Estimating the nitrogen emissions from agricultural production

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Csilla Farkas, Moritz Shore, Dominika Krzeminska, Mojtaba Shafiei, Robert Barneveld

Nitrate pollution of drinking water sources /reservoirs

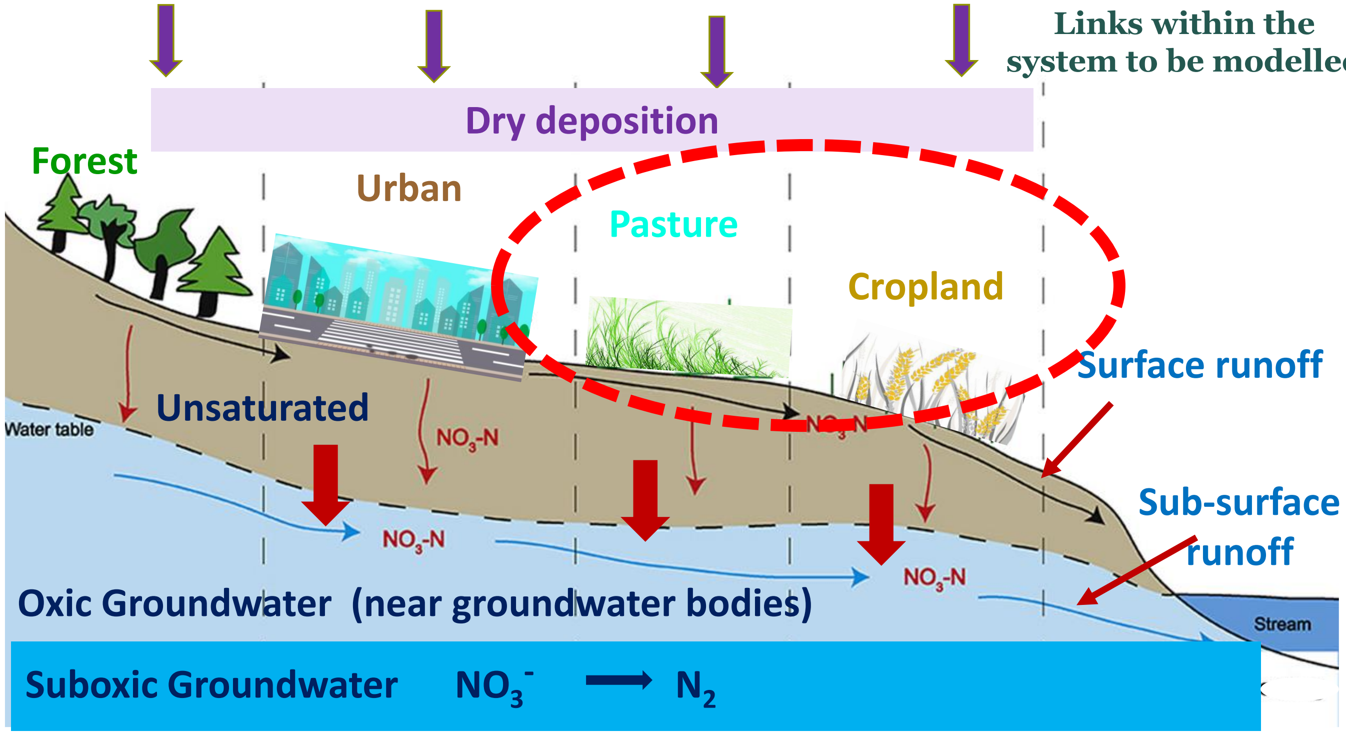
Overall **goal**:

to estimate the health effects and unit prices of drinking nitrate polluted water

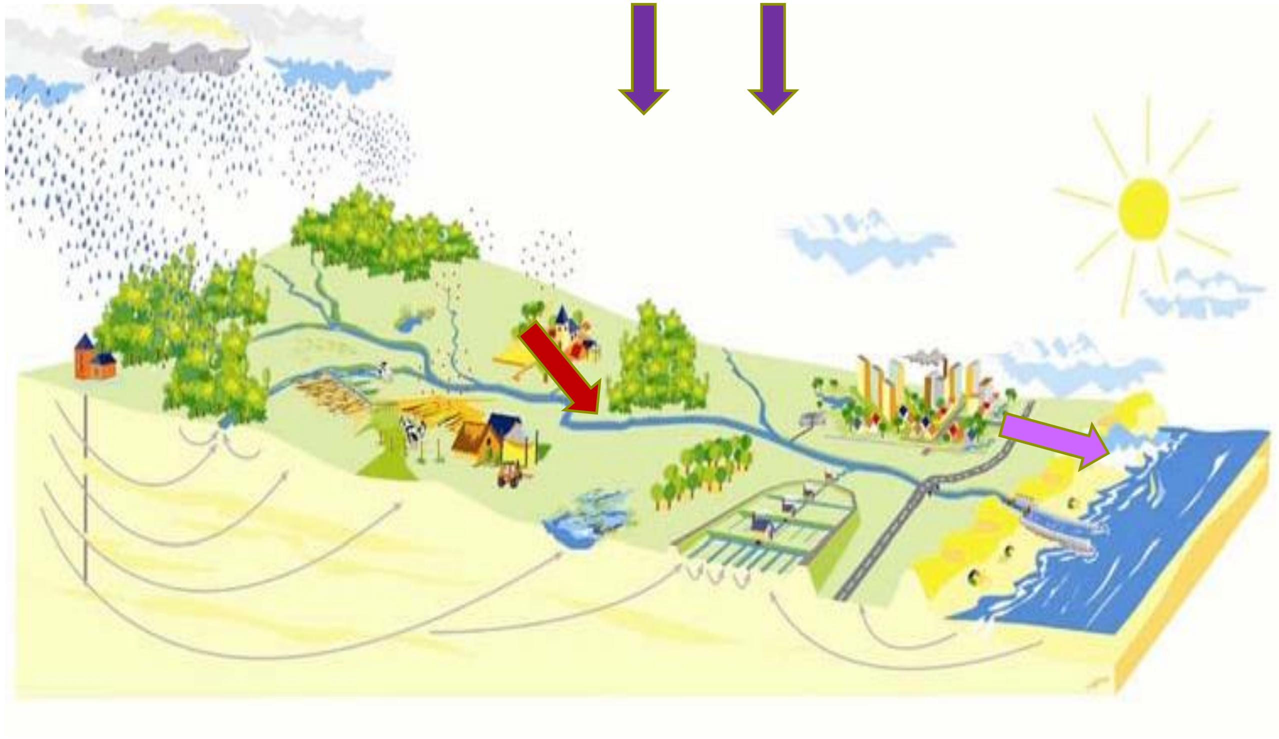
Specific goal:

- to evaluate the impact of agriculture on nitrate concentration of surface water (CZ) **and groundwater (DK)**
- to assess the single and combined effects of mitigation measures on nitrate pollution of drinking water sources

Links within the system to be modelled



Why focusing on agriculture?

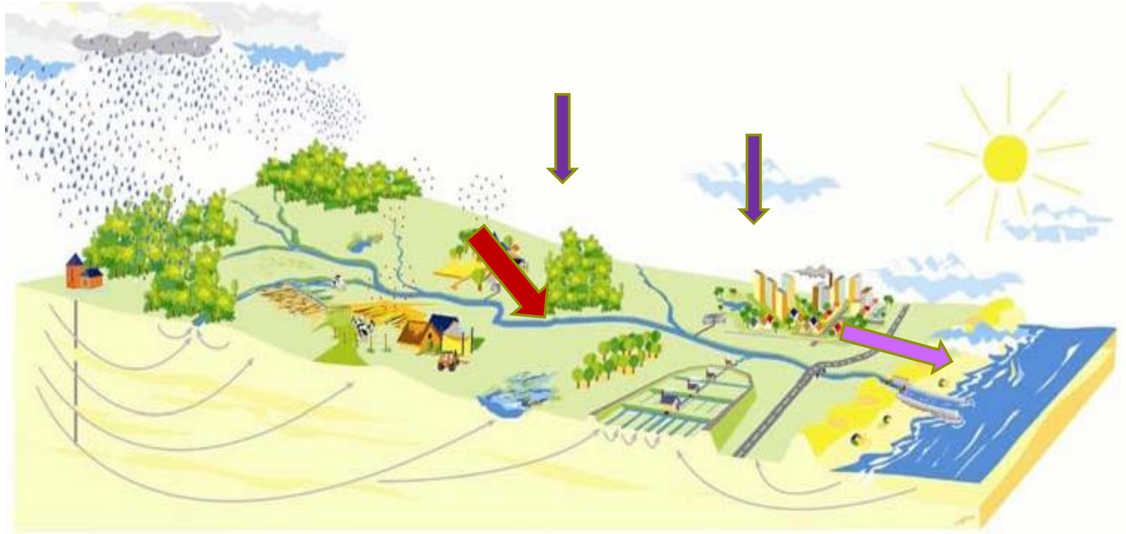


Various nitrogen sources

- Atmospheric deposition
  (problem at larger scales, other WPs)
- Point sources
  (industry, wastewater treatment plants)
- **Diffuse sources**
  (manure, mineral fertilizers ….)

" Along with gradually controlled point source discharges, diffuse nitrogen pollution has become an important cause of eutrophication" and water pollution. (Wang et al., Journal of Hydrology, 585:124833)

Why focusing on agriculture?



Various nitrogen sources

- Atmospheric deposition

  (problem at larger scales, other WPs)

- Point sources

  (industry, wastewater treatment plants)

- **Diffuse sources**

- Identification of **sources**
- Determining the main **pathways**
- Developing retention / removal **methods**

- **Region- and site specific**
- **Depend on several natural and antrophogenic factors**
- **Require complex assessment**

" Along with gradually controlled point source discharges, diffuse nitrogen pollution has become an important cause of eutrophication" and water pollution. (Wang et al., Journal of Hydrology, 585:124833)

Impact of agriculture on water quality

WE KNOW MUCH

- Impact of soil tillage practices
- Impact of crop management
- Effects of mitigation measures
- Impact of ongoing climate change

↓

- Local field-scale experiments
- Data mining and analyses
- Catchment and sub-catchment scale assessments

Some examples of practical experience / knowledge

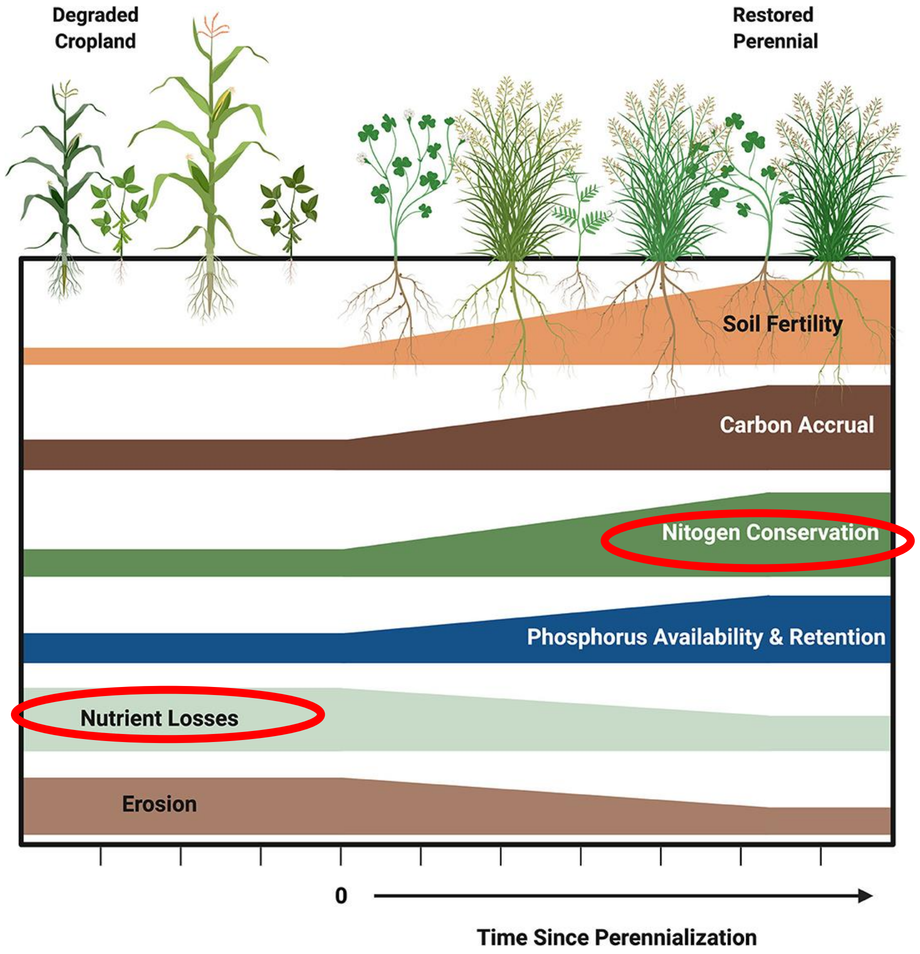
1. Soil tillage: from intensive to extensive systems - increase in water retention and reduction of N losses

	Conventional	Reduced
soil compaction	↑	↓
water retention	↓	↑
carbon sequestration	↓	↑

Some examples of practical experience / knowledge

1. Soil tillage: from intensive to extensive systems - increase in water retention and reduction of N losses

2. Land use change: from arable to grassland



www.frontiersin.org/articles/10.3389/fsufs.2021.706142/full

Some examples of practical experience / knowledge – in-field measures

1. **Soil tillage**: from intensive to extensive systems - increase in water retention and reduction of N losses

2. **Land use change:** from arable to grassland

3. **Winter cropping / stubble**

	Bare soil	Soil coverage
soil structure	↓	↑
water retention	↓	↑
soil loss	↑	↓
N- and P-loss	↑	↓

Some examples of practical experience / knowledge – structural measures

MULTI-FUNCTIONALITY AND ADVERSE EFFECTS OF MITIGATION MEASURES FOR WATER QUALITY IMPROVEMENTS IN THE AGRICULTURAL LANDSCAPE

PhD thesis 2020

Mette Vodder Carstensen

AU AARHUS UNIVERSITY

Chapter 25

DNMARK: Danish Nitrogen Mitigation Assessment: Research and Know-how for a Sustainable, Low-Nitrogen Food Production

Check for updates

Tommy Dalgaard, Steen Brock, Birgitte Hansen, Berit Hasler, Ole Hertel,
Nicholas J
Chris Kjel
Torben Sig
Katrine Tu

Abstract
Assessmen
alliance, fo

Journal of Environmental Management 352 (2024) 119877

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

ELSEVIER

Research article

Discordance between farmers and scientists - Perspectives on nitrogen reduction measures in Denmark

Sara V. Iversen *, Tommy Dalgaard, Morten Graversgaard

Department of Agroecology, Aarhus University, Blichers Allé, 8830, Tjele, Denmark

ARTICLE INFO

Handling Editor: Lixiao Zhang

Keywords:
Experience vs. expertise
Practice vs. research
Policy implementation
Water quality
Nitrogen governance
Q-methodology

ABSTRACT

Mitigating nitrogen leaching from agricultural land is imperative for enhancing the ecologic
ecosystems. Incorporating the knowledge and perceptions of farmers regarding the feasibility
implementing nitrogen reduction measures is vital for increasing the adoption rate of such m
policies. Concurrently, the insights and perspectives of scientists advising policymakers on the
these measures can facilitate a more comprehensive understanding of the barriers and p
mentation. In this study, we employ Q methodology to elucidate the opinions of 11 farmers a
involved in providing contractual science policy advice to Danish ministries on nitrogen r
Results show that across the perspectives of farmers and scientists, four main factors (

