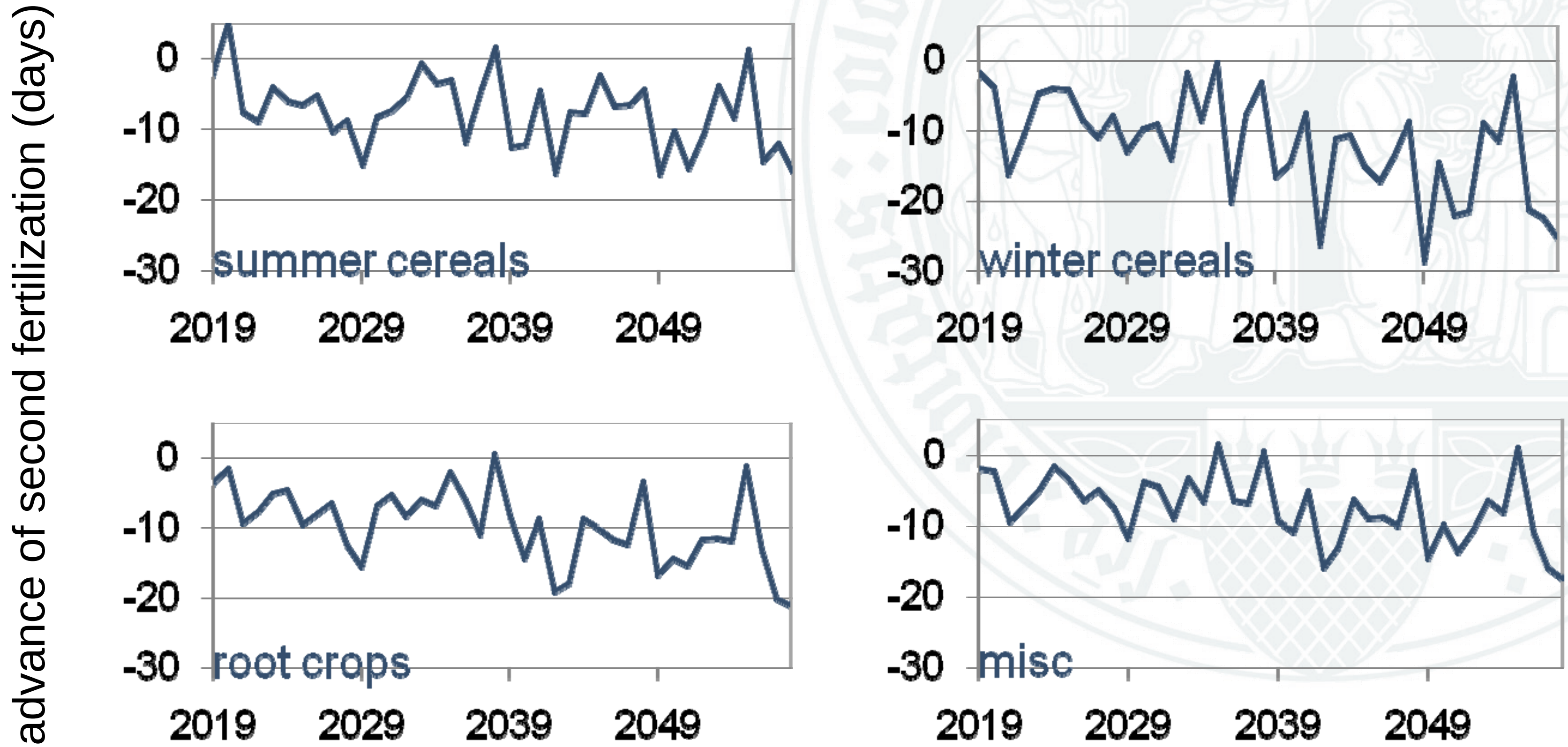
model application: results



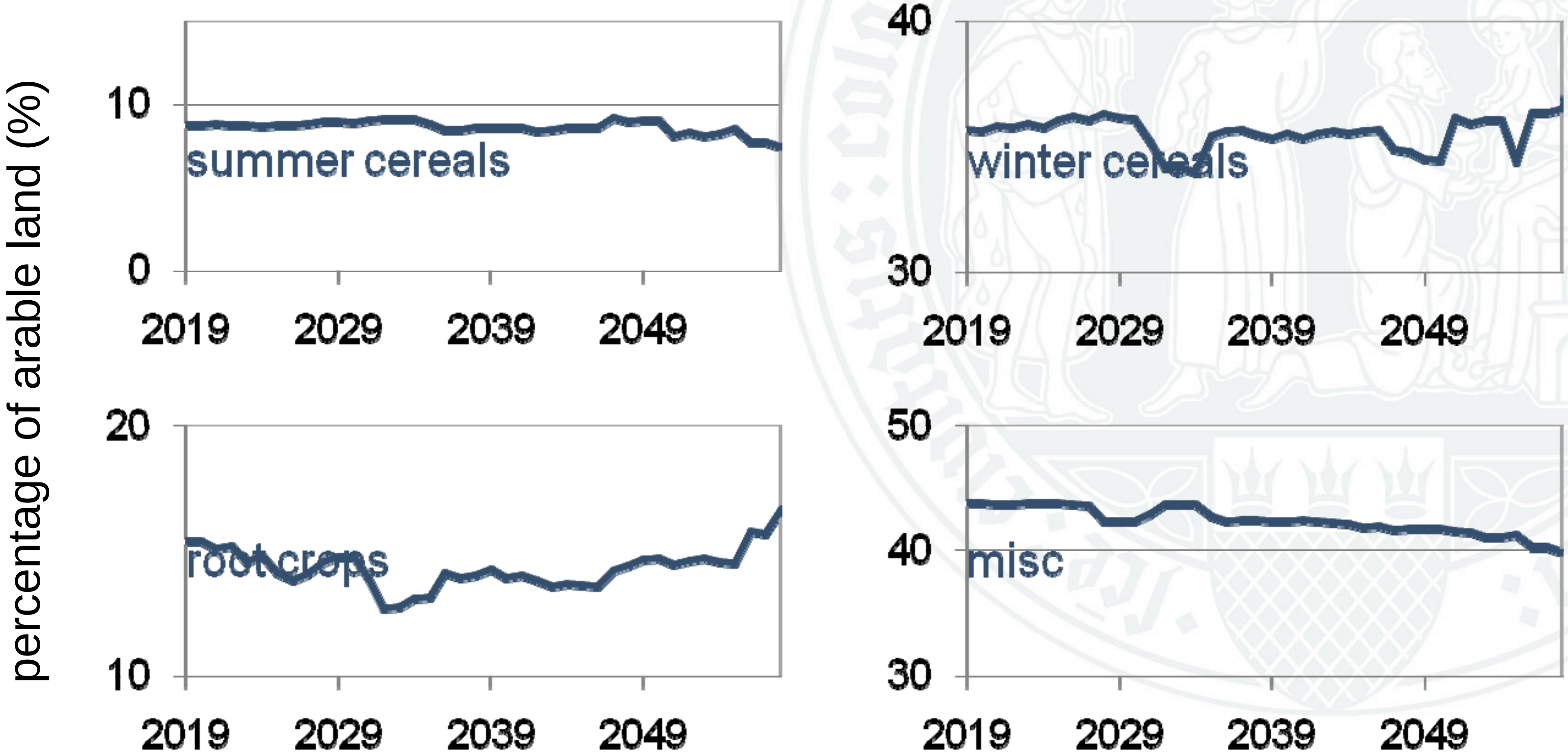
deviation from *static*

nitrate	+14 % (dynamic), +14 % (semi)
yield	+8 % (dynamic), +6 % (semi)
transpiration	+4 % (dynamic), +4 % (semi)

