The Effect of Cover Crops on Nitrate Loads in an Irish Catchment Under Climate Change

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Teagasc - Irish Agriculture and Food Development Authority

- Teagasc is a national body providing research, advisory, and training services to the agriculture and food industry and rural communities.

- Teagasc is involved in:
  - Farm Advisory
  - Education
  - Research & Innovation

- Similar role to the USDA - ARS

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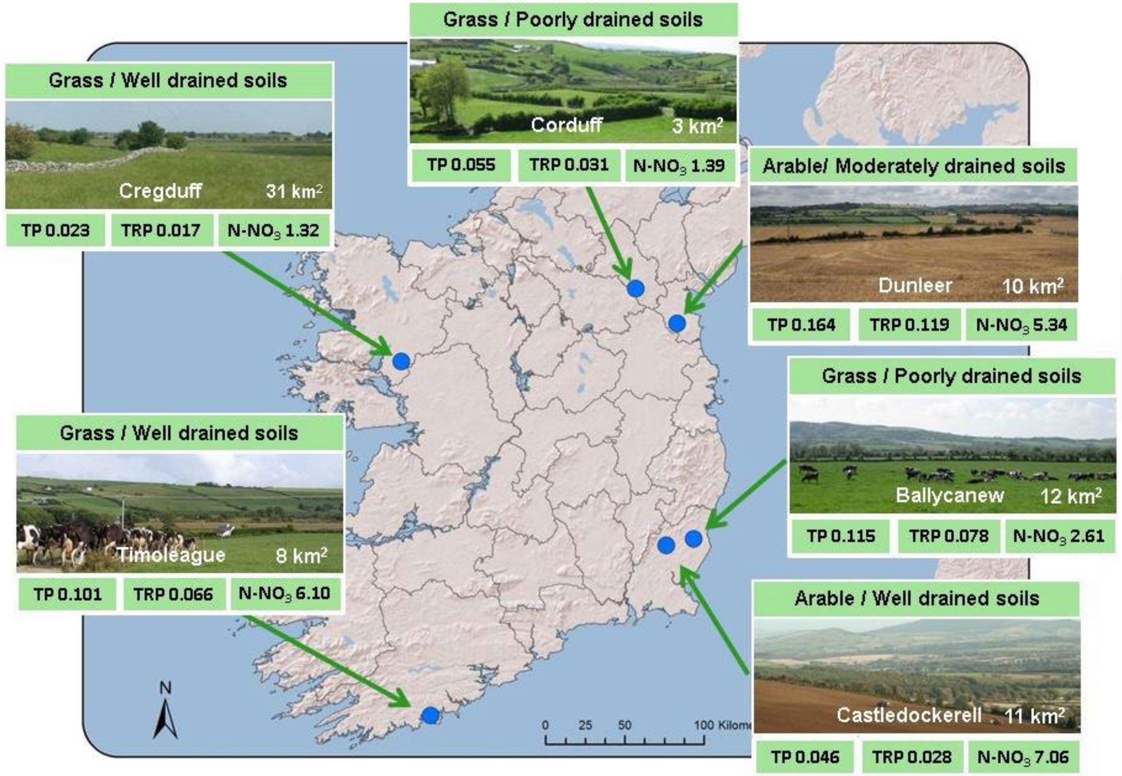
The Agricultural Catchment Programme (ACP)

- The ACP is a long-term program designed to monitor and assess the efficacy of measures put in place to protect water quality (2008 – ongoing)

- Combines biophysical & socio-economic research with knowledge exchange: scientists, advisors, technologists, and technicians.