Mitigation measure applicability in the landscape

(after Mette Vodder Carstensen, PhD thesis)

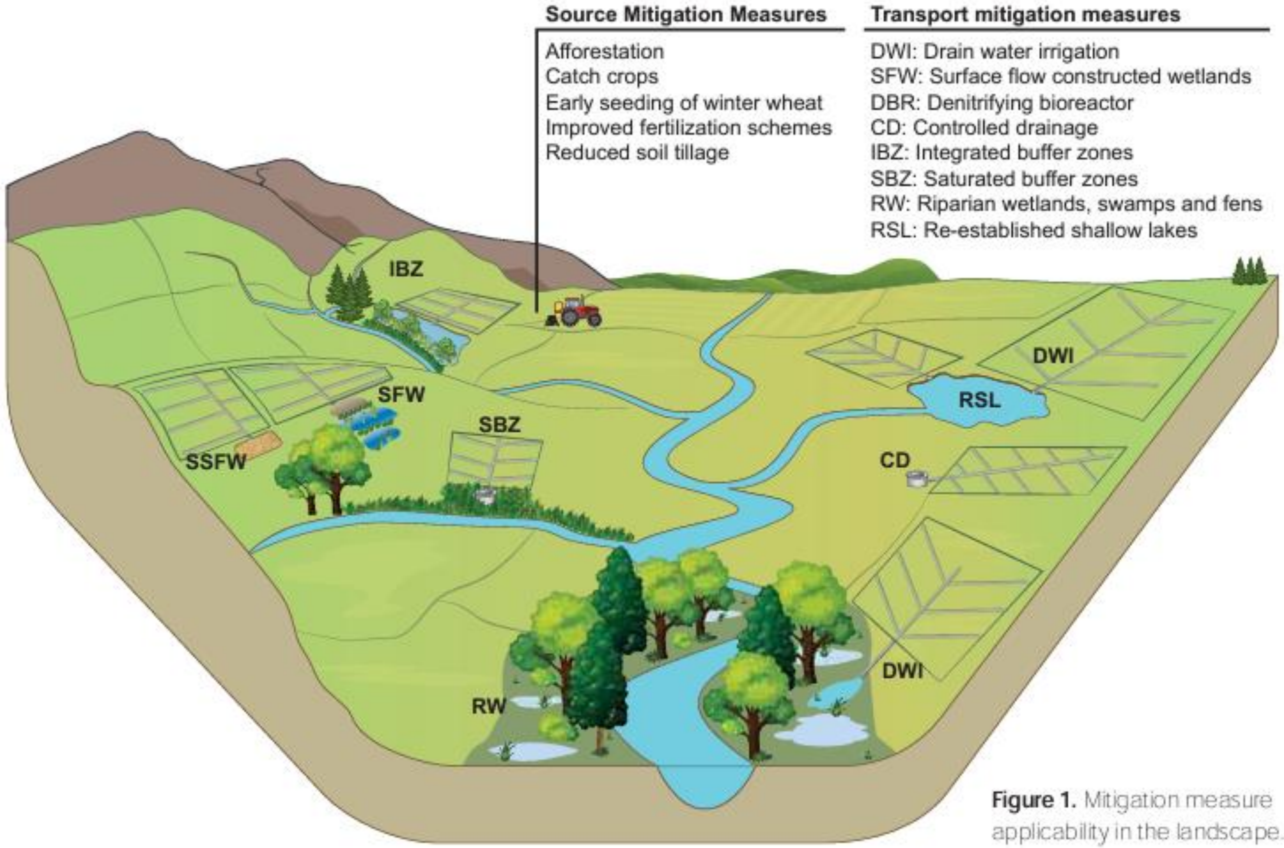


Figure 1. Mitigation measure applicability in the landscape.

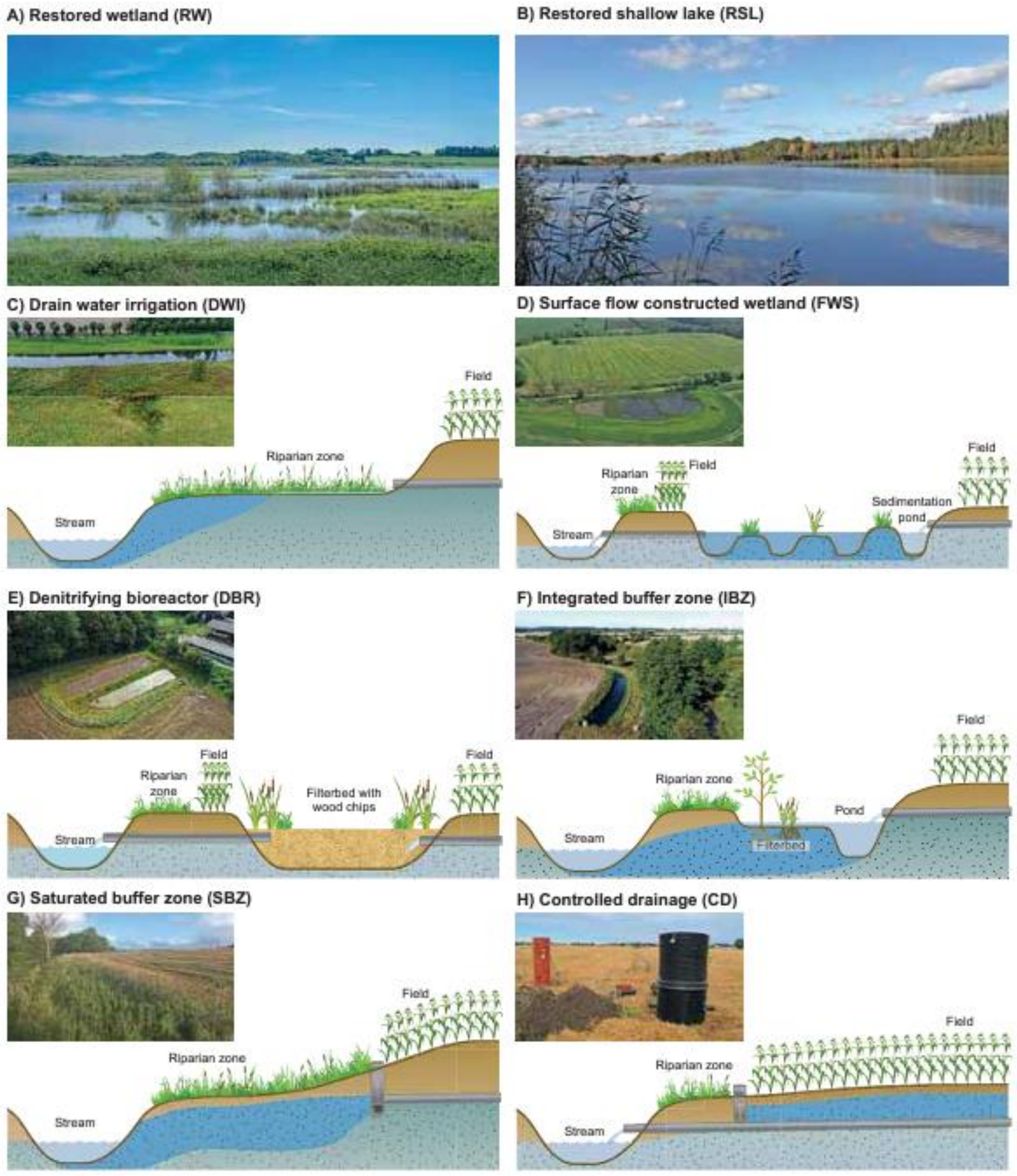
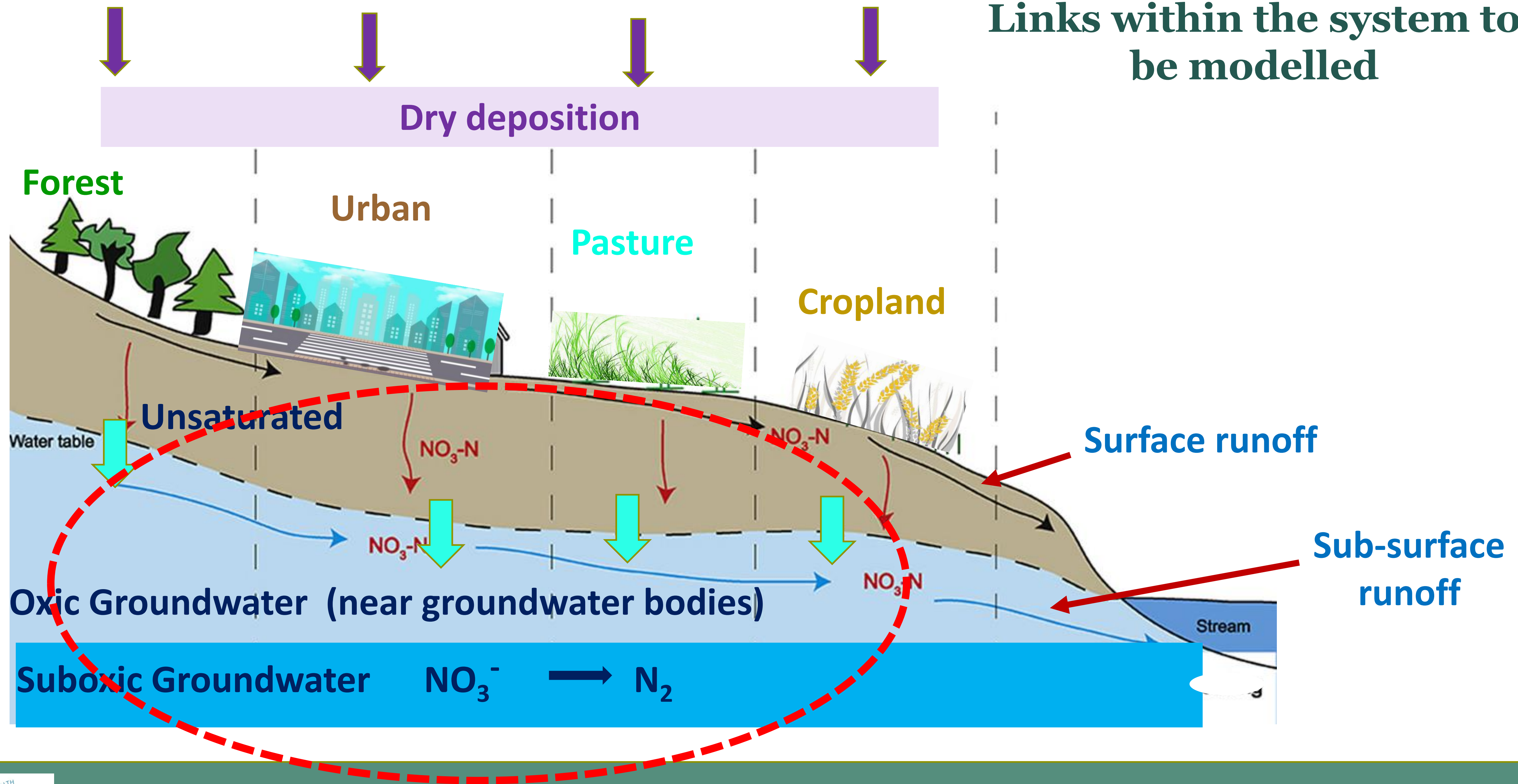


Figure 2. Types of nutrient transport mitigation measures and the sub-group of drainage mitigation measures (C-H).

Links within the system to be modelled



Impact of agriculture on water quality

WE KNOW MUCH

- Impact of **soil tillage** practices
- Impact of **crop management**
- Effects of **mitigation measures**
- Impact of ongoing **climate change**

- Soil- and site specific
- Crop-, soil- and site-specific
- Strongly depends on the **local conditions**
- **Cannot be interpreted for future climate conditions**

- Local field-scale experiments
- Data mining and analyses
- Catchment and sub-catchment scale assessments

BUT NOT ENOUGH

- Our knowledge is region-, crop-, soil etc. specific
- Limited knowledge on the effects of mitigation measures on groundwater nitrate input / concentration
- **Can not be extrapolated for so far unknown conditions**

Process-based environmental models

- **Integrate** the existing data, expertise and knowledge
- Incorporate **physically based description** of various processes
- Capable to describe **complex systems** and relationships

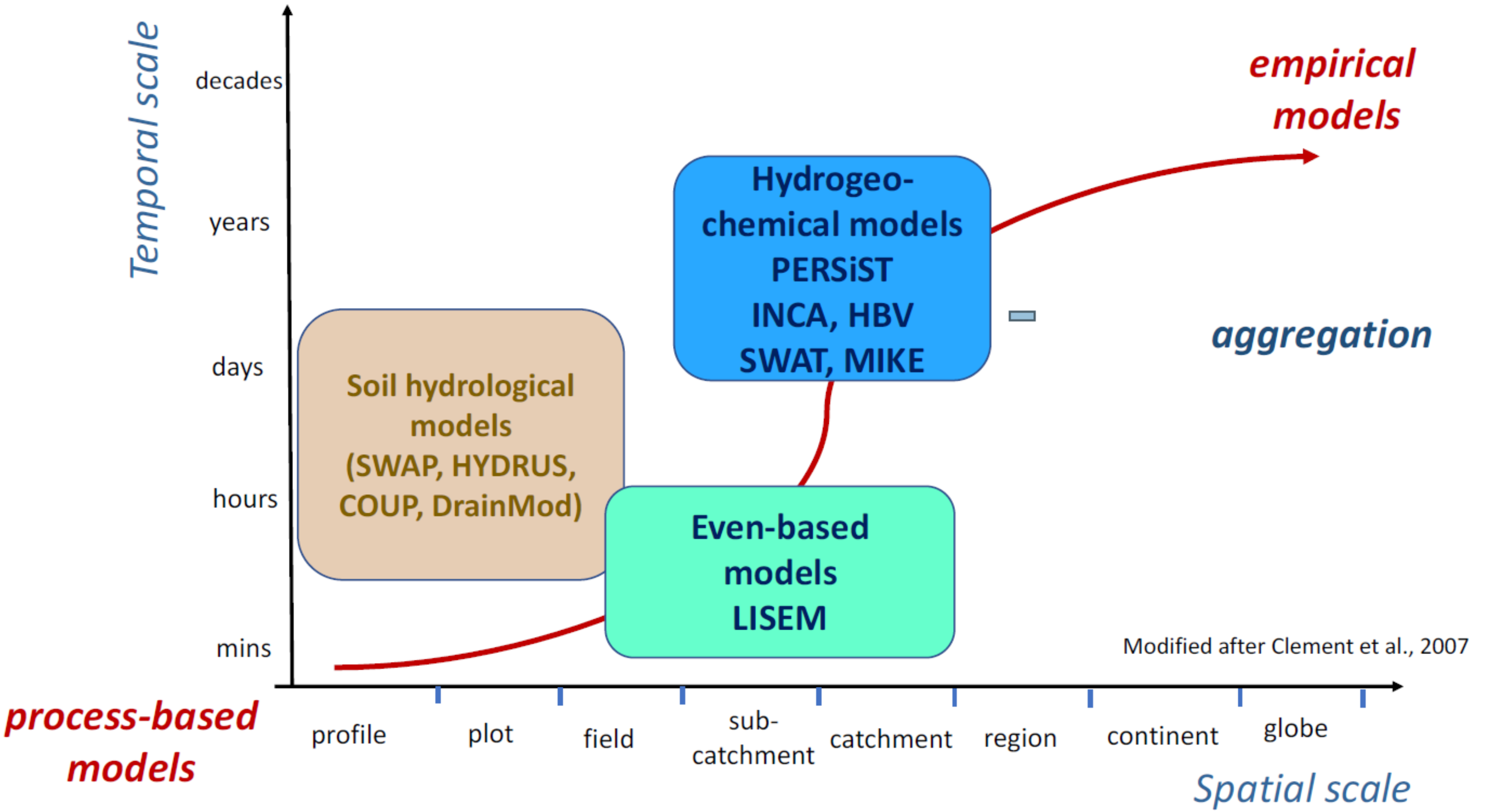
Can be used for

- Improving our knowledge about the systems and processes in focus and **process-understanding**
- **Spatio-temporal extension** of knowledge gained
- **Extrapolating** our knowledge for conditions that we have not experienced before
- **Optimising** various solutions for planning and decision-making