Results of DeepFarming: advance in date of second fertilization



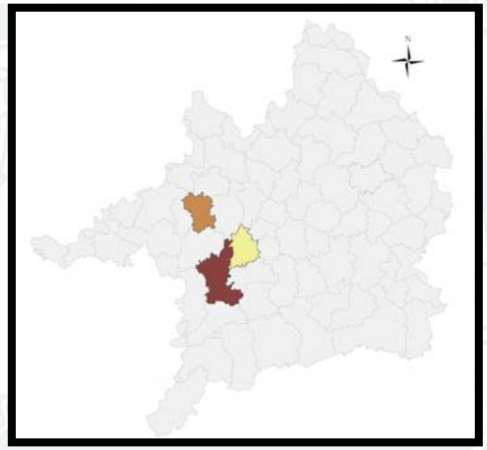
Results of ACRE: land use development



agroeconomic reults

development of gross margin (income)

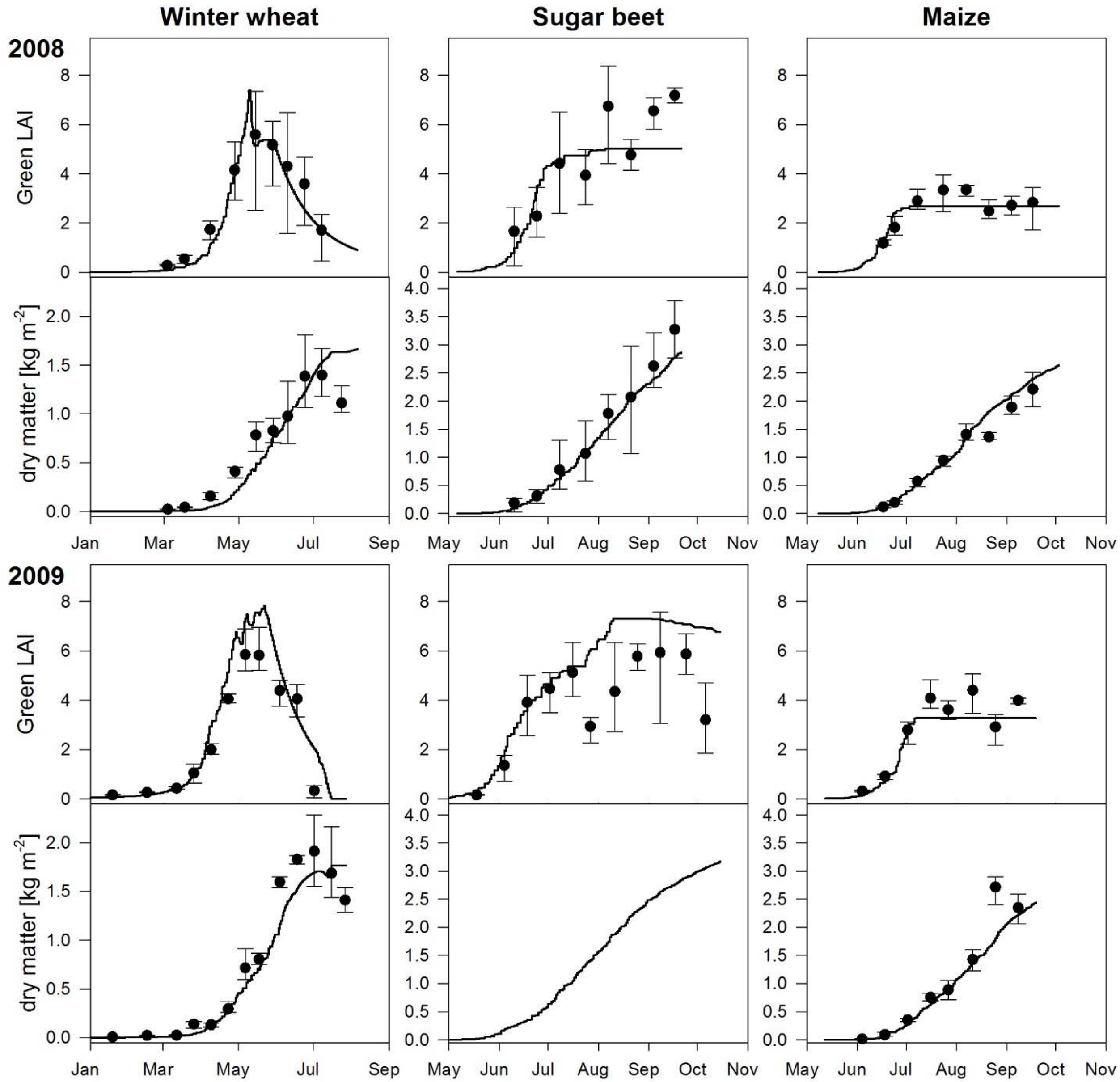
Landkreis	Gesellschaftsszenario			
	Baseline 2012-2021	Performance 2012-2021	Baseline 2049-2058	Performance 2049-2058
	Änderung Deckungsbeitrag gegenüber Referenz (%)			
Günzburg	11	-7	20	-10
Landsberg	16	-4	25	-11
Ostallgäu	20	4	22	-6



percentage of subsidies in gross margin

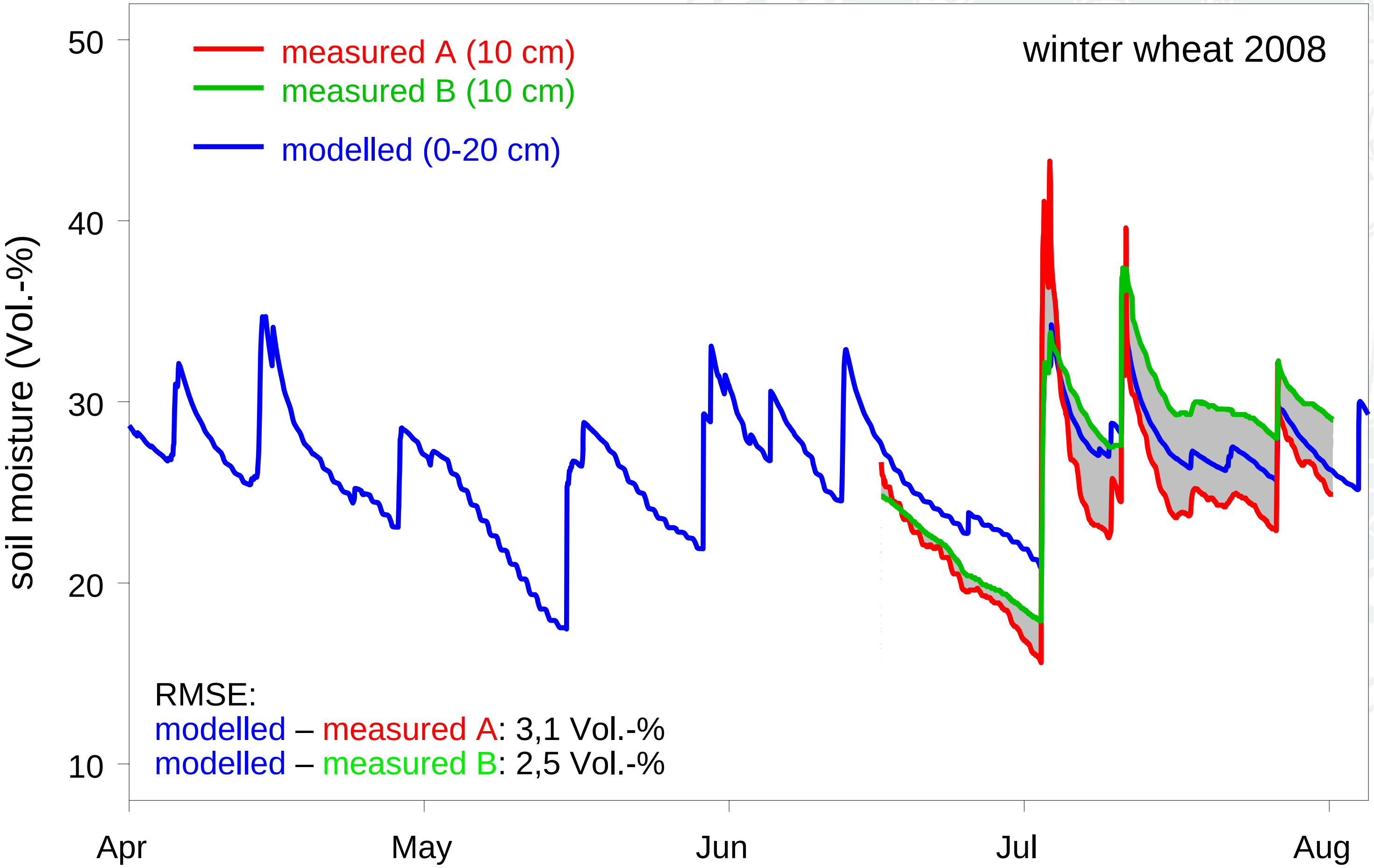
Landkreis	Szenario				
	Referenz 1996-2005	Baseline 2012-2021	Performance 2012-2021	Baseline 2049-2058	Performance 2049-2058
	Anteil Prämien am Deckungsbeitrag (%)				
Günzburg	25	27	14	26	2
Landsberg	23	30	15	29	2
Ostallgäu	12	27	14	27	3