- Collaboration with >300 farmers in 6 catchments

Agricultural Catchment Programme Data



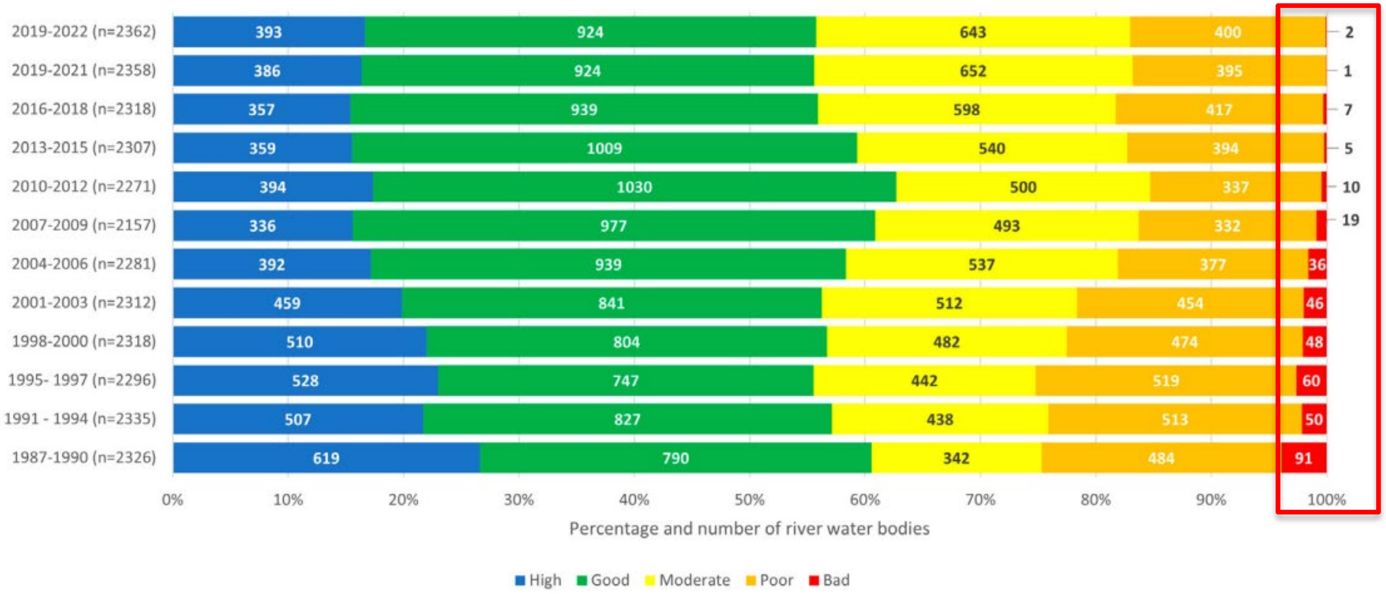
	Location	Parameters	Frequency	Number of sites per catchment
Weather	Catchment centre low-land	Rain, T_{air}, T_{soil}, RelHum, SolRrad, WindSpeed, WindDir	10-minutes	1 or 2
	Highland	Rain	10-minutes	1 or 2
Groundwater	Focused study sites	Water level, Chemistry: nutrients, metals, DO, Rh, EC, Temp, pH	30-minutes, Month	0, 6, 10, 17 or 19 piezometers
Surface water	Outlet	River flow, T_{water}, Water Chemistry: TP, TRP, TON, TOC, Turb, EC	10 minutes	1
	River network	Chemistry: nutrients, metals, DO, Rh, EC, Temp, pH	Monthly	10
	River network	Aquatic ecology: macro invertebrates, diatoms	6 months	8
Soil	Whole catchment	Soil sampling: N and P	4 year	Each field
Soil/bedrock	Focused study sites	Geophysical survey: EM, 2-D res, seismic refraction, GPR	once	2 hillslopes
Topography	Whole catchment	LiDAR survey 0.5m	once	

Water Quality in 2022
An Indicators Report

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

River Biological Quality
1987-2022
Q-Value (water body level)

The Good News



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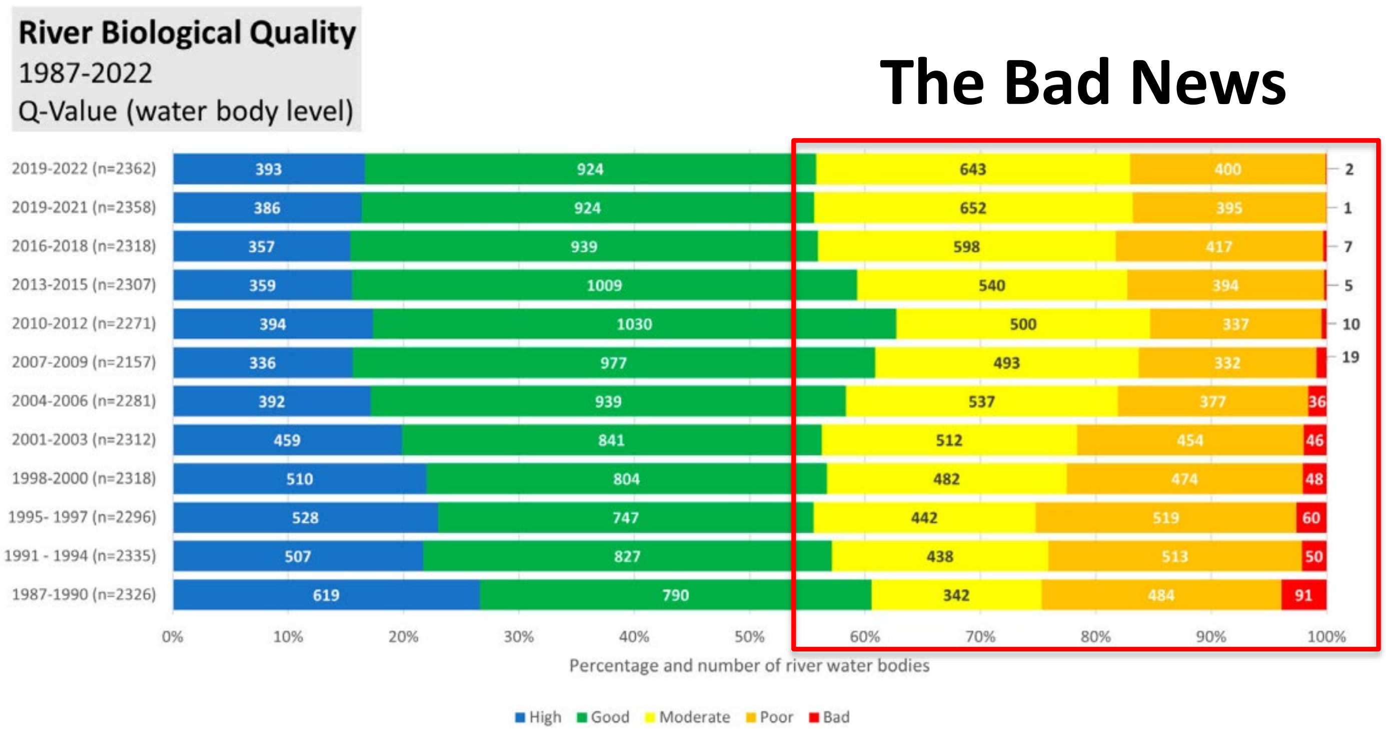
The Bad News