Tools for establishing linkages between farm nitrogen inputs and nitrogen concentrations in subsurface water

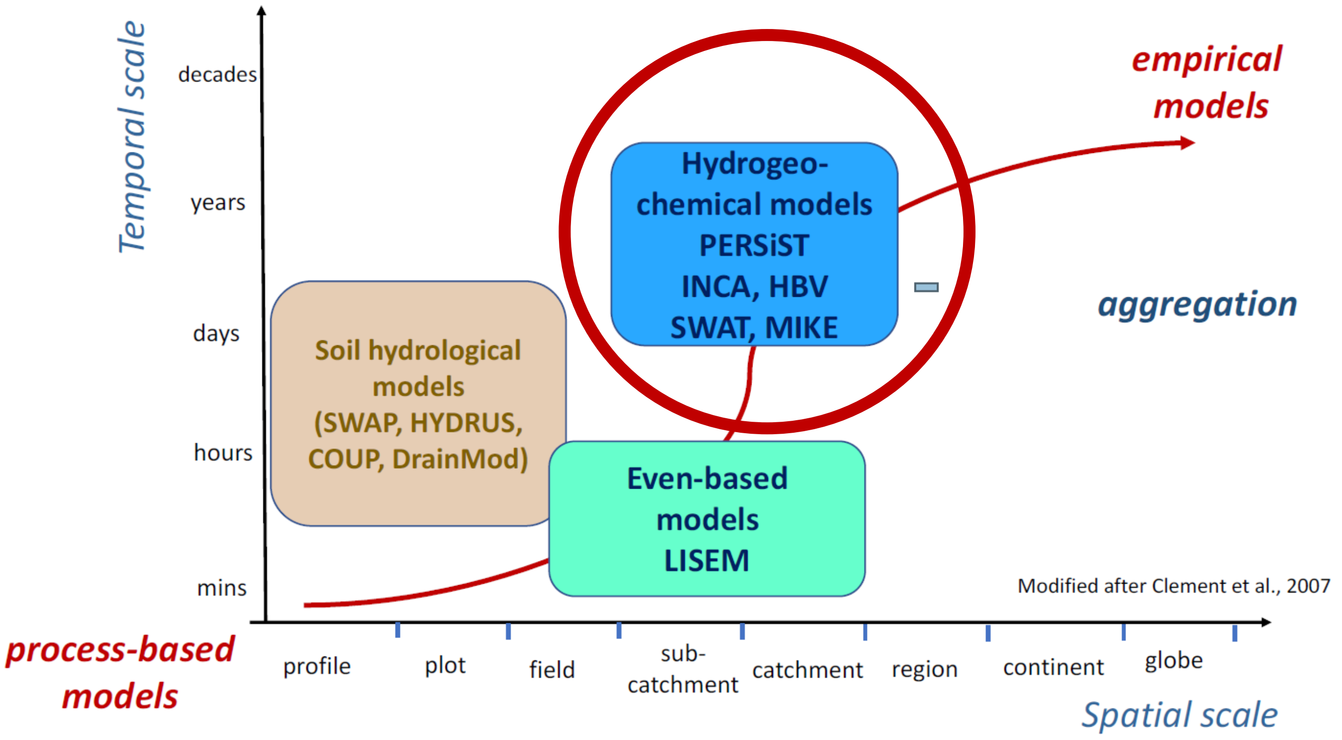
BUT!!! Should be used following the principles of „good modelling practice”

Hydro-geochemical models in their respective spatio-temporal scale



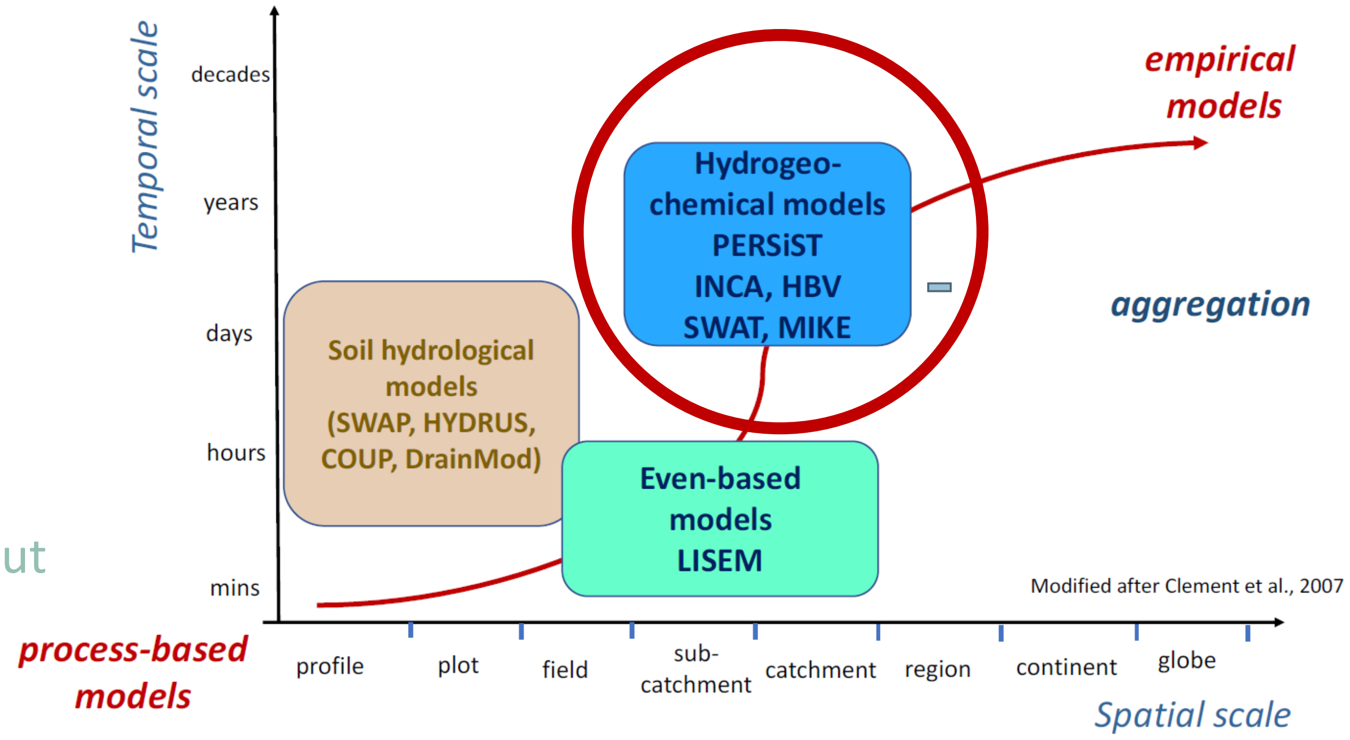
Advantages of using SWAT+ in MARCHES – WHY?

- Capable to simulate the processes in focus
- Accounts for connectivity
- Free software
- Widely used and tested
- Good support team and support group
- Spatial aspects of representing a catchment
- **Implementation of structural measures**
- **Agriculture-oriented (field management schemes, in-field measures)**



Particularities of SWAT+ / disadvantages

- Extremely **robust** model
- Extremely **data demanding** model
- Data scarcity problems
- Time consuming to set it up and calibrate
- Bugs found all the time, newer versions come out
- Different version, not easy to find support
- Relatively new model (developed from SWAT2012) – documentation is not yet complete



HORIZON | HEALTH MARCHES

NIBIO

Modelling workflow

- **Model setup and parameterisation**
  - Available data from the study catchment(s) and reach(es)
  - Literature review
  - **Expert assumptions (qualitative information)**
- **Verification**
- **Soft calibration – verifying the modelling results against expert knowledge, experience**
- **Hard calibration** (minimizing the difference between measured and modelled discharge and nitrate values)
- **Validation**
- **Scenario analyses** (evaluating the effects of NBSs on water quality under present and future conditions)

  Management scenarios

  Implementation of measures

  Climate change scenarios

Local expert knowledge useful for successful soft- and hard calibration

1. **Information about typical crop rotation and crop yields**

   Detailed information is available, but extremely time consuming to implement in the SWAT+ model

2. **Characteristic crop- and soil management information**

   Type and timing of tillage; fertilization amount and timing; winter crops, cover crops, stubble ..

3. **Mitigation measures applied and their effects on water and N fluxes and crop yield**

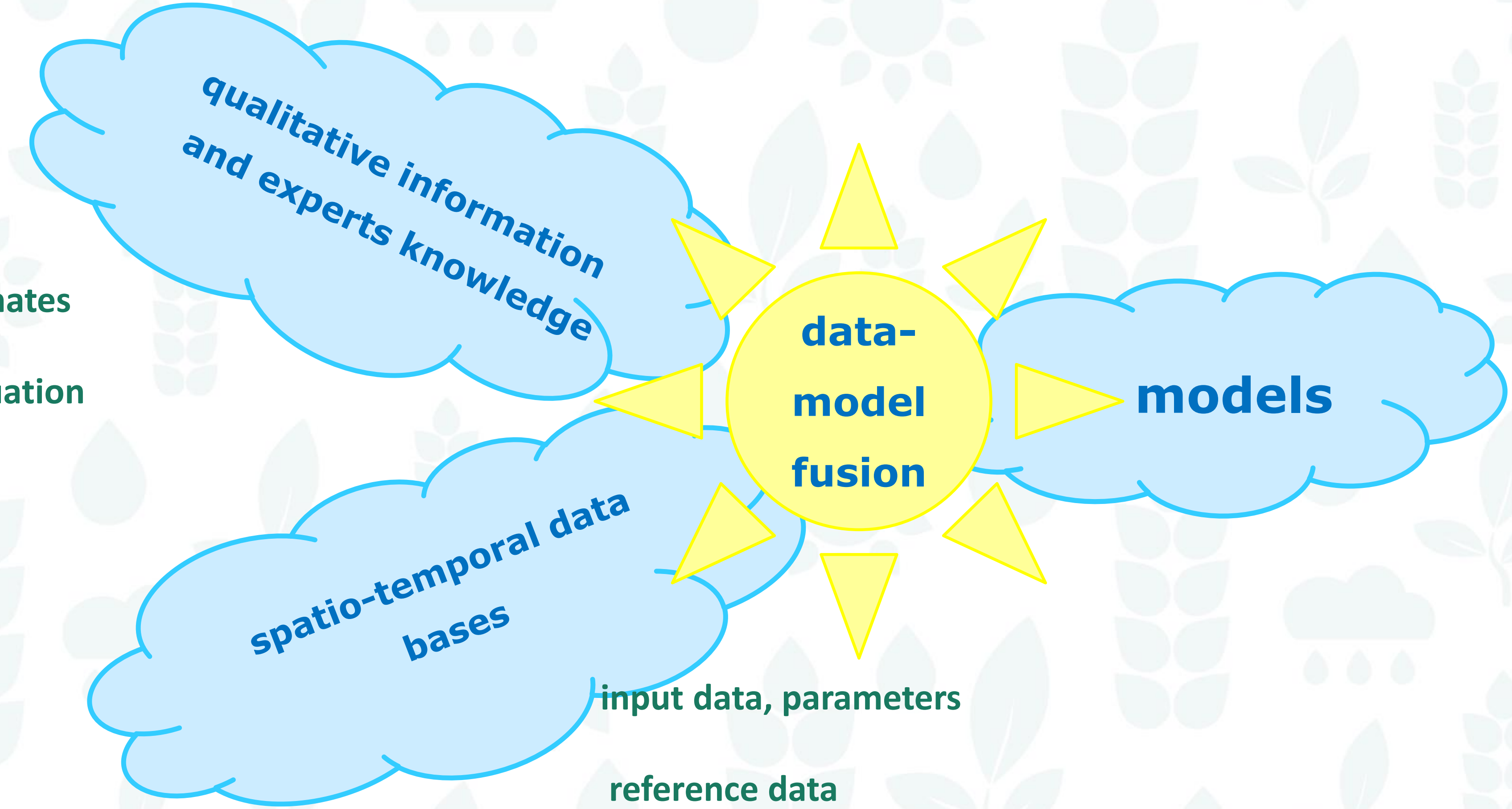
- *Used for model setup (refining, adjusting the current setup)*
- *Would be important to use for evaluating the results of soft-calibration*
- *Would be important to use for evaluating the first results on the effects of measures*

Data-model fusion – an advanced approach for studying complex systems

Model developers

expert estimates

expert evaluation



input data, parameters

reference data

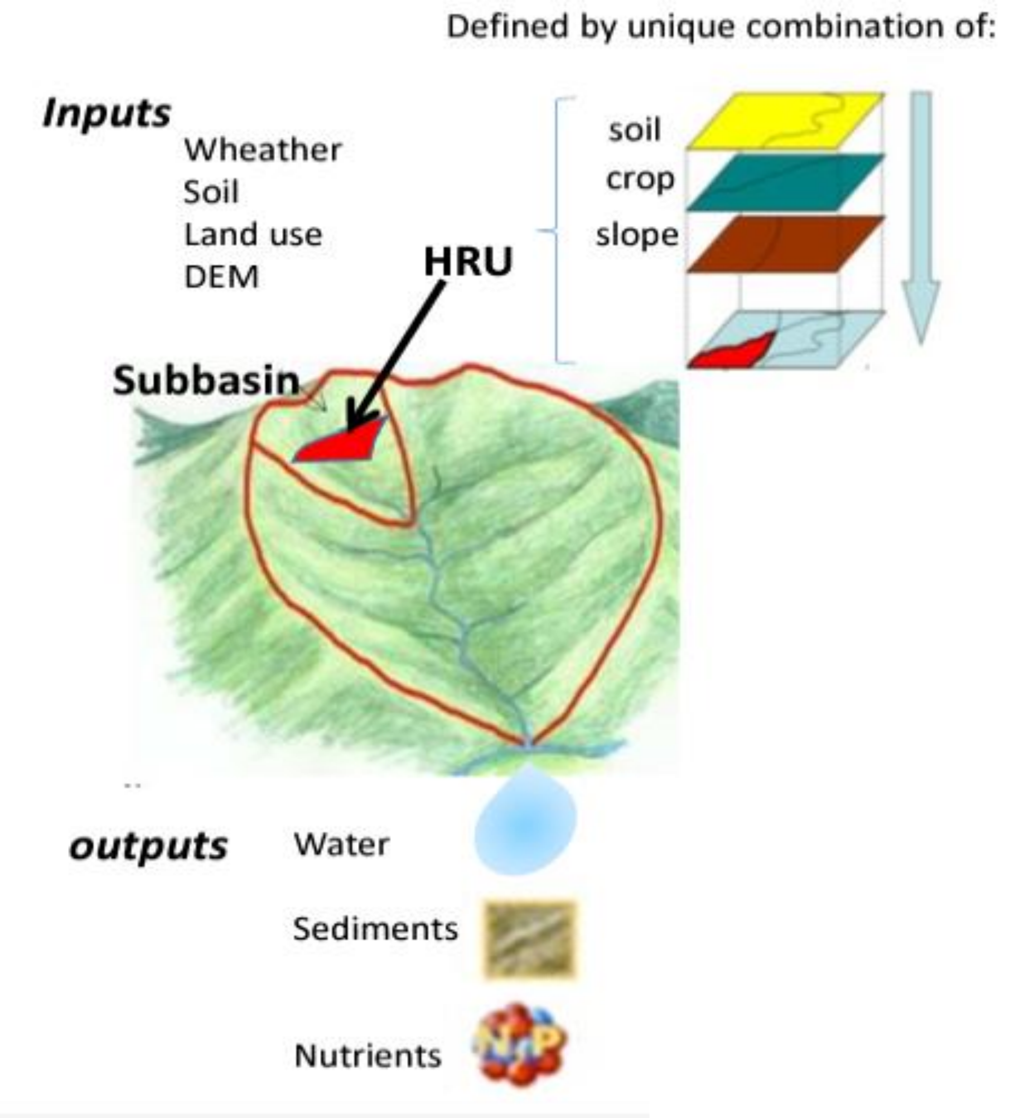
„Modeller"