model validation: crop growth

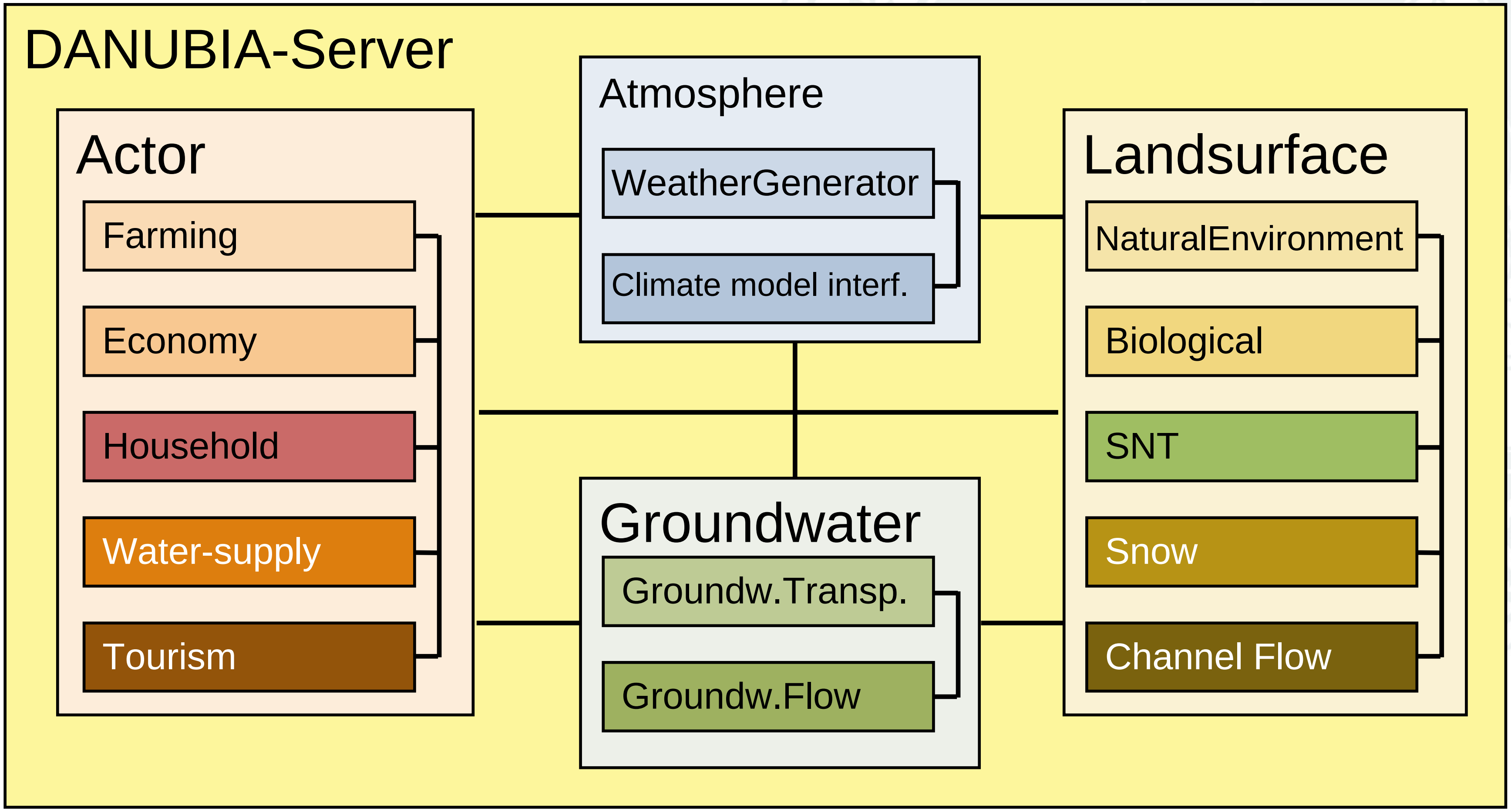


Source: Korres et al. 2013, Journal of Hydrology 498: 89

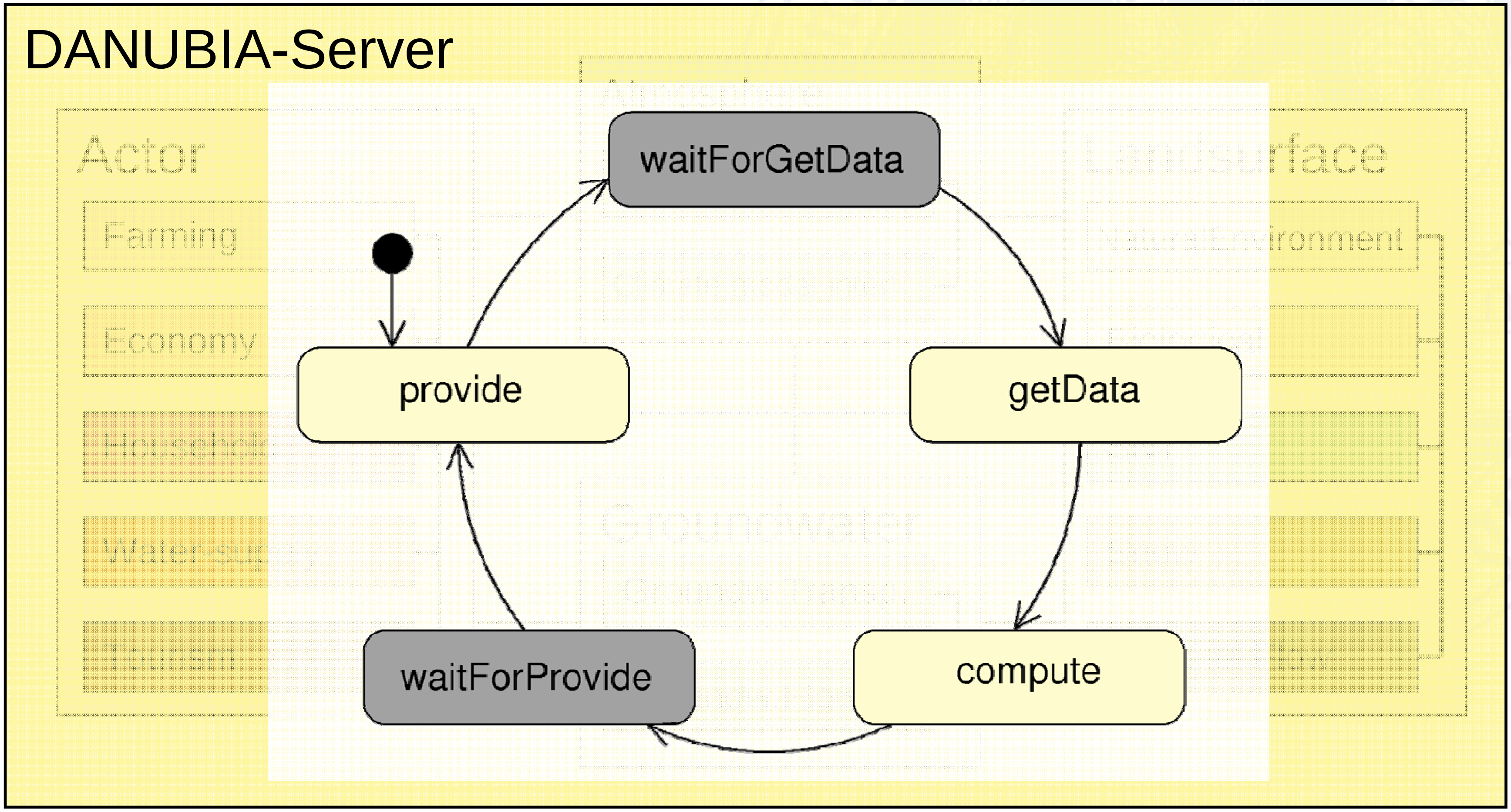
model validation: hydrology



Components of DANUBIA



DANUBIA: simulation of a timestep



Components used for the analysis of mass balances on the catchment scale

NaturalEnvironment	• **Surface and soil hydrology, energy- and radiation balances**
Biological	• **Plant growth, exchange of C, N, and water with the environment**
SNT	• **Soil nitrogen transformation, degradation processes**
AtmosphereToLandsurfaceDummy	• **Meteorological drivers, atmospheric CO_2 concentration**
FarmingDummy	• **Agricultural management (sowing, harvesting, fertilizing, cutting)**

General technical realisation

NaturalEnvironment	• **Processes thematically grouped, configurability untested**
Biological	• **Implemented using the CologneProcessModelFramework, configurable via configuration file**
SNT	• **Structured process framework, configurable via configuration file**
AtmosphereToLandsurfaceDummy	• **Simple data reader**
FarmingDummy	• **Configurable via configuration file, can dynamically adjust harvest date**

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Socio-economic influences on the discharge of the River Rhine
26.03.2014 - 27.03.2014, Bregenz

4.2.4 Agriculture and Agricultural Land Use Change

The Farming component simulates agro-economic management decisions made under consideration of prevailing natural and economic conditions, with a particular focus on water-related factors. It includes the regional economic production model ACRE (AgroeConomic pRoduction model at rEgional level, Henseler et al. 2009) and the agent-based model DeepFarming. ACRE is mainly driven by climate-induced yield expectations, agricultural policy conditions, and product prices; the model utilizes this information to output annual, district-level plans for acreage per crop and the number of livestock. Information about these plans as compared to plans made for previous years is then transferred to the actors in the DeepFarming model.