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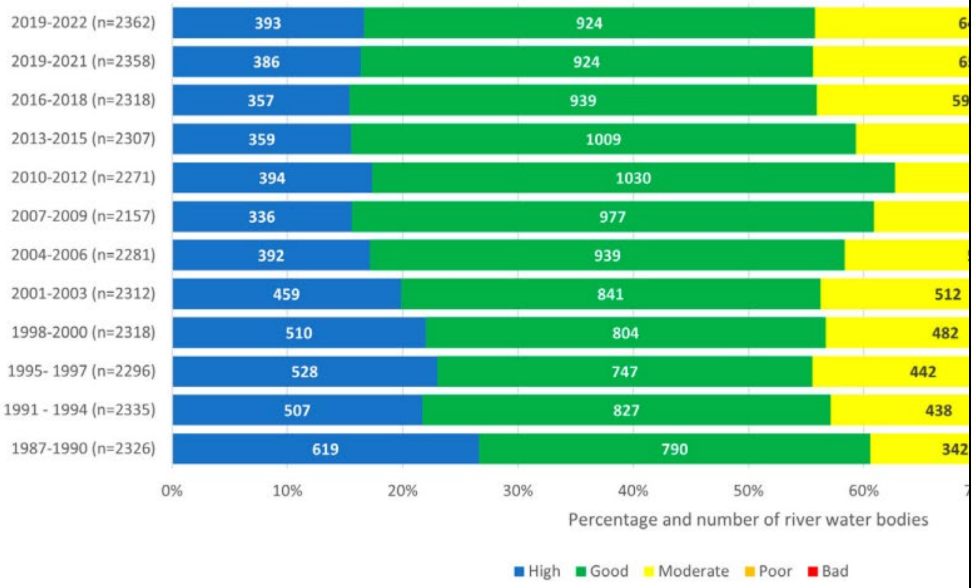
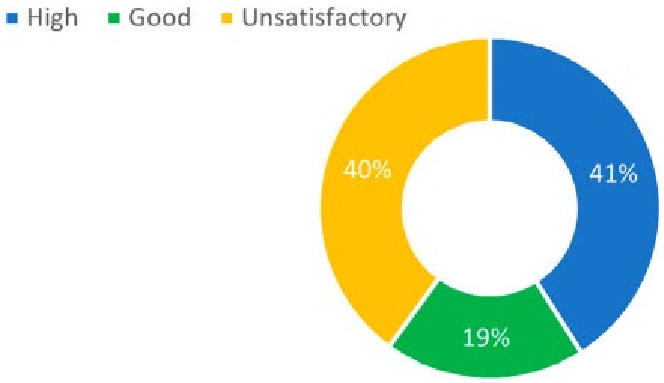
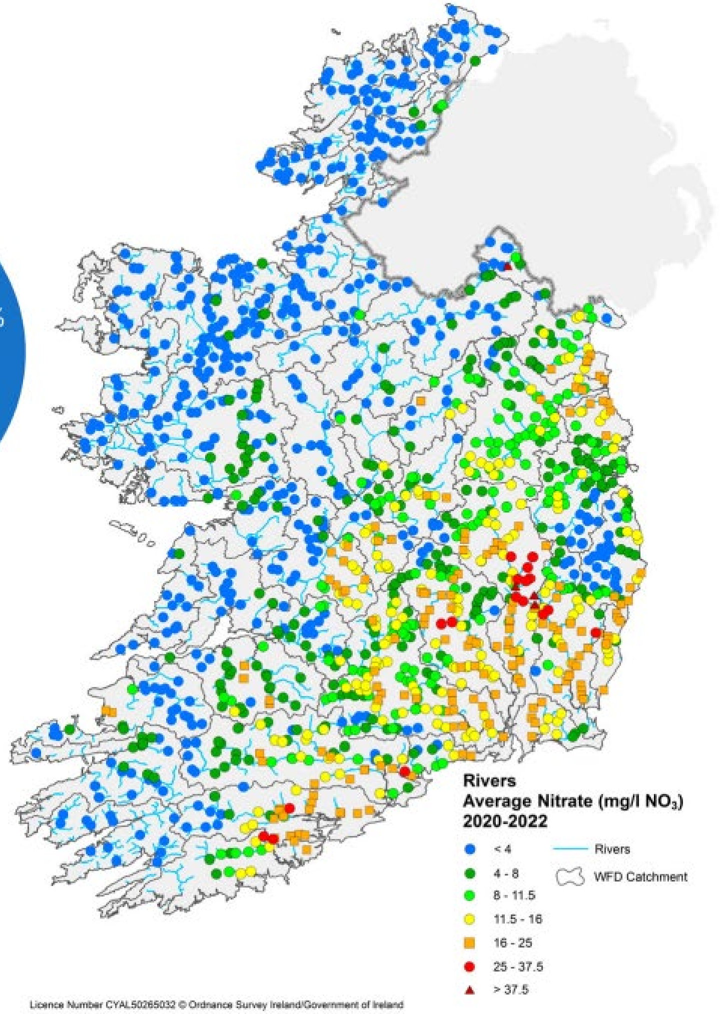