Modelling is TEAM work

Stakeholders involvement from modelling prespective

- Spring 2024
  - Introduce the modelling concept
  - Introduce the data implemented in the SWAT+ model
  - Show the steps where expert / stakeholder knowledge is highly welcome
- Summer 2025
  - Joint evaluation of the model soft-calibration results
  - Evaluation of the calibration / validation results
  - Evaluation of the first results on the effects of mitigation measures
- Undefined in 2026
  - Presenting and discussing the modelling results (strengths, uncertainty etc.)
  - Presenting and discussing the results on mitigation measures
  - Discussing the opportunities of reducing nitrate leaching to groundwater systems

SWAT+ data requirement



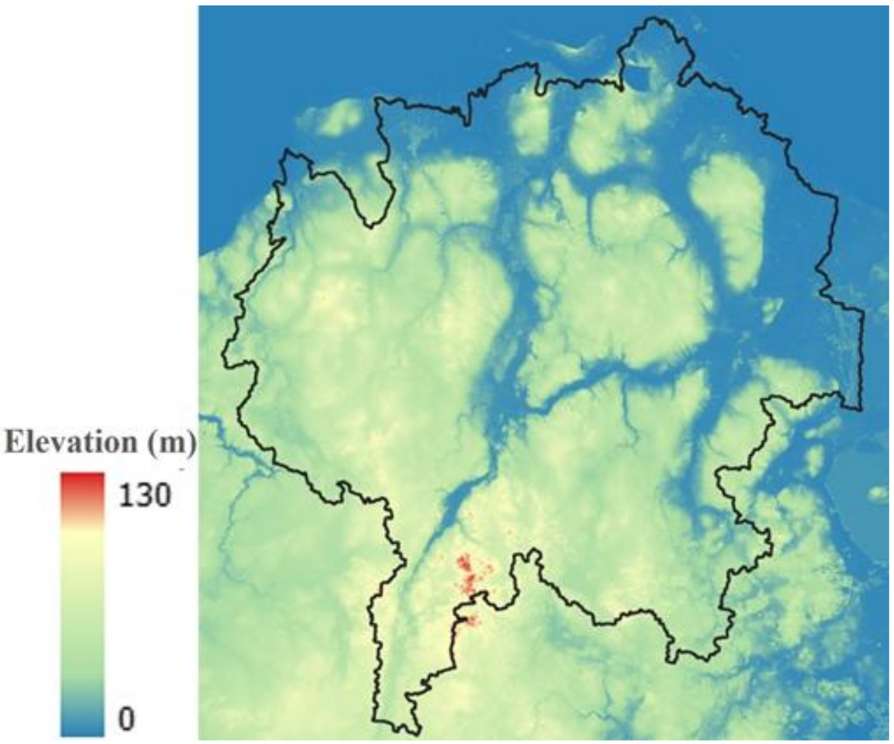
- Digital Elevation Model
- Soil data
- Land use data
- Watershed information
    - Catchment boundaries
    - Stream network
    - Ponds, lakes etc.

- Meteorological data
- Crop data
- Management data
- Data on point sources

- Reference data for model calibration

Digital elevation model

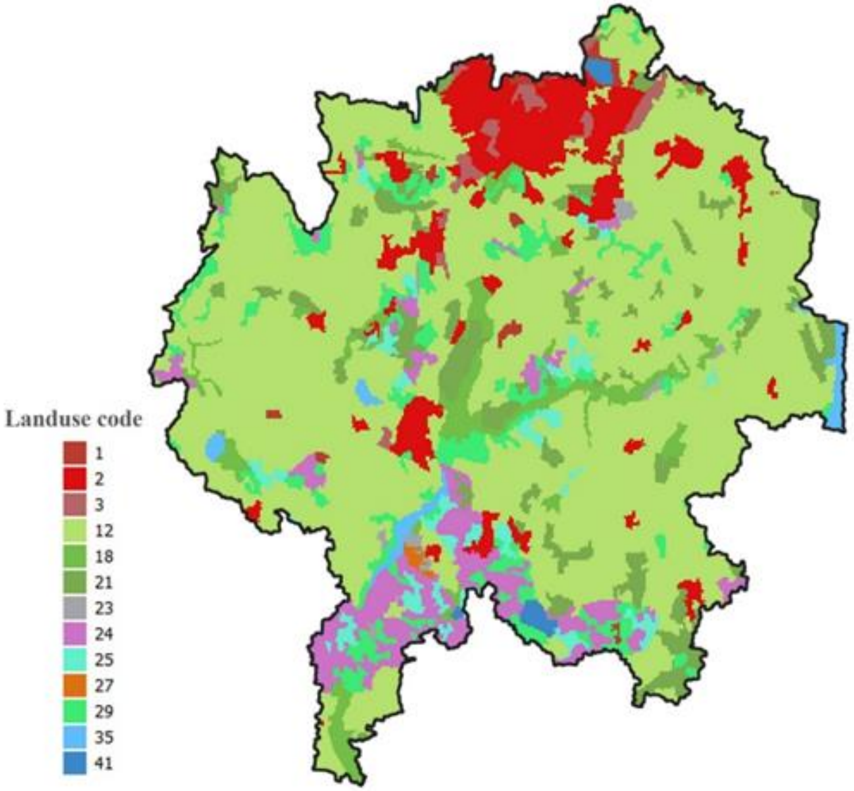
- Copernicus Digital Elevation Model (DEM)
- 30 m resolution



Land use

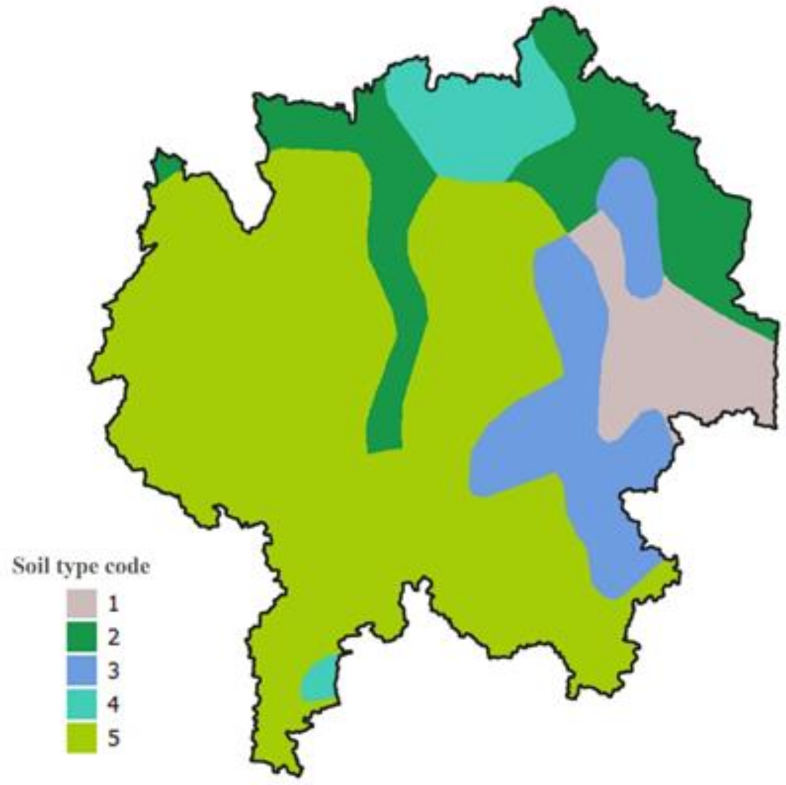
- CORINE Land Use data (v. 2018)
- 100 m resolution, raster

Code	land use type
1	Continuous urban fabric
2	Discontinuous urban fabric
3	Industrial or commercial units
12	Non-irrigated arable land
18	Pastures
19	Annual crops associated with permanent crops
20	Complex cultivation patterns
21	Land principally occupied by agriculture with significant areas of natural vegetation
23	Broad-leaved forest
24	Coniferous forest
25	Mixed forest
27	Moors and heathland
29	Transitional woodland-shrub
35	Inland marshes
41	Water bodies



Soil map

- ➢ European Soil Database v2.0 (EUSD)
- ➢ Soil metadata; shape file



Soil data

Soil class	Information
1	Medium AWC at both top and sub layer. Also contains peat.
2	Medium AWC at top layer, low AWC at sublayer.
3	High AWC at both top and sub layer.
4	Medium AWC at top layer, high AWC at sublayer.
5	Medium AWC at top layer, low AWC at sublayer.

No.	Parameter	Code
1	Soil texture (in terms of clay, silt, and sand content in percentage of soil weight)	Texture
2	Depth of the soil layer in mm	SOL_Z
3	The number of layers present in the soil profile.	N-layer
4	Maximum rooting depth of the soil profile	SOL_ZMX
5	Bulk density in gm/cm3	SOL_BD
6	Saturated hydraulic conductivity in mm/hr	SOL_K
7	Organic carbon content in percentage of soil weight	SOL_CBN
8	Rock fragment content in percentage of the total weight of that layer	ROCK
9	Available water capacity of the soil layer in mm H20/mm soil	SOL_AWC
10	Moist soil albedo only for the topsoil layer	SOL_ALB
11	Soil hydrologic group (A, B, C or D)	-
12	Soil erodibility factor K in (metric ton m2 hr)/(m3 metric ton cm) estimated using the Universal Soil Loss Equation	USLE_K

Crop rotation and management

- Google Earth Engine platform
- Uses the EU LUCAS database based on Sentinel data
- https://zenodo.org/records/6669644

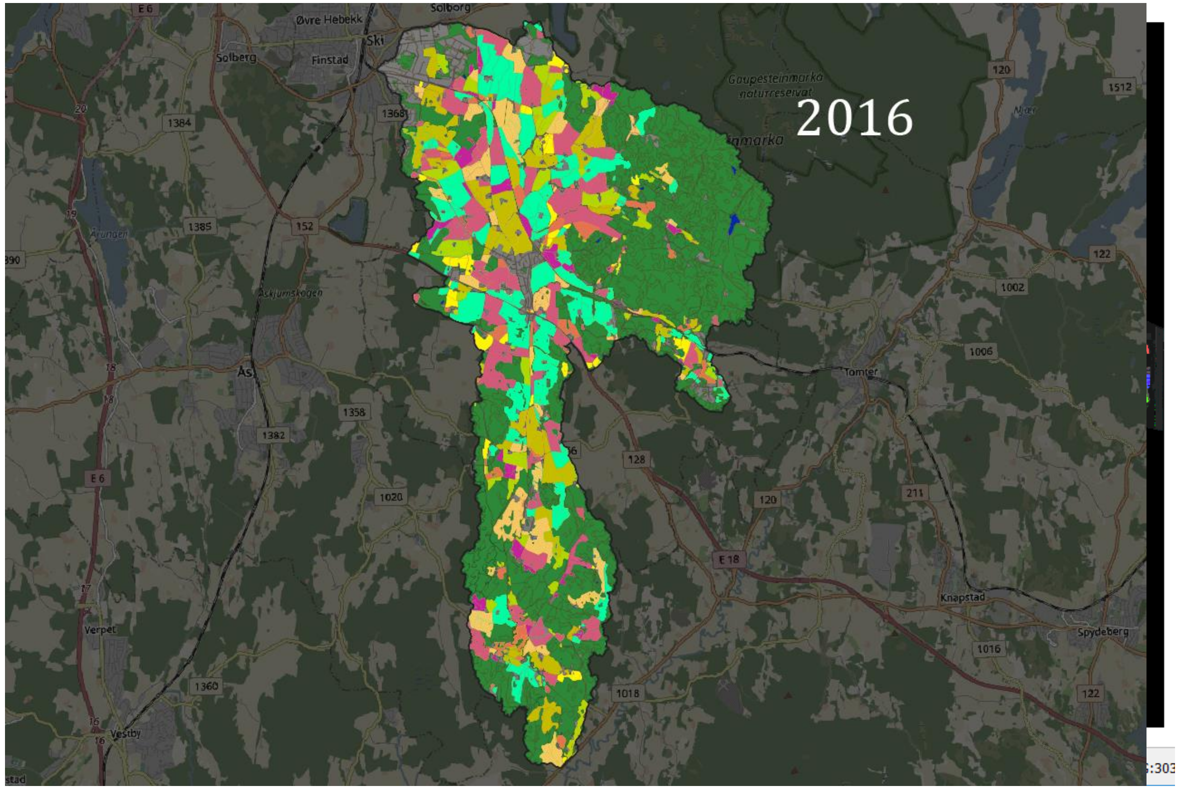


Table 2: LUCAS and OPTAIN-optimized crop codes legend.