The DeepFarming model runs at the proxel level using a daily time step (Apfelbeck et al. 2007; Krimly et al. 2008). For each of the 58,984 proxels in the UDC that contains utilized agricultural area, a farm system actor is allocated to represent one of 28 different farm types. At simulation initialization, each farm system type is associated with a fixed crop rotation, acreage of arable land and/or grassland, and a number of livestock. During the simulation, the farm system actors in DeepFarming interpret the plans input from ACRE and based on this information, effect changes in their individual crop rotation and animal husbandry practices. Actor decision-making in DeepFarming also covers the timing of crop planting, fertilizing, and harvesting as dictated by prevailing climatic conditions (Barthel et al. 2011b). The practicability of these operations depends on the trafficability of the field as a function of soil moisture, the soil temperature, and precipitation. Further, fertilizing and harvesting are only viable once the crop has reached a particular stage of development, while the amount of N-fertilizer to be applied depends on yield expectations.

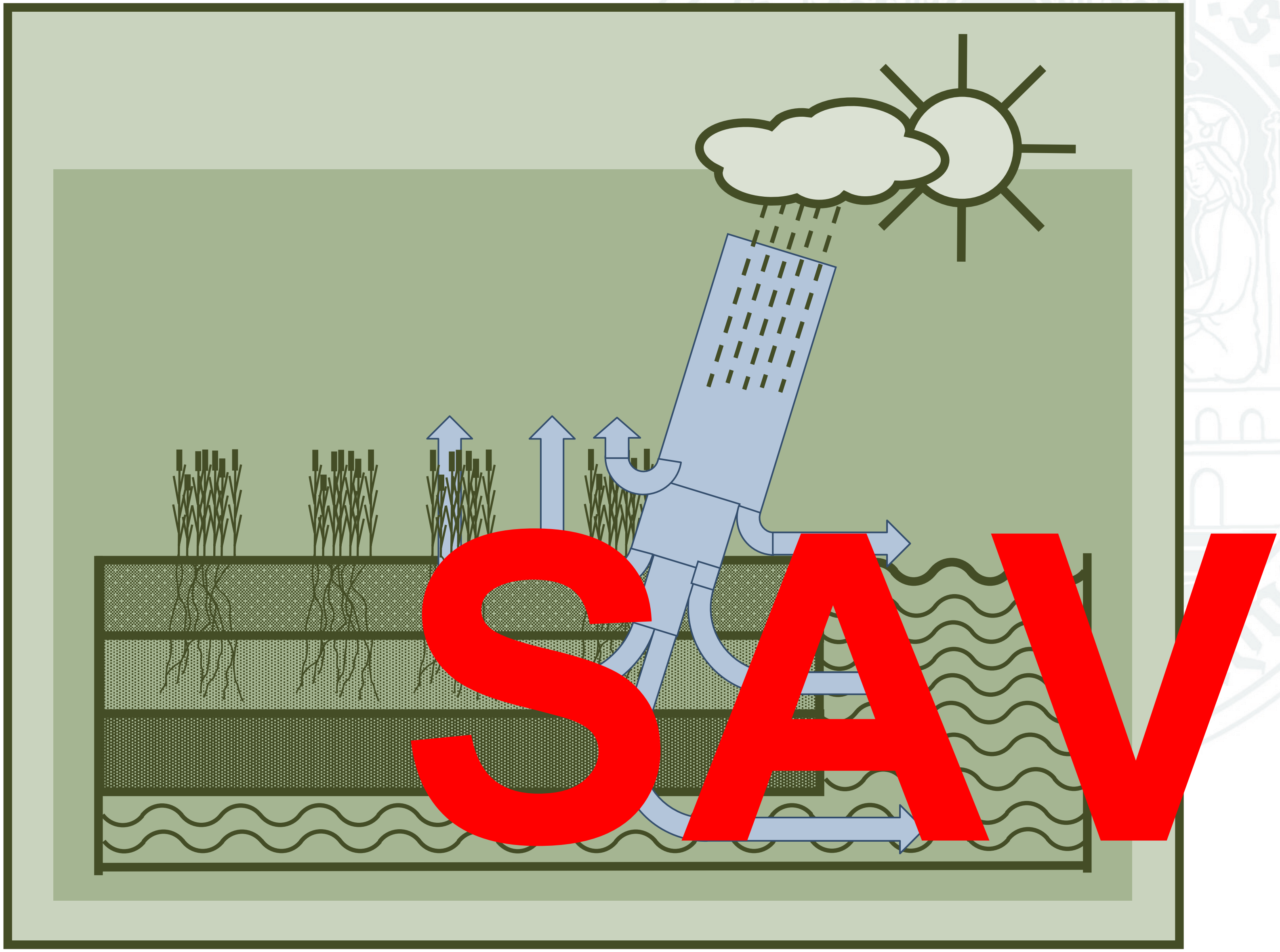
The Farming component calculates the potential irrigation demand for each crop planted according to the DeepFarming model by following the Geisenheim irrigation scheduling (Paschold et al. 2010). A simplified daily water balance (transpiration minus precipitation) is cumulatively calculated and then compared to a water deficit threshold that depends on the crop and its development stage. Irrigation is applied when the threshold is exceeded; the determination of whether or not to apply irrigation does not include economic aspects of irrigation. The Farming component also calculates water demand for livestock.