River Nitrate Quality
2020-2022



Clear Geographic Pattern



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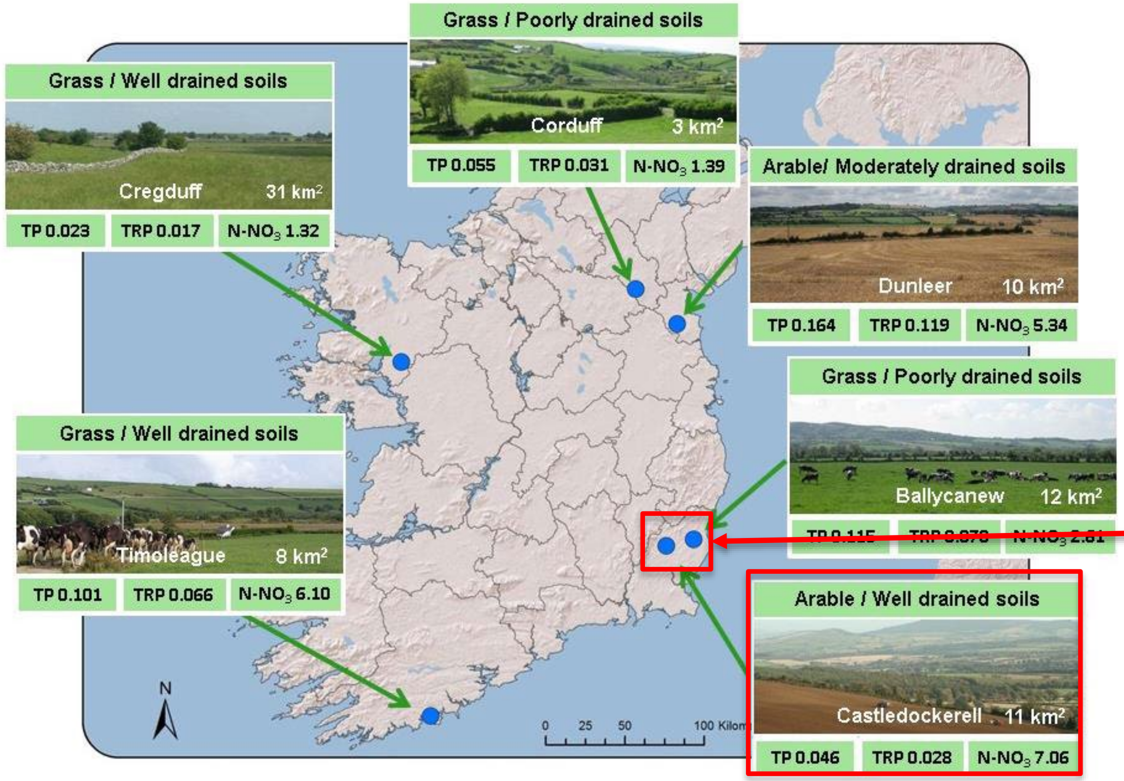

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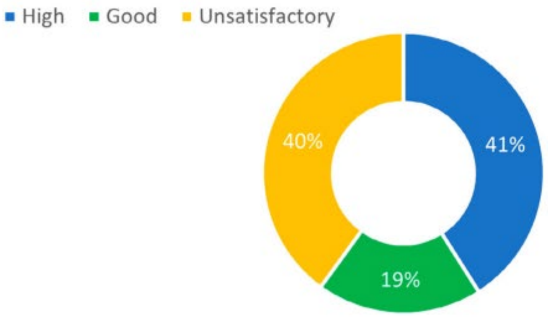