OPTAIN cropmap code	Name	LUCAS codes
1	Artificial land	A11, A12, A13, A21, A22
3	Wood- and shrubland	C10, C21, C22, C23, C31, C32, C33, D10, D20
5	Grassland	E10, E20, E30 + B55 (temporary grassland)
6	Bare land	F10, F20, F30, F40
7	Water surfaces	G10, G11, G12, G20, G21, G22, G30, G50
8	Wetlands	H11, H12, H21, H22, H23
11	Common wheat	B11
12	Durum wheat	B12
13	Barley	B13
14	Rye	B14
15	Oats	B15
16	Maize	B16
17	Rice	B17
19	Other cereals	B19
21	Potatoes	B21
22	Sugar beet	B22
23	Other root crops	B23
31	Sunflower	B31
32	Rape and turnip rape	B32
33	Soya	B33
34	Cotton	B34
35	Other fibre crops	B35
36	Tobacco	B36
37	Other non-permanent industrial crops	B37
41	Dry pulses	B41
42	Tomatoes	B42
43	Other fresh vegetables	B43
44	Floriculture and ornamental plants	B44
45	Strawberries	B45
51	Clovers	B51
52	Lucerne	B52
53	Other leguminous and mixtures for fodder	B53
54	Mixed cereals for fodder	B54
71	Apple fruit	B71
72	Pear fruit	B72
73	Cherry fruit	B73
74	Nuts trees	B74
75	Other fruit trees and berries	B75
76	Oranges	B76
77	Other citrus fruit	B77

- ✓ Set up weather stations and weather generators
- ✓ Wrote SWAT+ input files
- ✓ Ran SWAT+
- ✓ Imported SWAT+ output into a database for analysis

FirstRun

testrun

S+ Split Landuses

Select landuse to split: AGRL

Select split landuse to edit:

Add sub-landuse

Delete sub-landuse

Delete split landuse

Landuse	Sub-landuse	Percent
AGRL	WWHT	25
	BARL	25
	CLVR	25
	CORN	25

Cancel edits | Save edits

Save splits | Cancel

Tota

Sim

Obj

4

230

16

4

16

16

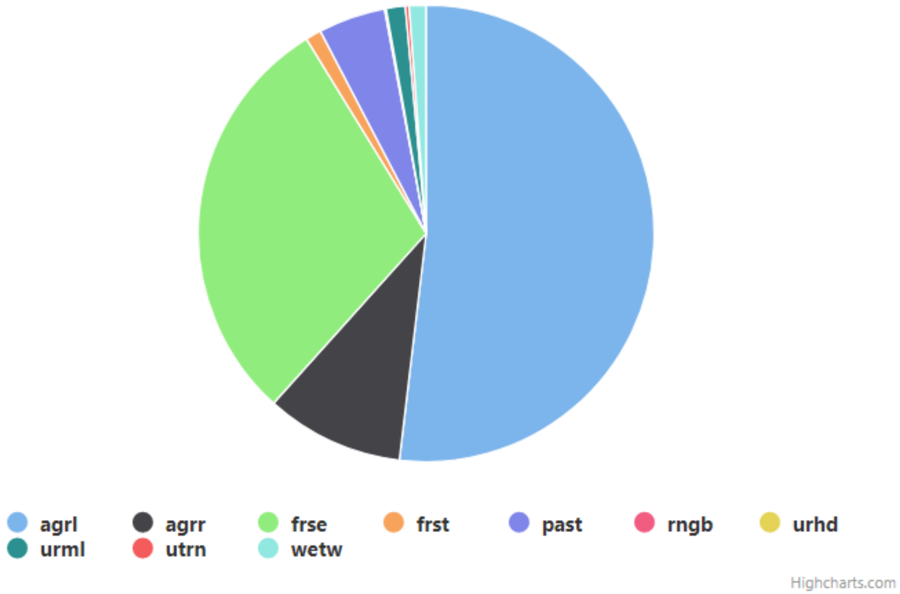
16

0 Delivery Ratio

SWAT+ Project information

Software	SWAT+ Editor 2.3.3, QSWAT+ 2.4.7
Last saved	Sun, May 12, 2024 8:46 PM

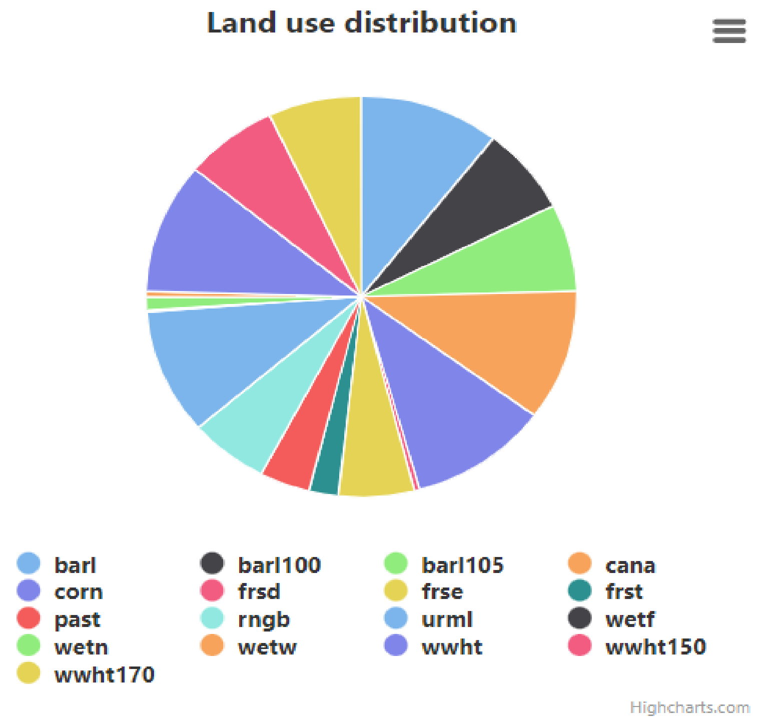
CORINE land use categories



Run Model / Save Scenario | Open in SWAT+ Toolbox | Change Name/Description | Re-import from GIS

Crop rotation and management

- ➢ Google Earth Engine platform
- ➢ Uses the EU LUCAS database based on Sentinel data
- ➢ https://zenodo.org/records/6669644

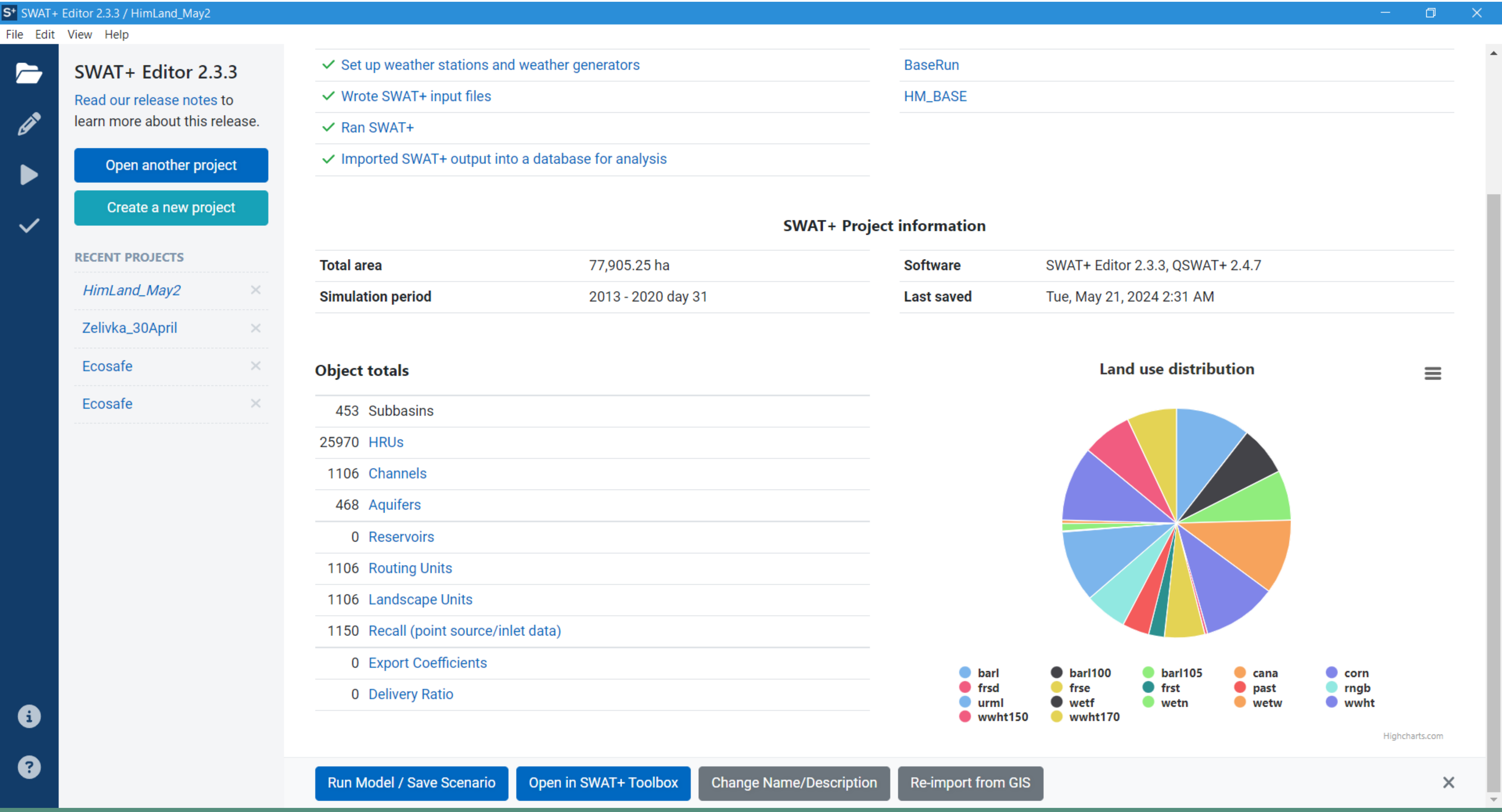


	Area (% of AGRL)							
	15	15	15	15	10	10	10	10
	Canola	Barley	Corn	wwht	wwht150	wwht170	barl100	barl105
2015	RAPE	SBARL	CORN	WCER	WCER	WCER	SBARL	SBARL
2016	SBARL	RAPE	SBARL	SBARL	CORN	WCER	WCER	WCER
2017	SBARL	SBARL	RAPE	SBARL	WCER	CORN	WCER	WCER
2018	SBARL	SBARL	SBARL	SBARL	SBARL	RAPE	CORN	WCER
2019	WCER	CORN	SBARL	RAPE	SBARL	SBARL	SBARL	SBARL
2020	SBARL	SBARL	SBARL	SBARL	WCER	CORN	RAPE	SBARL
2021	SBARL	SBARL	SBARL	SBARL	SBARL	WCER	CORN	RAPE

IKT3	Green spring barley-Grass-clover	Grass-clover	Grass-clover	Grass-clover	Green spring barley-grass	Spring barley
IKT4	Green spring barley-grass	Grass	Grass	Grass	Spring barley	Spring barley
IKT6	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat
Je1	Winter wheat	Winter wheat	Spring barley	Winter wheat	Winter wheat	Winter wheat
K3	Silage maize	Green spring barley-Grass-clover	Grass-clover	Grass-clover	Grass-clover	Spring barley MCC
K4	Green spring barley-Grass-clover	Grass-clover	Spring barley MCC[b]	Spring barley	Winter barley	Winter wheat
K5	Green spring barley-Grass-clover	Grass-clover	Grass-clover	Spring barley MCC	Spring barley	Winter wheat
K6	Green spring barley-Grass-clover	Grass-clover	Grass-clover	Grass-clover	Spring barley	Winter barley MCC
K7	Green spring barley-Grass-clover	Grass-clover	Grass-clover	Grass-clover	Grass-clover	Spring barley MCC
K8	Grass-clover (ploughing; re-seeded)	Grass-clover	Grass-clover	Grass-clover	Grass-clover	
KK1	Silage maize	Silage maize	Silage maize	Silage maize	Silage maize	Silage maize
KK2	Silage maize	Silage maize	Green spring barley-Grass-clover	Grass-clover	Grass-clover	Spring barley MCC
P1	Winter rape	Spring barley MCC	Spring wheat	Spring barley	Winter wheat	Winter barley
PK2	Spring barley	Spring barley MCC	Potatoe	Spring barley		
PK4	Spring barley	Winter barley MCC	Spring barley-seed grass	Seed grass	Seed grass	Winter wheat
PK5	Spring barley	Winter wheat	Sugar beet	Spring barley	Winter wheat	Sugar beet
S2	Spring barley	Winter rape	Winter wheat	Winter wheat	Pea till maturity	Winter barley MCC
SK1	Spring barley MCC	Spring barley	Spring barley	Spring barley	Spring barley	Spring barley

[a] IDs denote crop rotations; also used in the paper text and figures.
[b] "MCC" after a few crops indicate a mandatory catch crop according to Danish environmental regulations, which was ryegrass and oil radish for spring barley and winter barley, respectively.

NIBIO

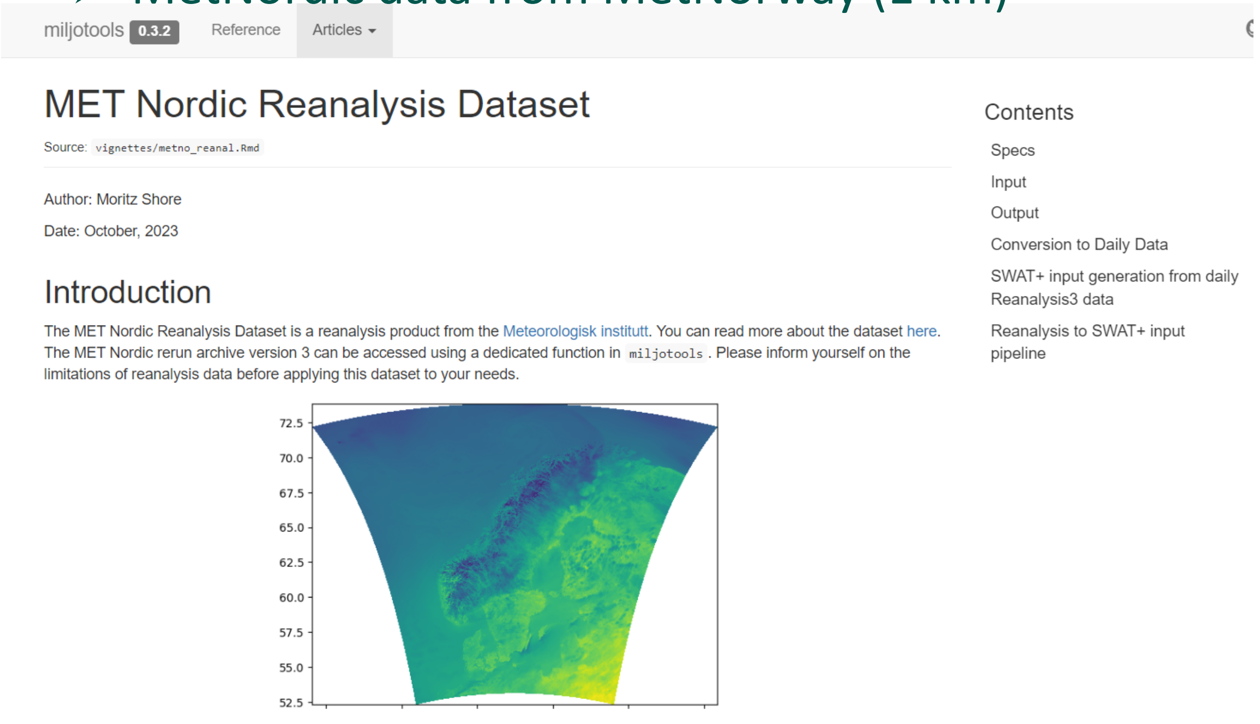

SWAT+ Editor 2.3.3 / HimLand_May2
File Edit View Help
SWAT+ Editor 2.3.3
Read our release notes to learn more about this release.
Open another project
Create a new project
RECENT PROJECTS
HimLand_May2
Zelivka_30April
Ecosafe
Ecosafe
Set up weather stations and weather generators
Wrote SWAT+ input files
Ran SWAT+
Imported SWAT+ output into a database for analysis
BaseRun
HM_BASE
SWAT+ Project information
Total area 77,905.25 ha
Simulation period 2013 - 2020 day 31
Software SWAT+ Editor 2.3.3, QSWAT+ 2.4.7
Last saved Tue, May 21, 2024 2:31 AM
Object totals
453 Subbasins
25970 HRUs
1106 Channels
468 Aquifers
0 Reservoirs
1106 Routing Units
1106 Landscape Units
1150 Recall (point source/inlet data)
0 Export Coefficients
0 Delivery Ratio
Land use distribution
barl
barl100
barl105
cana
corn
frsd
frse
frst
past
rngb
urml
wetf
wetn
wetw
wwht
wwht150
wwht170
Highcharts.com
Run Model / Save Scenario
Open in SWAT+ Toolbox
Change Name/Description
Re-import from GIS

Meteorological input data

- ECMWF ERA5 Re-analyses data
- Produced by the Copernicus Climate Service
- Approx. 31 km resolution
- 16 grid points within the catchment

  - Maximum air temperature
  - Minimum air temperature
  - Daily precipitation sum
  - Air humidity
  - Solar radiation
  - Wind speed

- Danish Meteorological Institute (5 km)
- MetNordic data from MetNorway (1 km)


miljotools 0.3.2 Reference Articles

MET Nordic Reanalysis Dataset

Source: vignettes/metno_reanal.Rmd

Author: Moritz Shore

Date: October, 2023

Introduction

The MET Nordic Reanalysis Dataset is a reanalysis product from the Meteorologisk institutt. You can read more about the dataset here. The MET Nordic rerun archive version 3 can be accessed using a dedicated function in miljotools. Please inform yourself on the limitations of reanalysis data before applying this dataset to your needs.