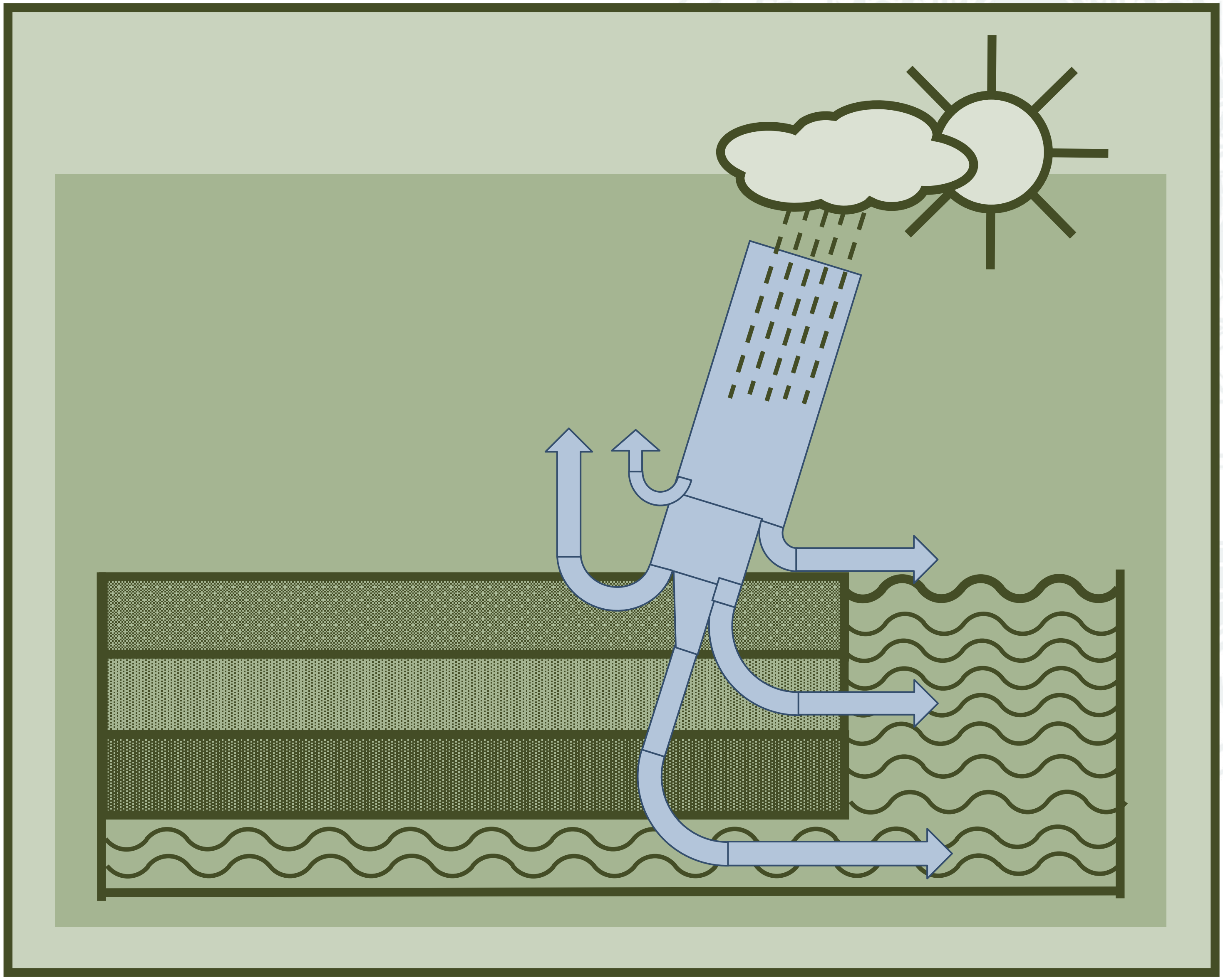
H_2O

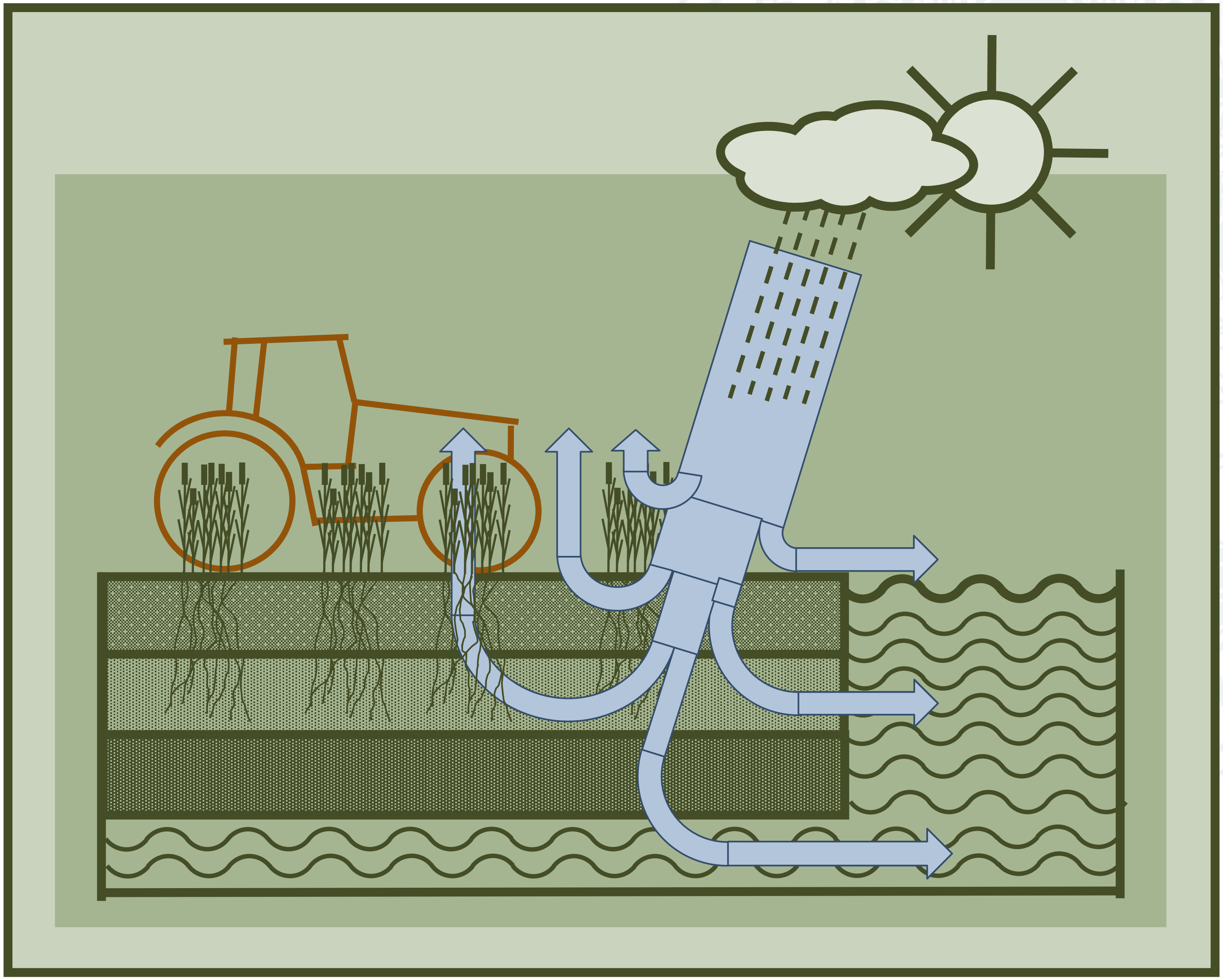
C

N

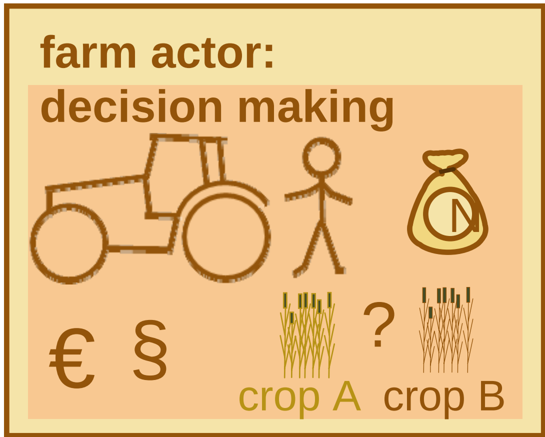
E





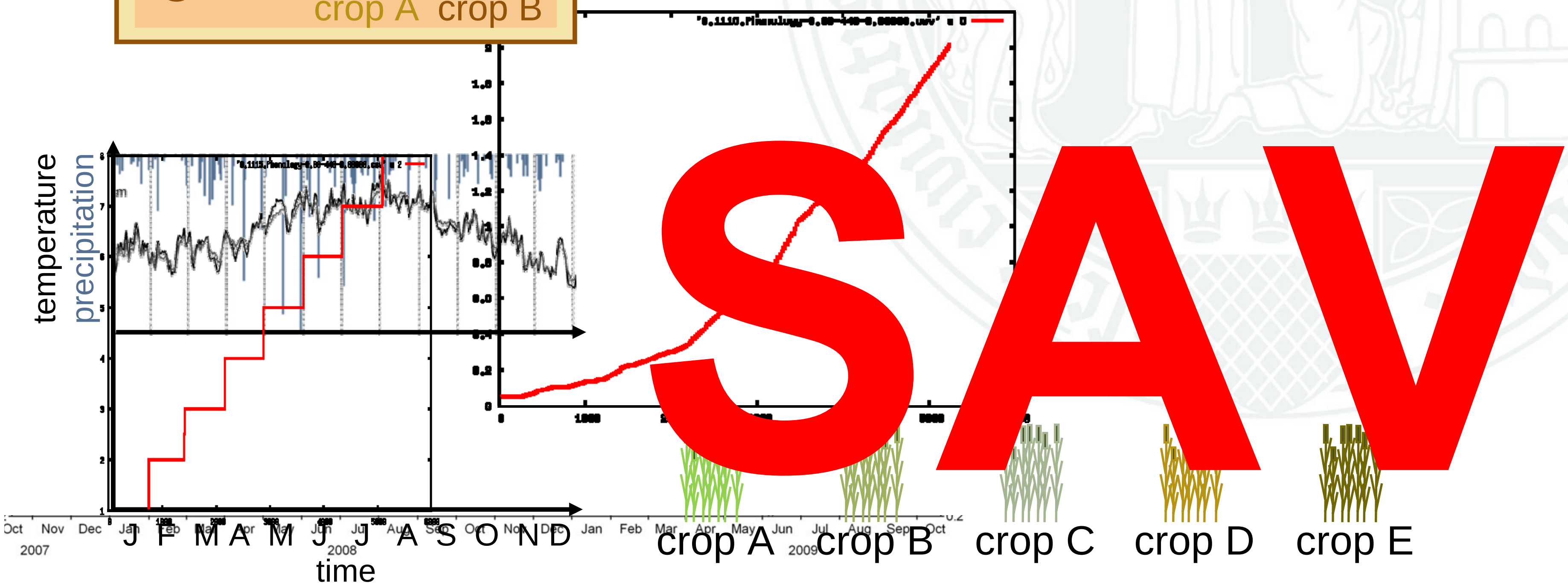


The agent-based cultivation model (DeepFarming)



→ decisions on timing of sowing, harvesting, fertilization