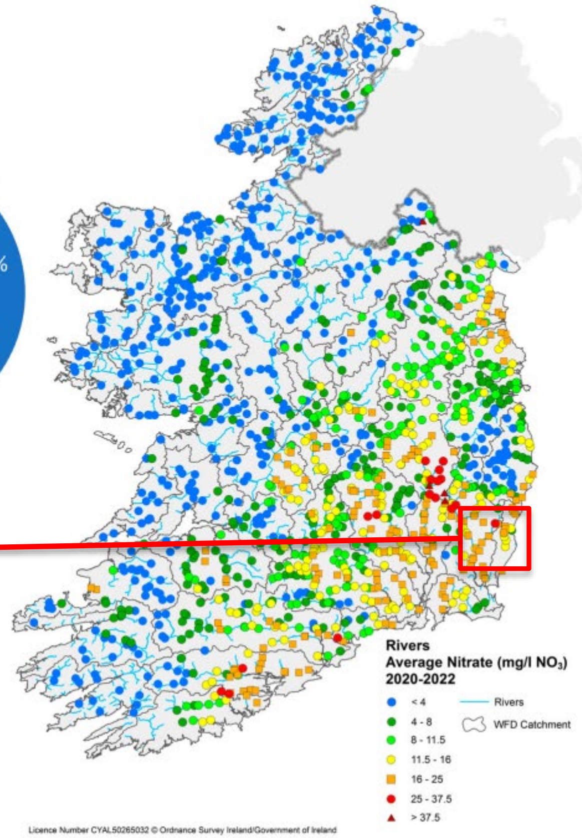

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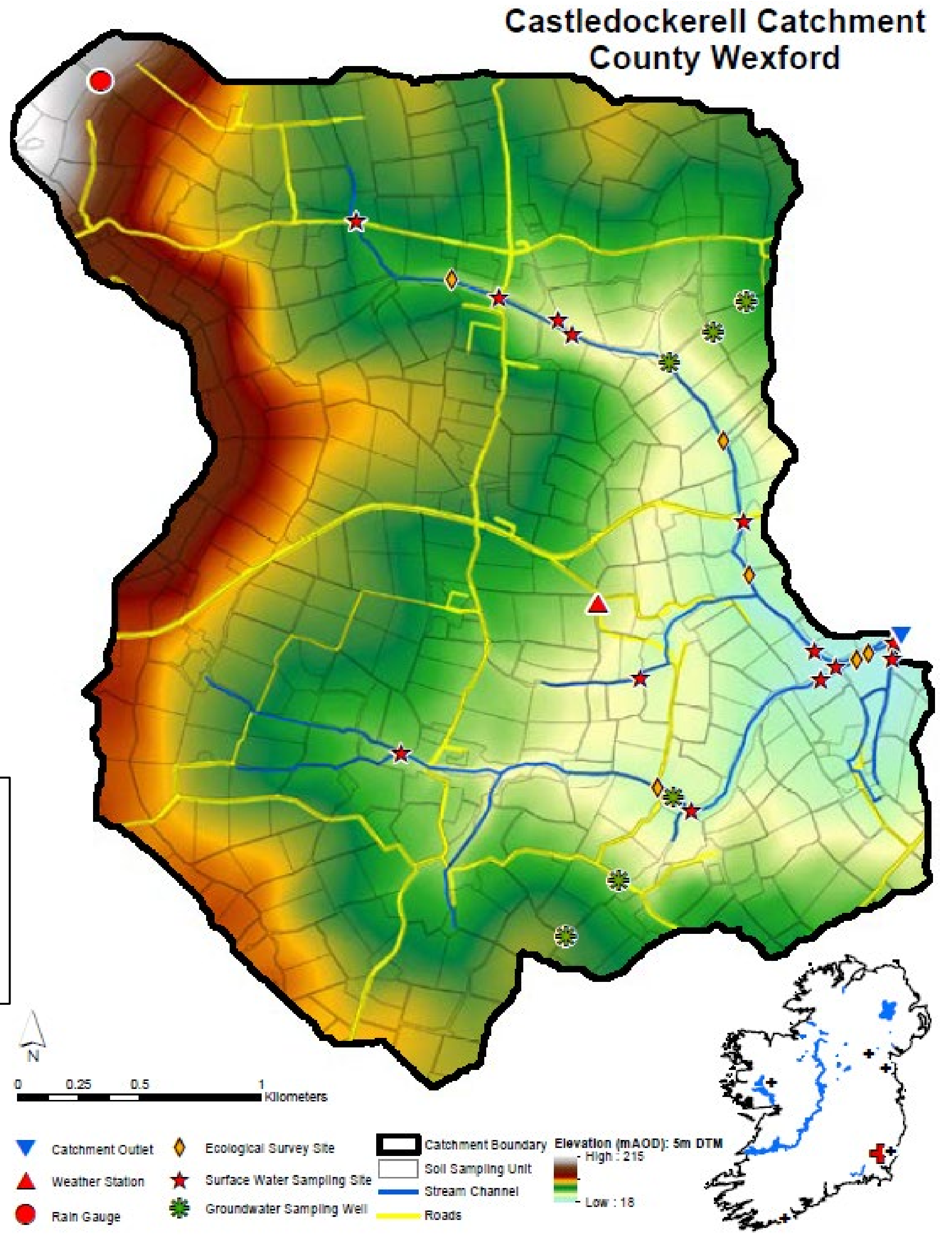
Study Catchment - Castledockrell

- 10-year annual average nitrate-N con in surface water is 7.06 mg/L (environmental quality standard is 2.60 mg/L)
- The main pathway is nitrogen leaching to the groundwater, ending up in the surface waters (Mellander et al., 2012; Mellander et al., 2022).
- Sources include both point and diffuse sources (i.e. farmyards, spreading of fertiliser / manure; Trodd et al., 2022).

Fig. 5: Castledockerell catchment – mainly tillage with drystock and some dairying

Area = 11.2 km^2
Precip = 1,015 mm
Streamflow = 528 mm
54% arable (Spring Barley)