Contents

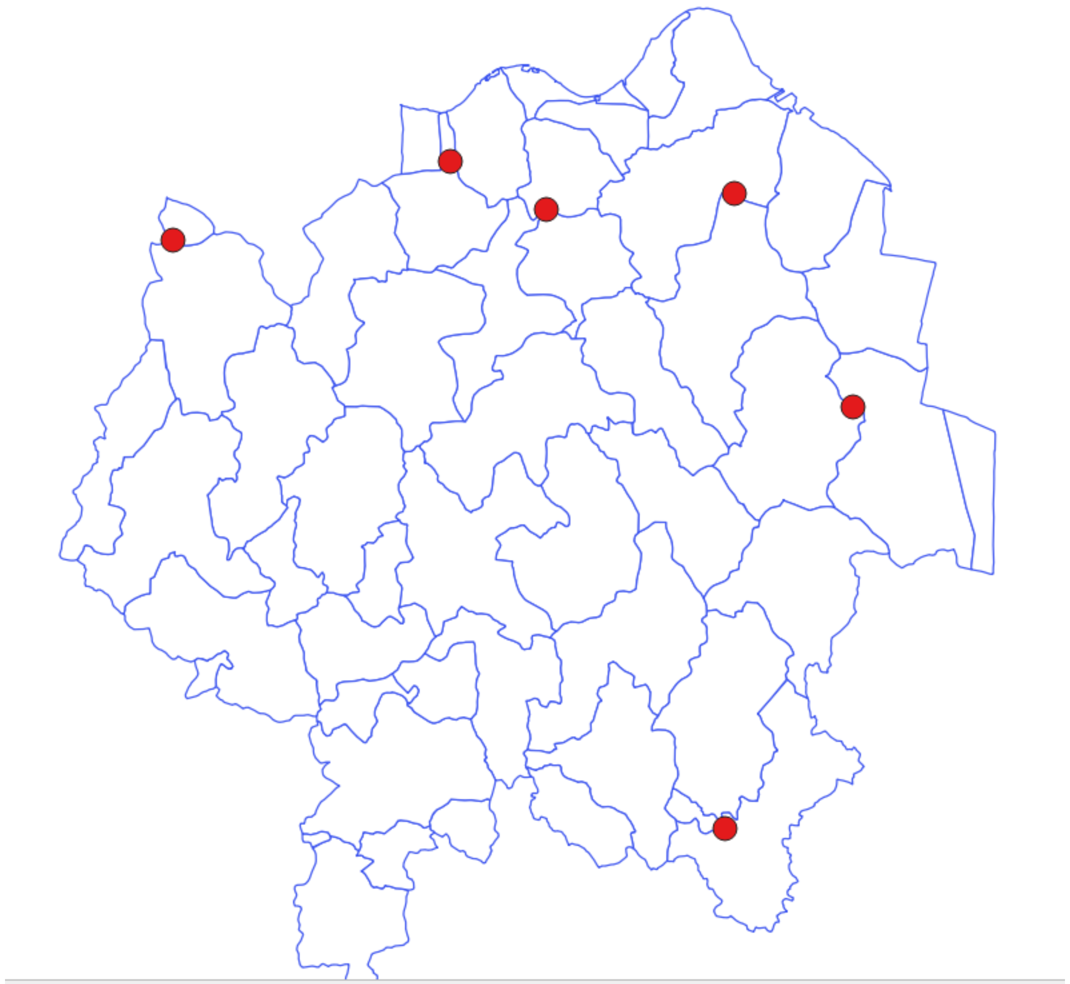
Specs
Input
Output
Conversion to Daily Data
SWAT+ input generation from daily Reanalysis3 data
Reanalysis to SWAT+ input pipeline

https://moritzshore.github.io/miljotools/articles/metno_reanal.html

https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5.

NIBIO

Reference data



Himmerland watershed

- Surface water database of the Danish Ministry of Environment
- Accessible via Aarhus University weebsite
- 6 stations in total
  - Daily average flow
  - Nitrate concentration data (bi-weekly)

NIBIO

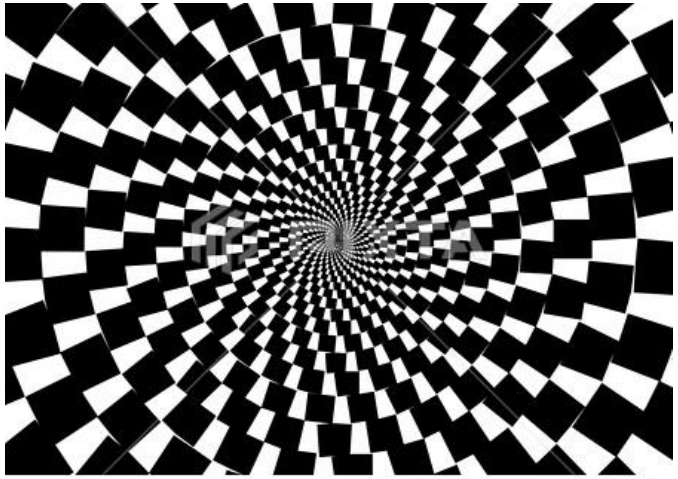
Modelling workflow

- **Model setup and parameterisation**
  - Available data from the study catchment(s) and reach(es)
  - Literature review
  - Expert assumptions (qualitative information)
- **Verification**
- **Soft calibration**
- **Hard calibration** (minimizing the difference between measured and modelled discharge and nitrate values)
- **Validation**
- **Scenario analyses** (evaluating the effects of NBSs on water quality under present and future conditions)

  Management scenarios

  Implementation of measures

  Climate change scenarios



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Model verification (highlights)

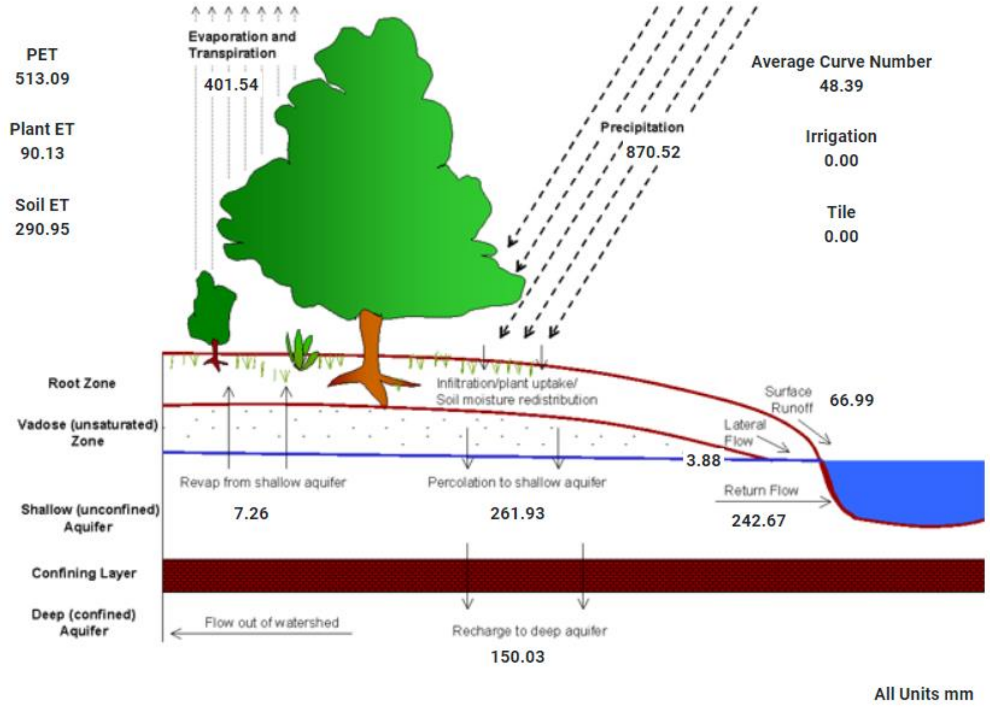
- Information
- **Hydrology**
- Sediment
- Nitrogen Cycle
- Phosphorus Cycle
- Plant Growth
- Landscape Nutrient Losses
- Land Use Summary
- Instream Processes
- Point Sources
- Reservoirs

SWAT+ Check / Hydrology

Realistic hydrology is the foundation of any model. Pay particular attention to evapotranspiration, baseflow and surface runoff ratios. Baseflow/streamflow ratios for the US are provided by the USGS, these data are accessible via the button below. The ranges specified here are general guidelines only, and may not apply to your simulation area.

Messages and Warnings

- Surface runoff ratio may be low (< 0.2)
- Groundwater ratio may be high



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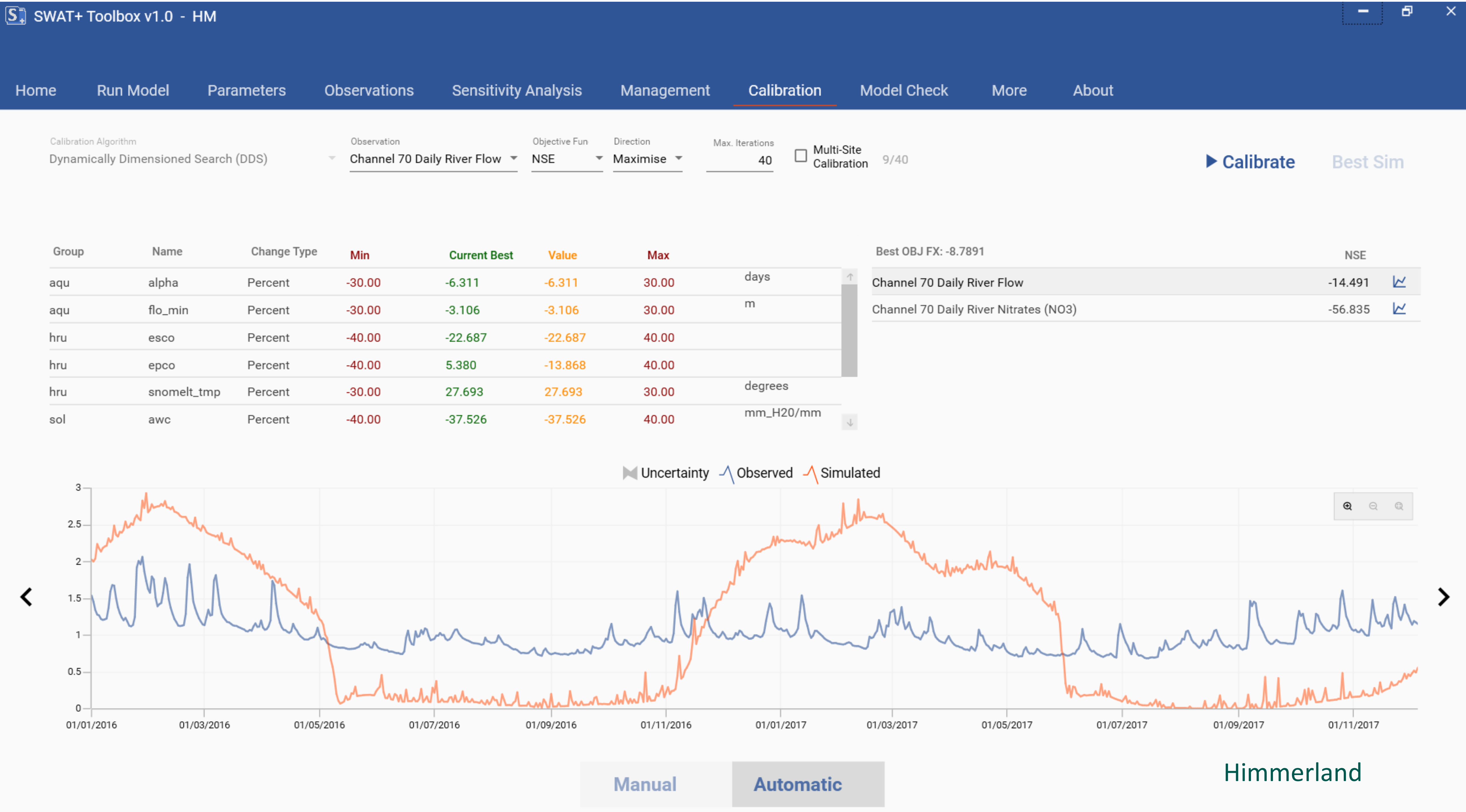
Exit SWAT+ Editor


SWAT+ Toolbox v1.0 - HM
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Maximise
Max. Iterations
40
Multi-Site Calibration
9/40
Calibrate
Best Sim
Group Name Change Type Min Current Best Value Max
aqu alpha Percent -30.00 -6.311 -6.311 30.00 days
aqu flo_min Percent -30.00 -3.106 -3.106 30.00 m
hru esco Percent -40.00 -22.687 -22.687 40.00
hru epco Percent -40.00 5.380 -13.868 40.00
hru snomelt_tmp Percent -30.00 27.693 27.693 30.00 degrees
sol awc Percent -40.00 -37.526 -37.526 40.00 mm_H20/mm
Best OBJ FX: -8.7891
NSE
Channel 70 Daily River Flow -14.491
Channel 70 Daily River Nitrates (NO3) -56.835
Uncertainty
Observed
Simulated
3
2.5
2
1.5
1
0.5
0
01/01/2016
01/03/2016
01/05/2016
01/07/2016
01/09/2016
01/11/2016
01/01/2017
01/03/2017
01/05/2017
01/07/2017
01/09/2017
01/11/2017
Manual
Automatic

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Calibration Algorithm: Dynamically Dimensioned Search (DDS)

Observation: Channel 70 Daily River Flow

Objective Fun: NSE

Direction: Maximise

Max. Iterations: 40

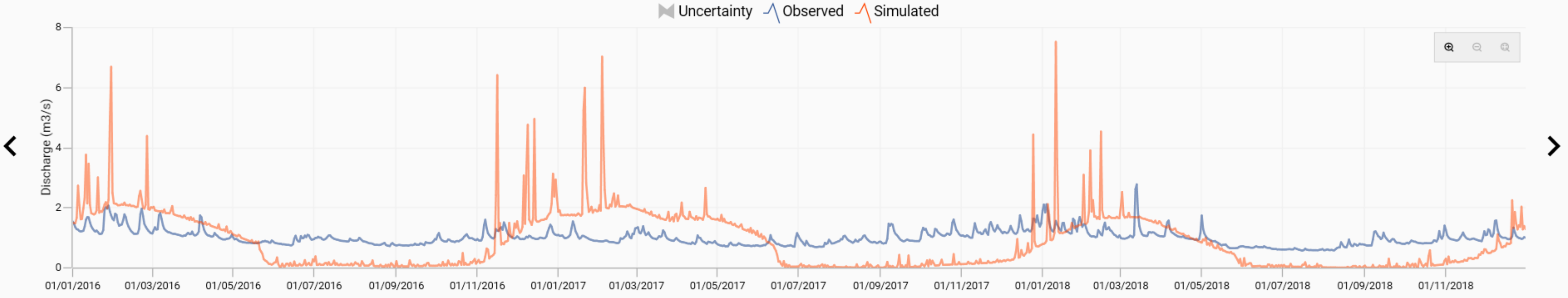
Multi-Site Calibration 40/40

▶ Calibrate

Best Sim

Group	Name	Change Type	Min	Current Best	Value	Max	
aqu	alpha	Percent	-30.00	-27.650	-27.650	30.00	days
aqu	flo_min	Percent	-30.00	-26.163	-26.163	30.00	m
hru	esco	Percent	-40.00	33.925	21.218	40.00	
hru	epco	Percent	-40.00	-39.344	-39.344	40.00	