→ decision on amount of fertilizer (N)



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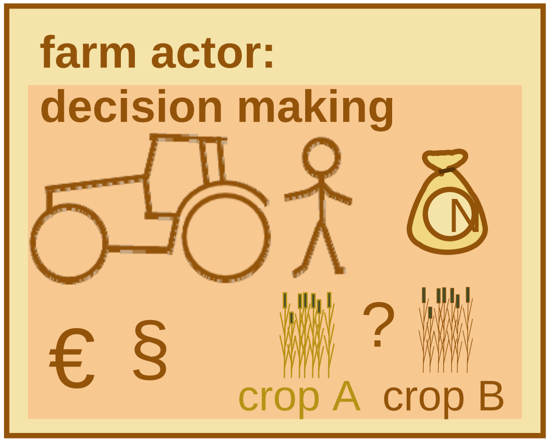
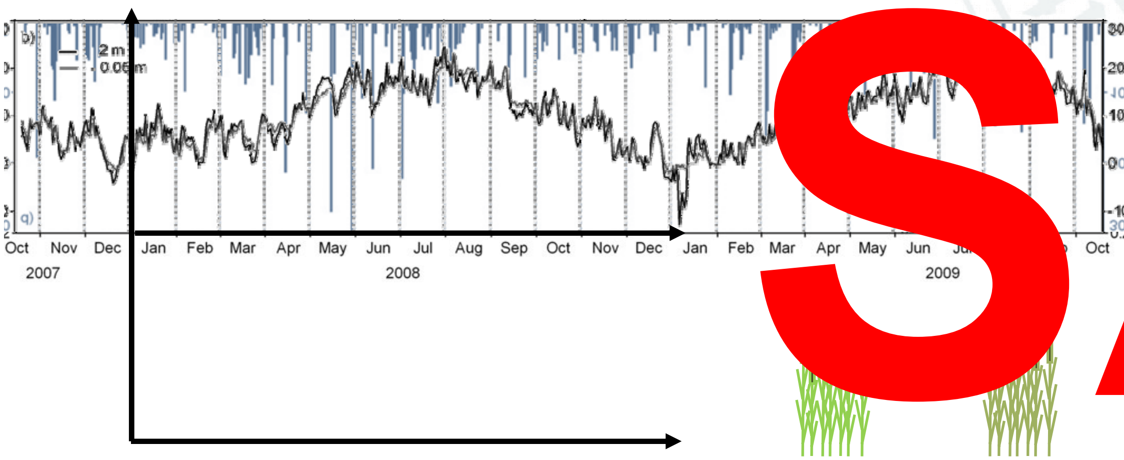
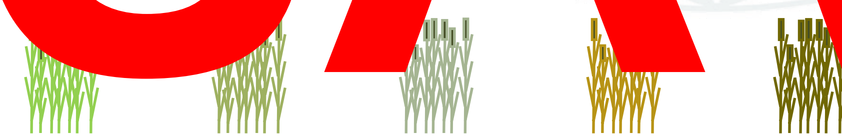


→ decisions on timing of sowing, harvesting, fertilization

→ decision on amount of fertilizer (N)