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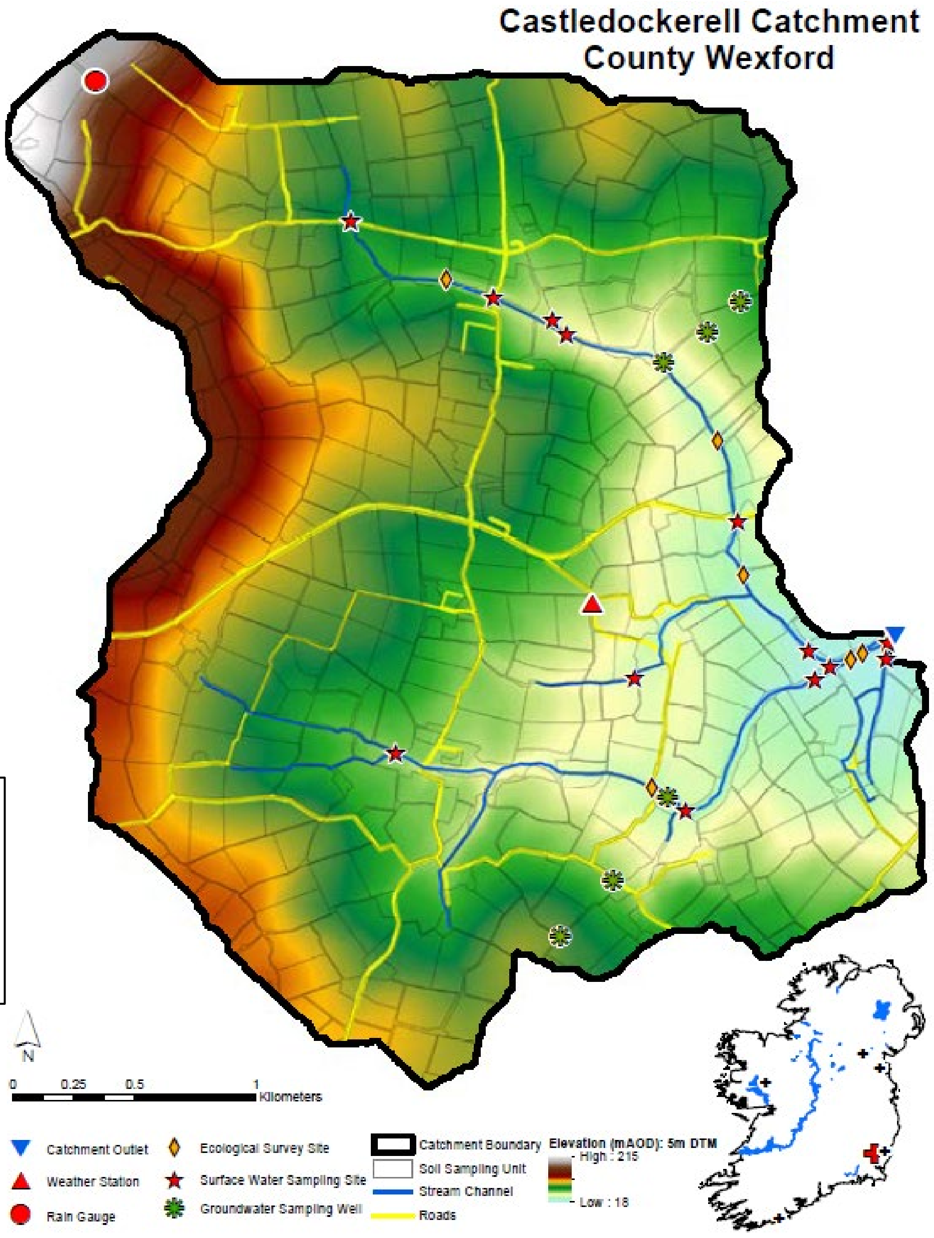

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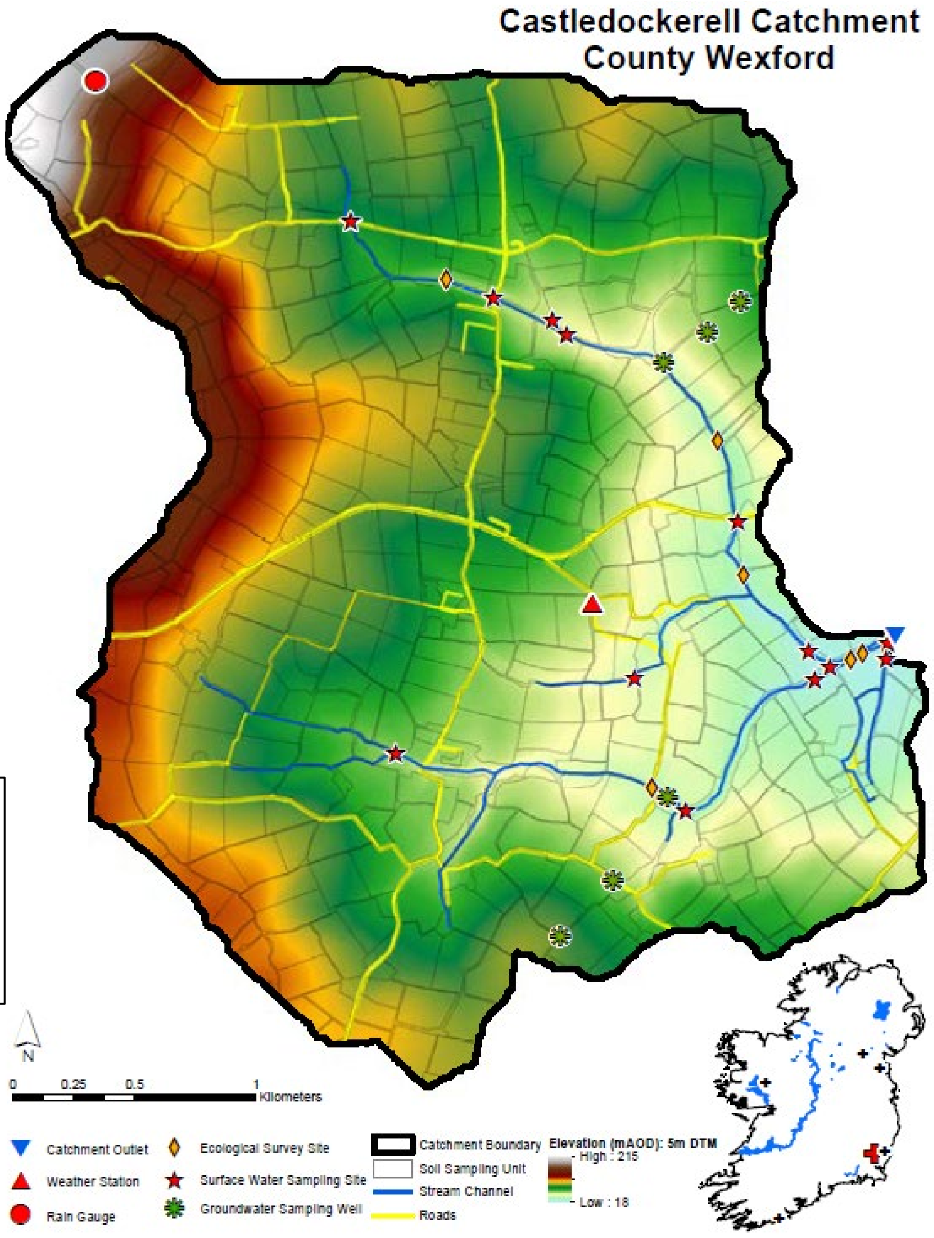