Best OBJ FX: -9.9042	NSE
Channel 70 Daily River Flow	-9.904



Manual | Automatic

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Conclusions

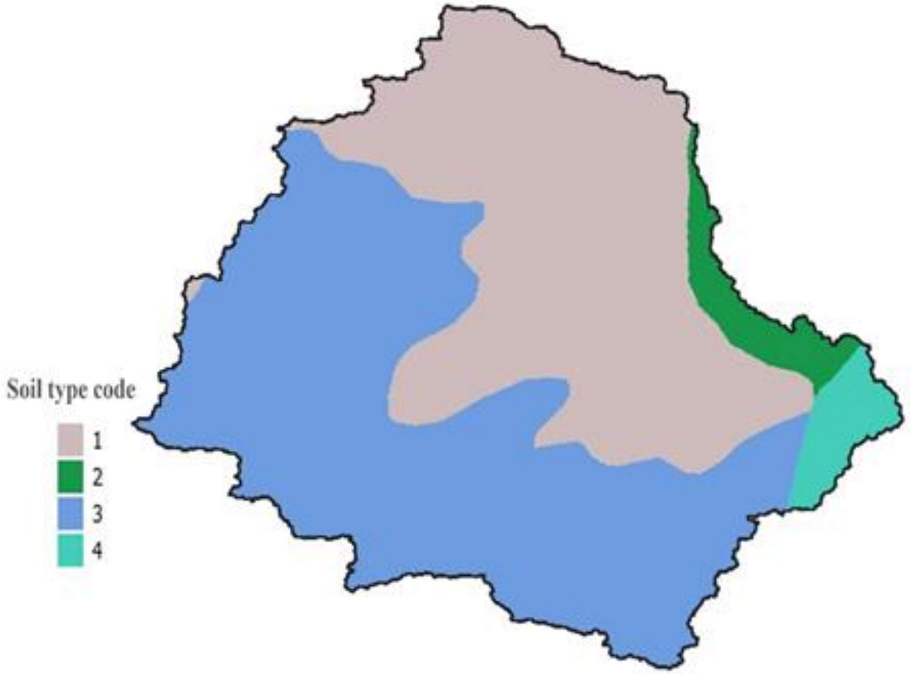
- Our modelling results are as good as good is our data implemented in the model
- Local knowledge, information (quantitative and qualitative) is very important
- EU-level available data for the „cooking book" is being tested, BUT so far the results show that data from local authorities, experts etc. are essential for successful model calibration
- Plans for improving model performance:
  - Using DEM available at national scale (1, 5, 10 m resolution instead of 30 m) - HRU number?
  - Applying national datasets for land use and soil
  - Using the Google Earth Engine output in a more sophisticated way (SWATfarmR)

BUT! The catchments are large; trade-off of detailness and robustness

Soil map

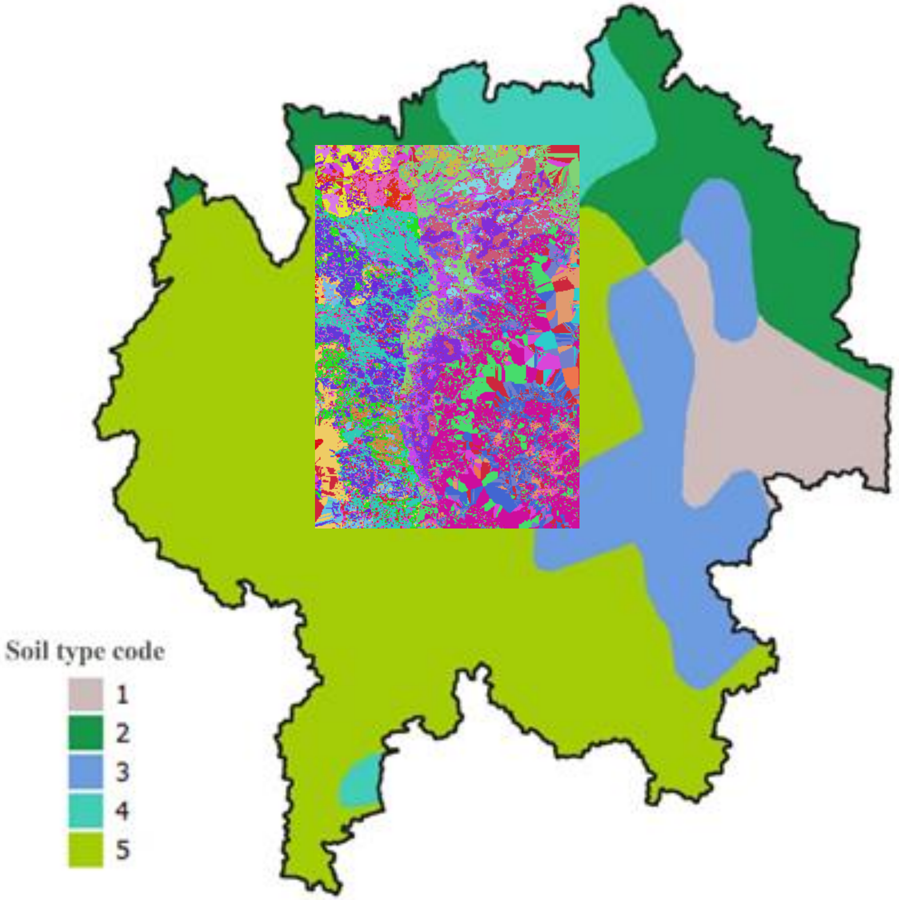
Želivka watershed

- Copernicus Digital Elevation Model (DEM)
- 30 m resolution

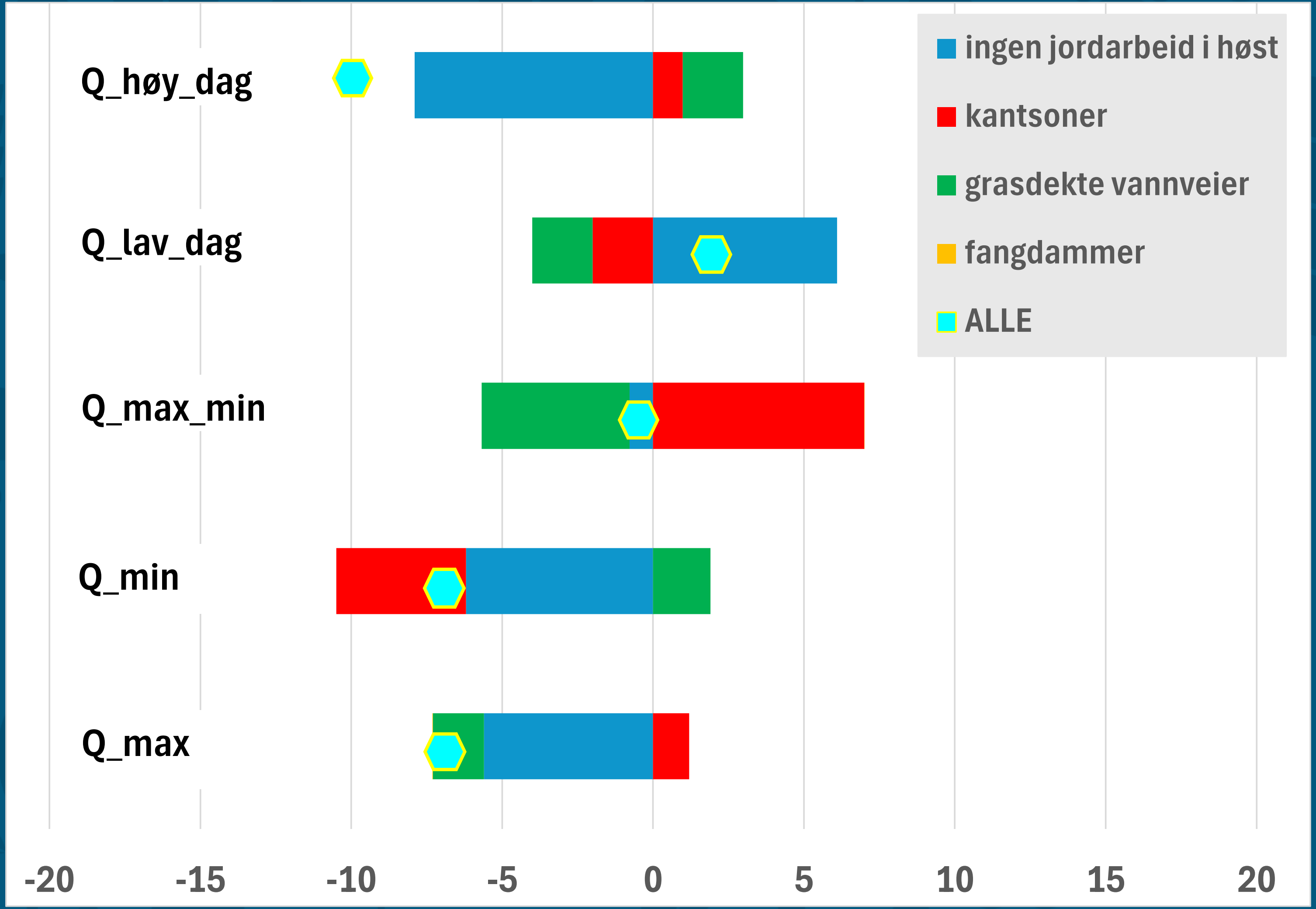


Himmerland watershed

- European Soil Database v2.0 (EUSD)



Endringer i hydrologiske parameterne i forhold til basisperioden (%) – tiltakseffekter ved maksimalt implementeringsnivå

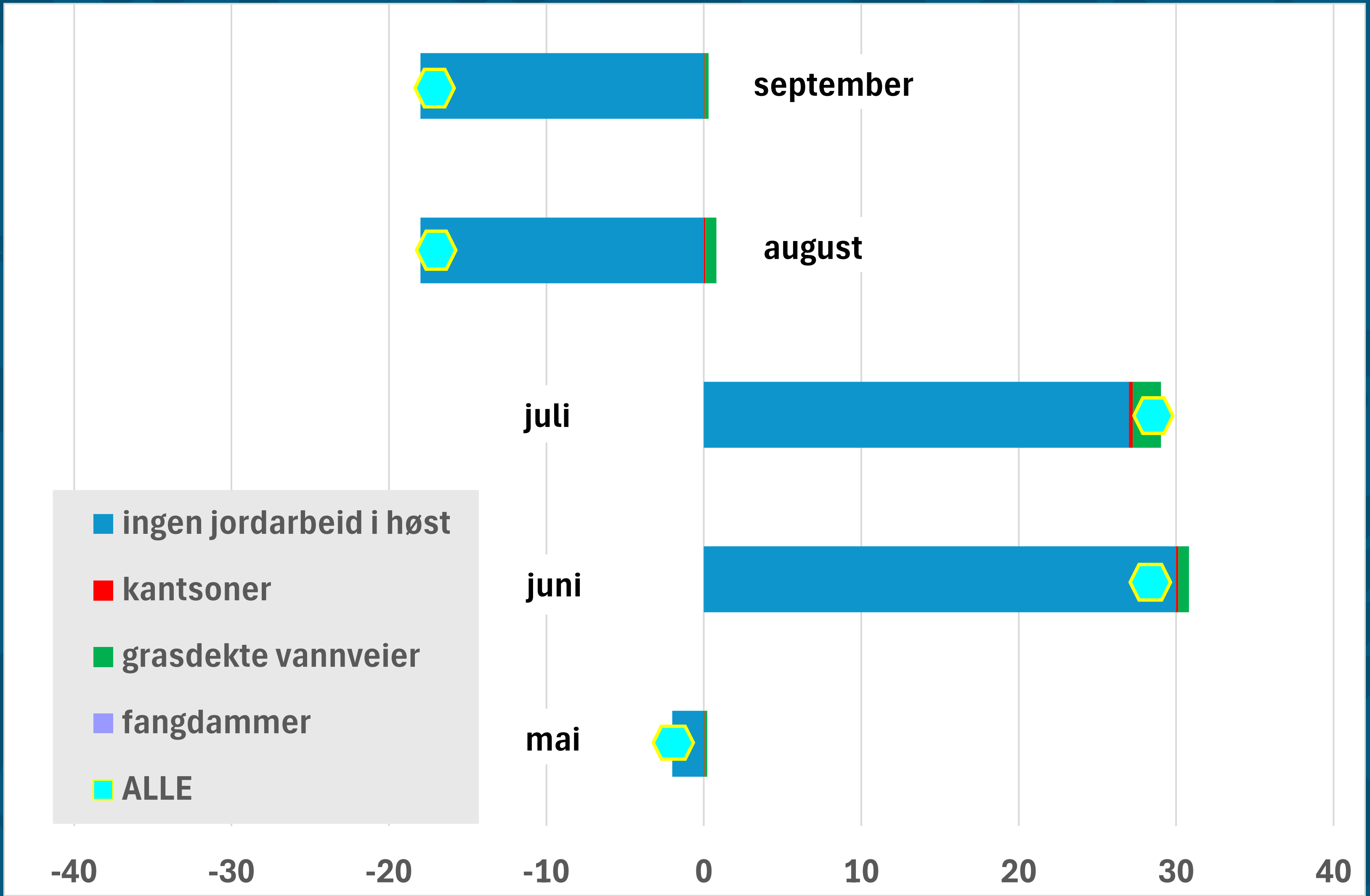


indikatorer	tiltakstyper				
antall dager med høy vannføring	↓	↑	↑		↓
antall dager med lav vannføring	↑	↓	↓		↑
Q_min: minimum vannføring	↓	↓	↑		↓
Q_max: maksimal vannføring	↓	↑	↓		↓
forskjell mellom Q_max og Q_min	↓	↑	↓		↓

Q_høy_dag: antall dager med høy ($>Q_{p05}$) vannføring
Q_lav_dag: antall dager med lav ($< Q_{p90}$) vannføring
Q_max_min: forskjell mellom maks og min Q