SAV

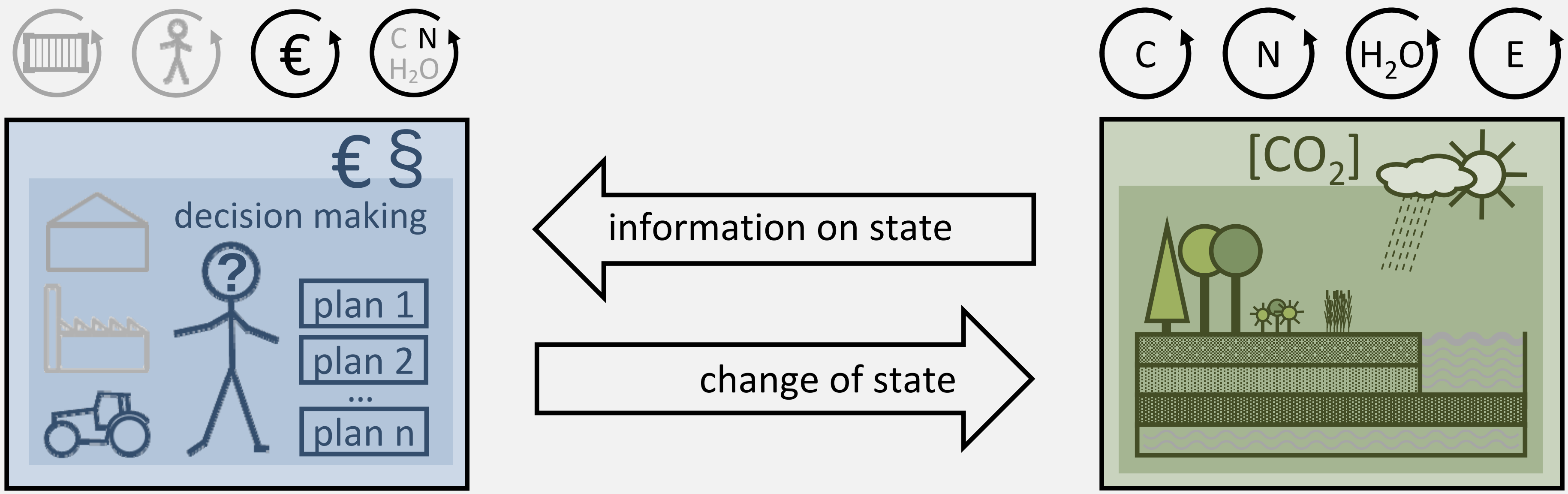


crop A crop B crop C crop D crop E

contribution to the group

societal, political, economic processes

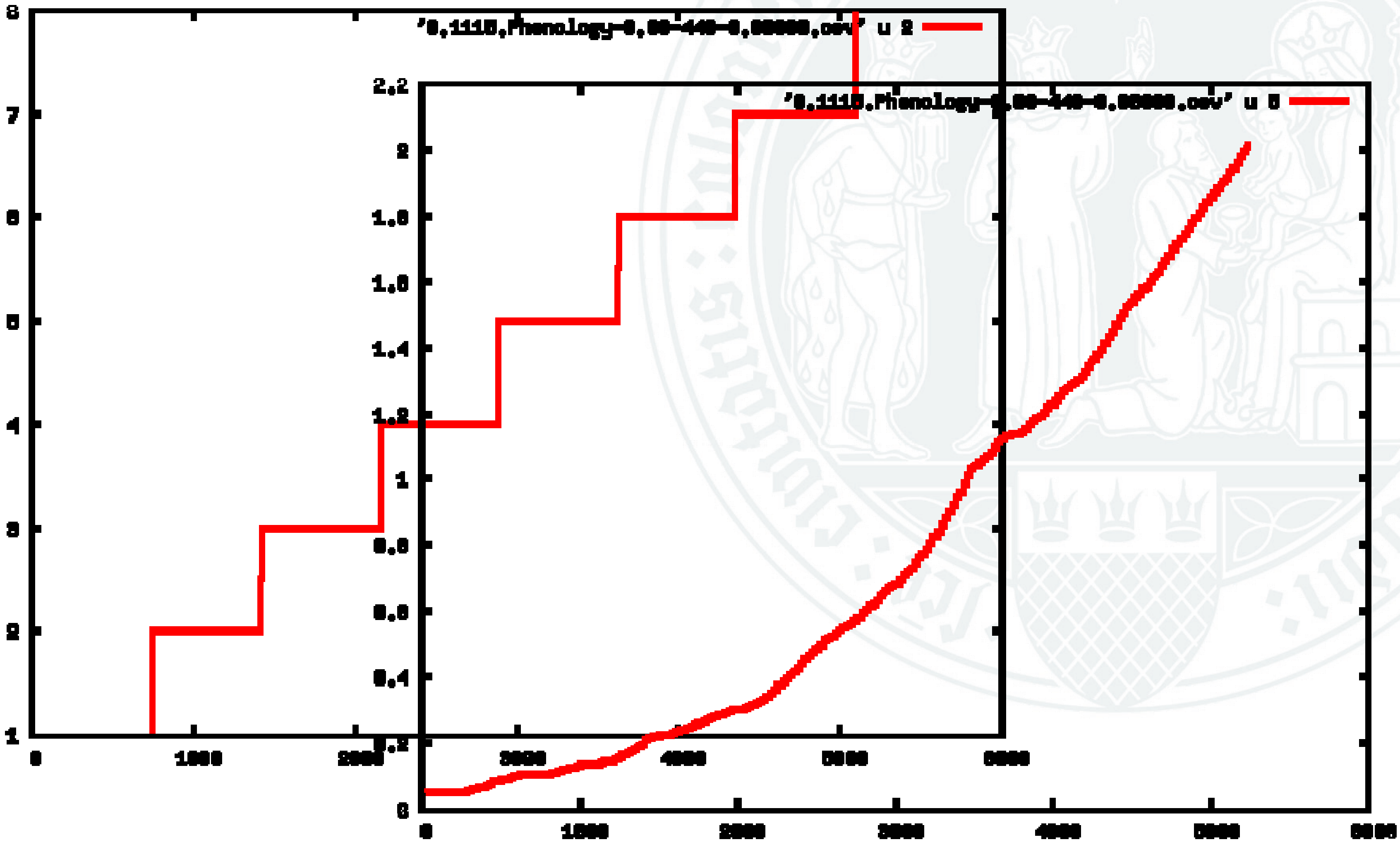
physical, physiological processes



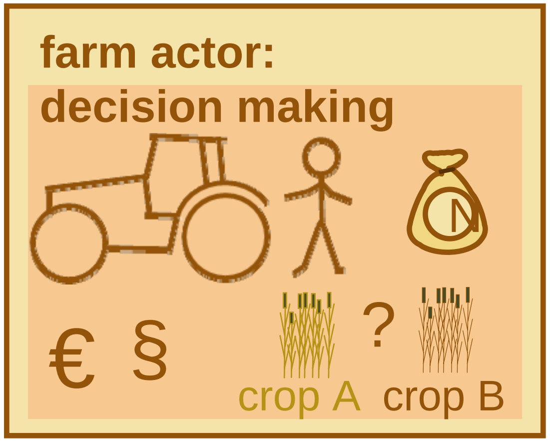
legal/political framework
market
societal development