Study Objective

- To investigate the **combined effect** of **climate change** and **cover crops** on **nitrate load** in Castledockrell.

- Use **SWAT** to quantify **future nitrate loads** under different **climate scenarios**.
  - How does this impact the water balance?
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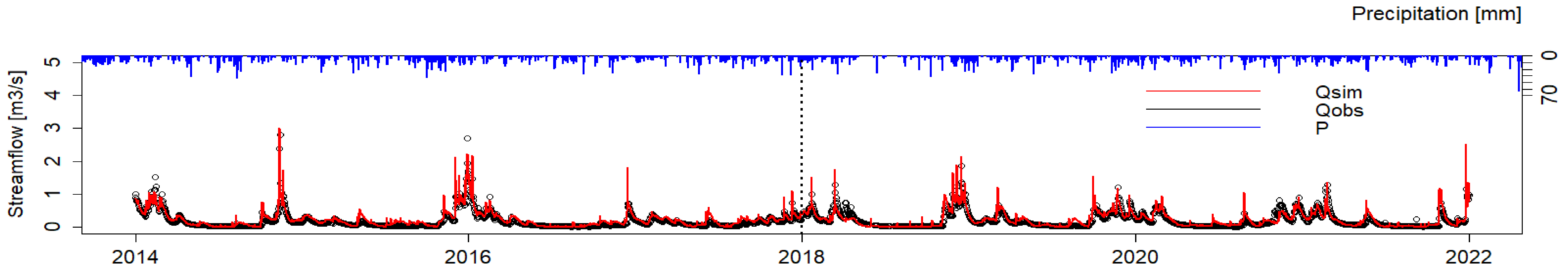
Model Calibration

- Manual Calibration: Q & N load
  - 8 hydrologic parameters
  - 10 nitrogen parameters
- Warmup: 2010 - 2013
- Calibration: 2014 - 2017
- Validation: 2018 - 2021
- Ob. Fun: KGE, PBIAS, R2

Data	Resolution
DEM	2 m
Land-cover	Field scale
Soil properties	1:1000
Meteorological Data (temperature, wind speed, radiation, precipitation, humidity)	Daily time series
Streamflow	Daily time series
Nitrate-N load	Daily time series