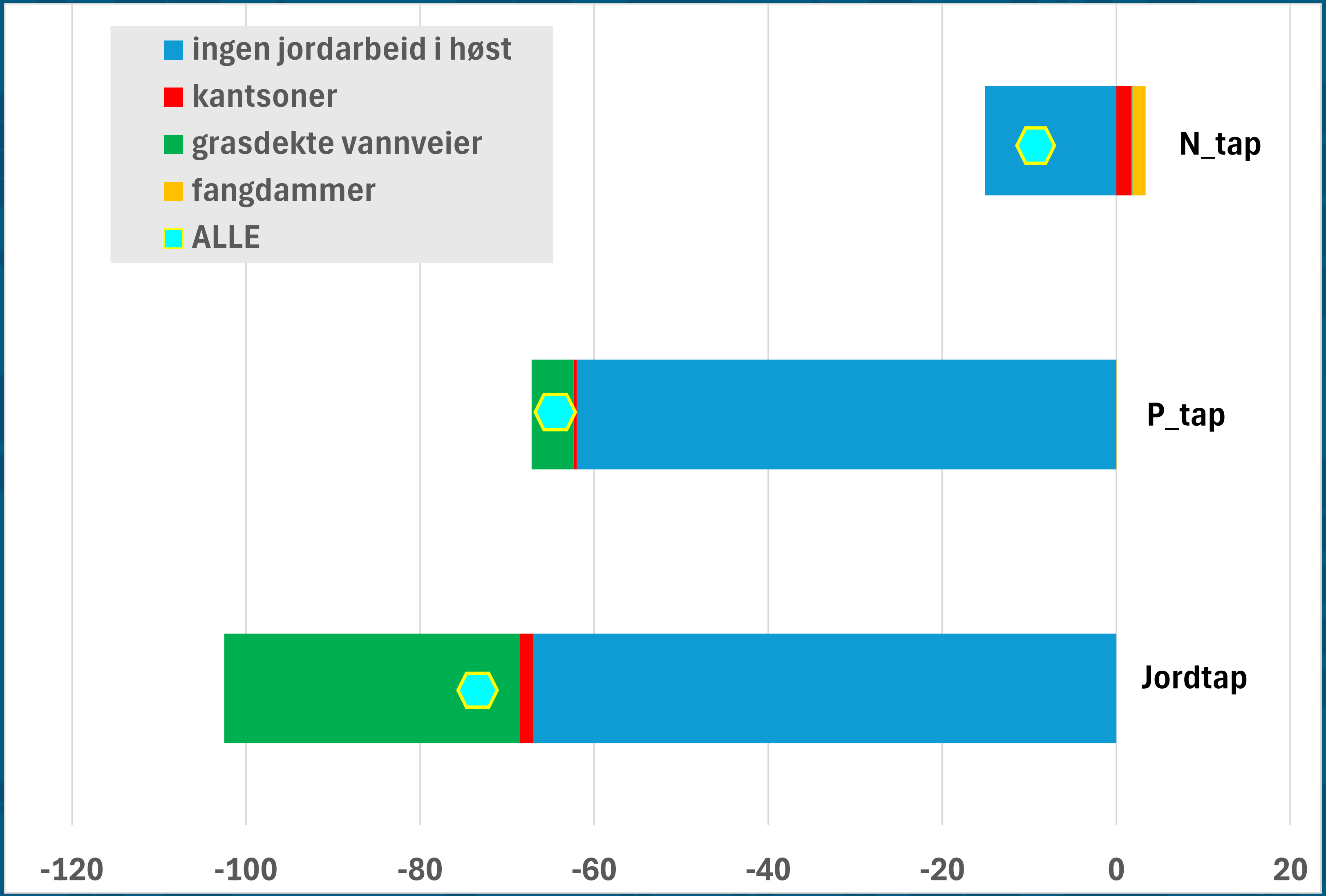
OPTAIN

Endringer i jordvanninnhold i forhold til basisperioden (%)
– tiltakseffekter ved maksimalt implementeringsnivå



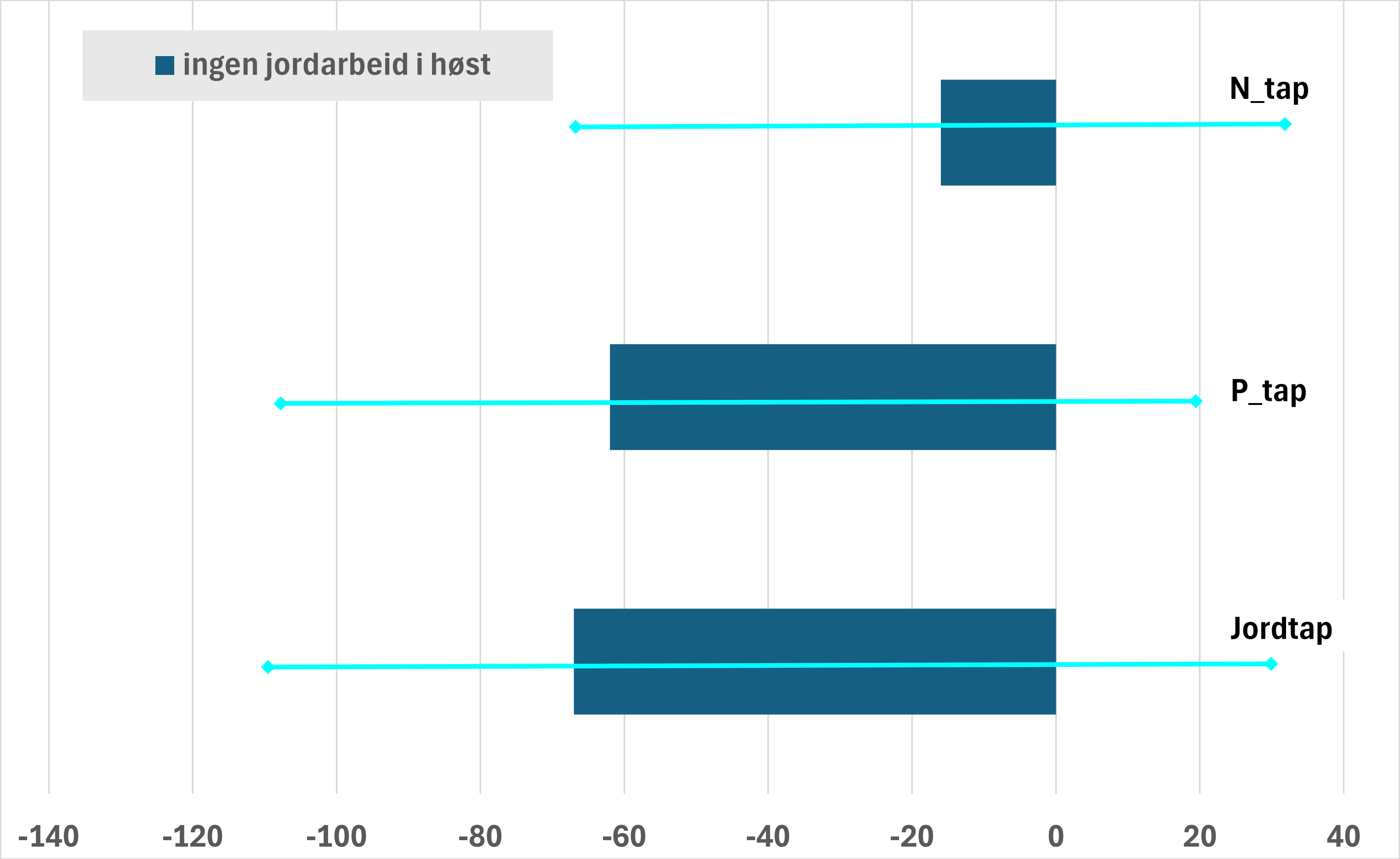
Vanninnholdet in jorda	tiltakstyper				
gjennomsnitt for MAI	↓				↓
gjennomsnitt for JUNI	↑		⇧		↑
gjennomsnitt for JULI	↑		⇧		↑
gjennomsnitt for AUGUST	↓		⇧		↓
gjennomsnitt for SEPTEMBER	↓		⇧		↓

Endringer i tap av jordpartikkel og næringsstoffer i forhold til basisperioden (%)
– tiltakseffekter ved maksimalt implementeringsnivå



indikatorer	tiltakstyper				
N-tap	↓	⇧		⇧	↓
P-tap	↓	⇩	↓		↓
Jordtap	↓	⇩	↓		↓

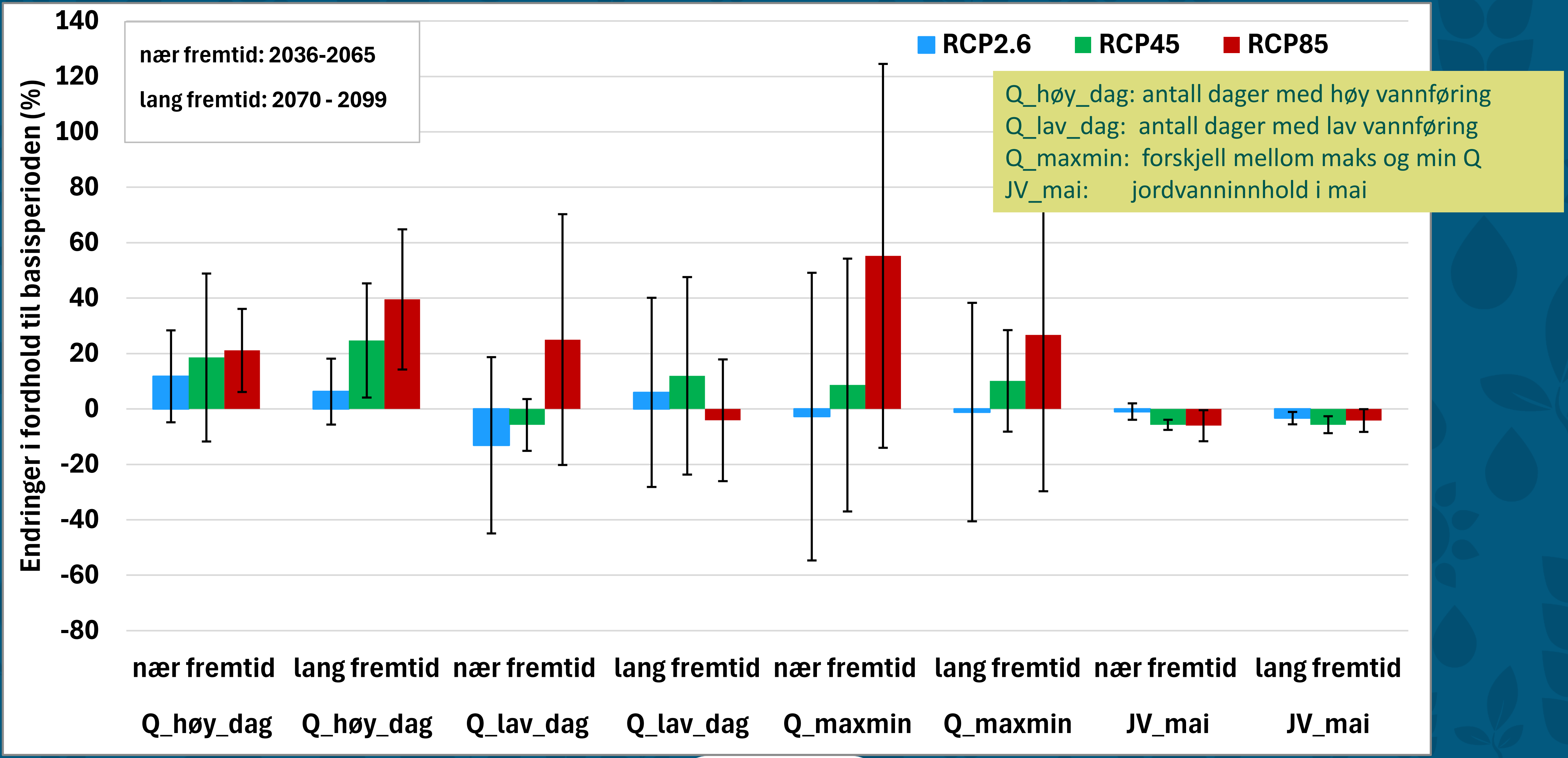
Demonstrasjon av usikkerhet i modelleringsresultater



Kilder av usikkerhet:

- Usikkerhet i inngangsdata
- Tidsmessige endringer i parametere (f.eks. jordegenskaper etc.)
- Romlig variabilitet av parametere
- Forenklinger i modellstruktur/ligninger
- Forutsetninger som ble gjort under oppsett av modellen
- Usikkerhet i referansedata

Endringer i de hidrologiske patameterne i forhold til basisperioden (%)



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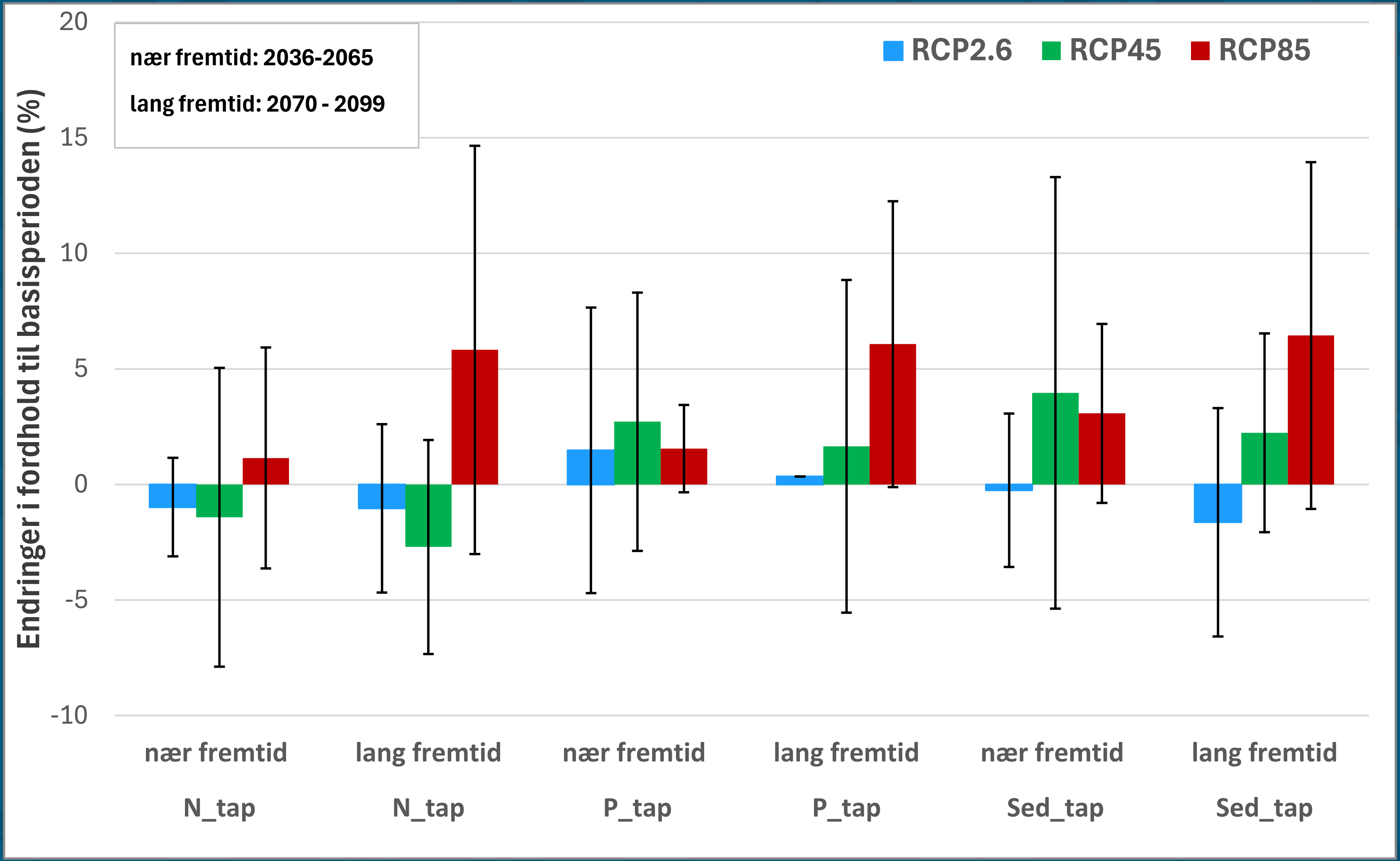
Endringer i tap av jordpartikkel og næringsstoffer i forhold til basisperioden (%)



Kilmascenarier		Indikatorer		
		N-tap	P-tap	Jordtap
RCP2.8	nær fremtid	↓	↑	
	lang fremtid	↓		↓
RCP4.5	nær fremtid	↓	↑	↑
	lang fremtid	↓	↑	↑
RCP8.5	nær fremtid	↑	↑	↑
	lang fremtid	↑	↑	↑

Thank you for the attention!

NIBIO