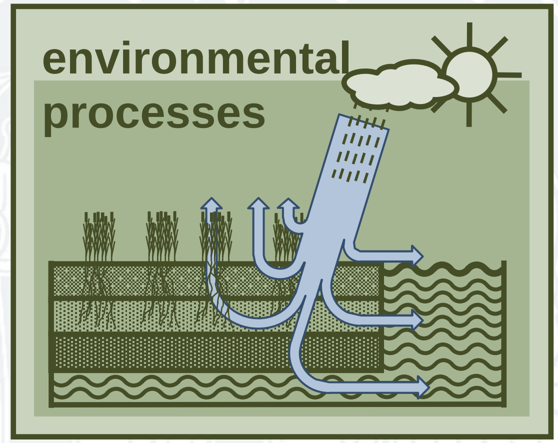
← scenario →

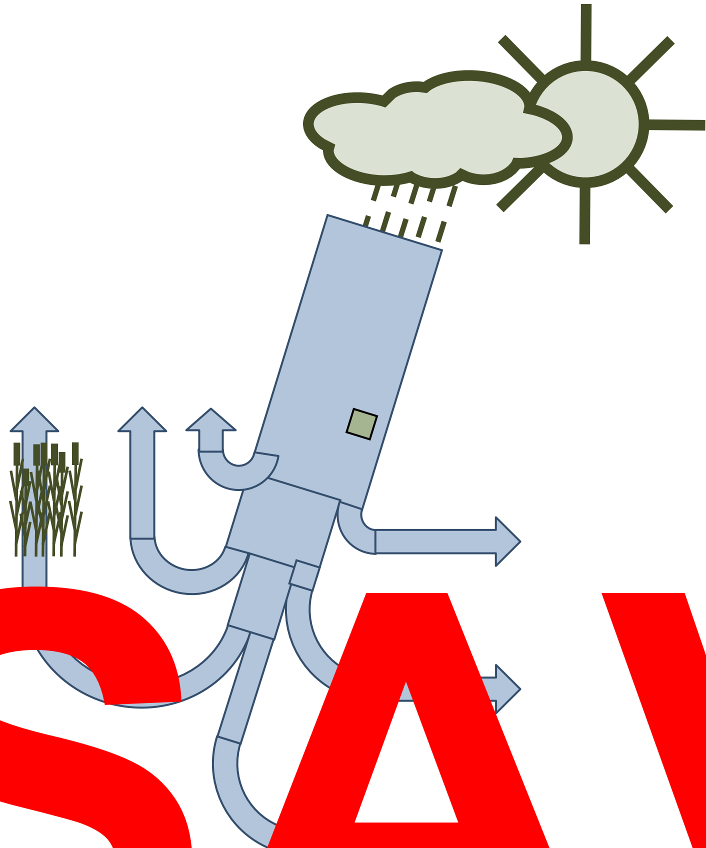
weather
atmospheric CO_2 concentration




crop A
crop B
$
N
N


farm actor:
decision making
€ §
?
crop A
crop B


environmental
processes



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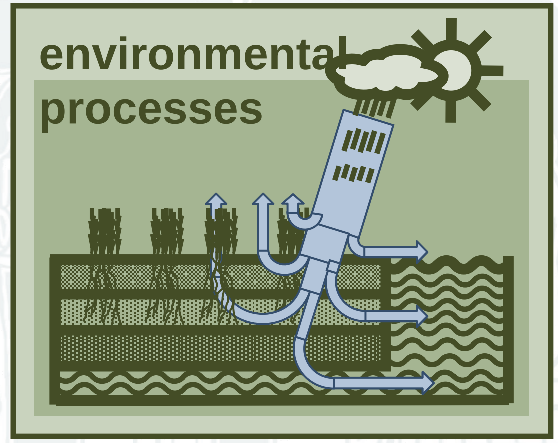

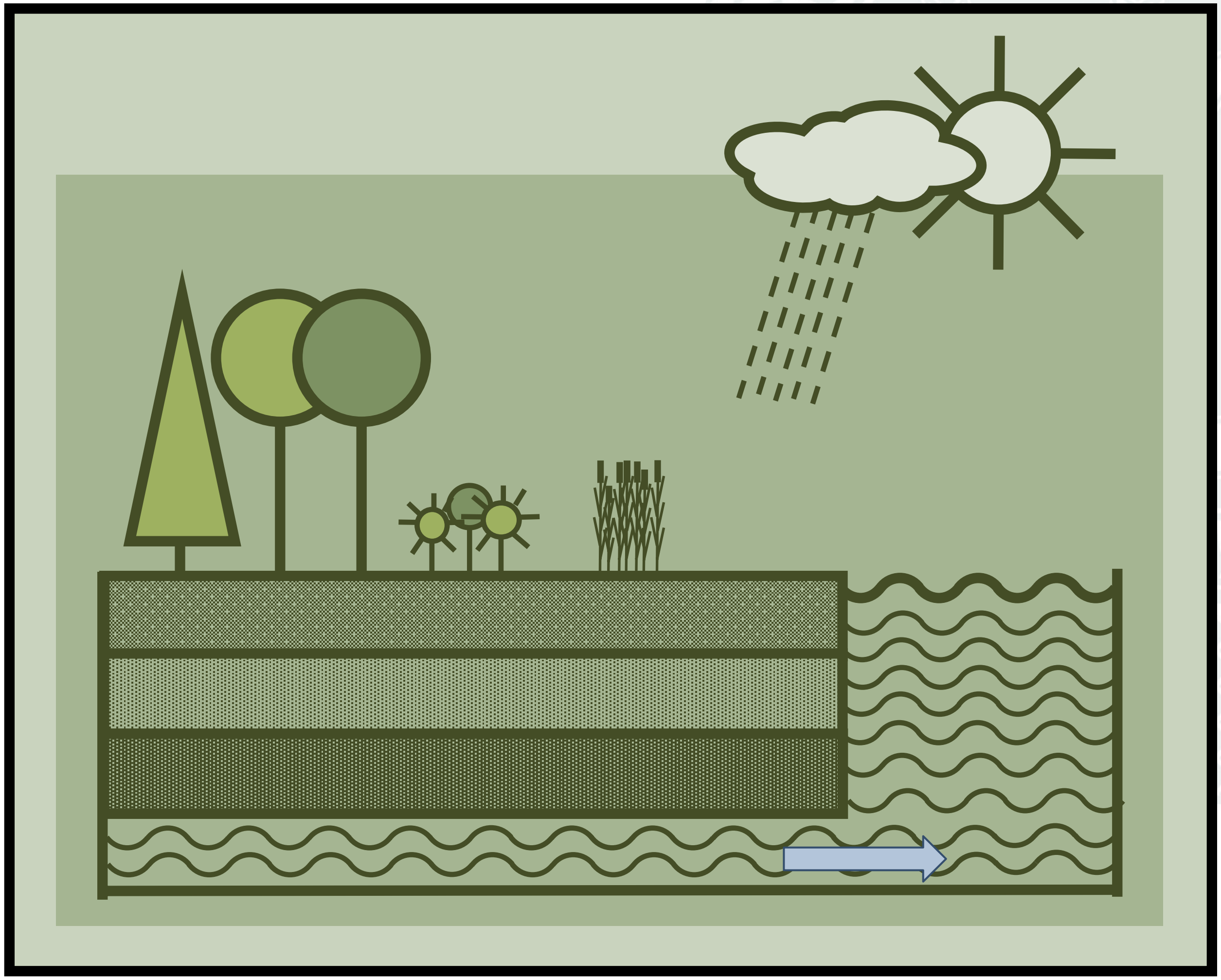

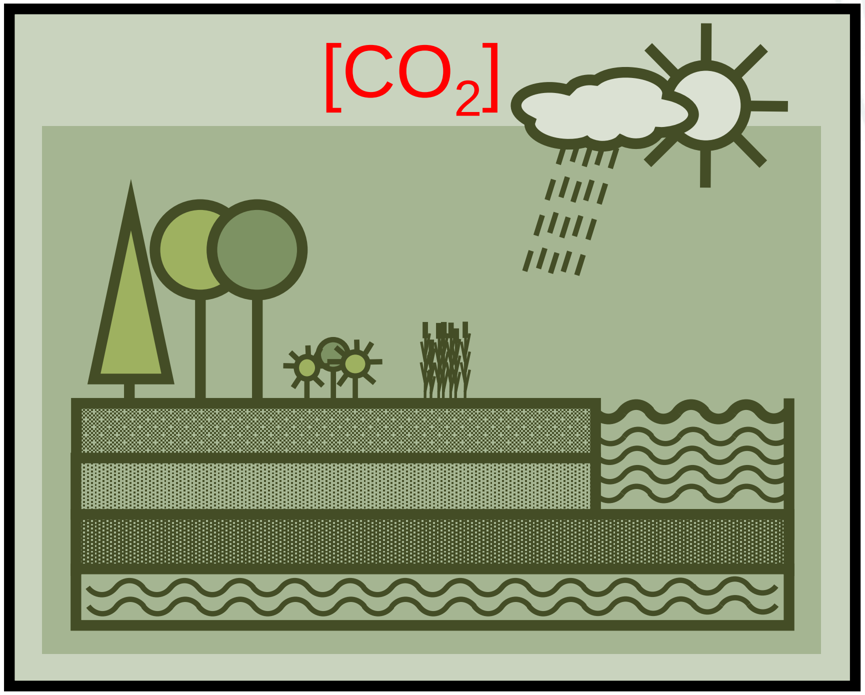
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