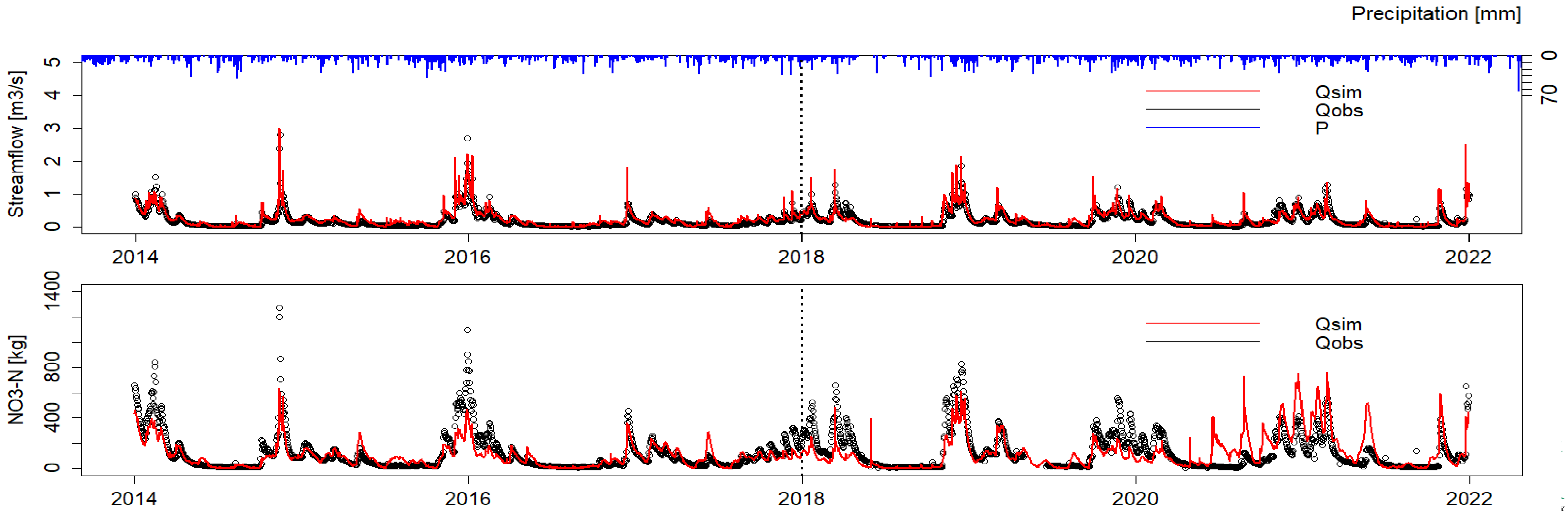
Calibration / Validation Performance

Daily	Period	R2	KGE	PBIAS
Streamflow	Calibration 2014-2017	0.91	0.71	-23.23%
	Validation 2018-2021	0.84	0.88	-8.72%



Calibration / Validation Performance

Daily	Period	R2	KGE	PBIAS
Streamflow	Calibration 2014-2017	0.91	0.71	-23.23%
	Validation 2018-2021	0.84	0.88	-8.72%
NO3 Load	Calibration 2014-2017	0.85	0.72	-5.57%



Climate Change & Cover Crop Scenarios

- Climate scenarios provided by the **WaterFutures** Project
  - **Key expected impacts**: increased precip (in particular from Aug – Feb) & an increase in the frequency and intensity of extreme events

- The cover crops worked into rotations are (primarily) brassicas or rye (with oil-seed rape)
  - Timing of sowing is more important than the specific crop used

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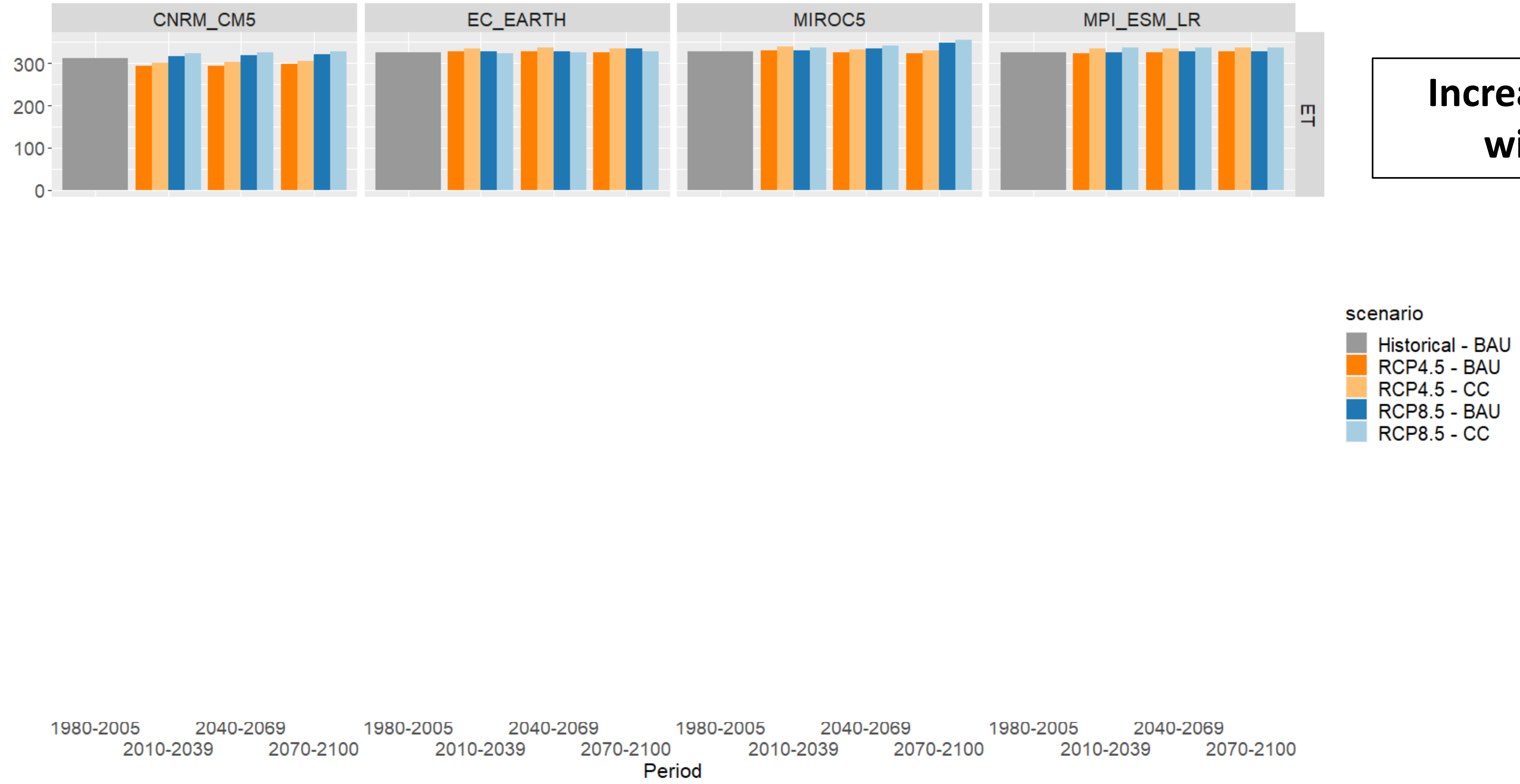
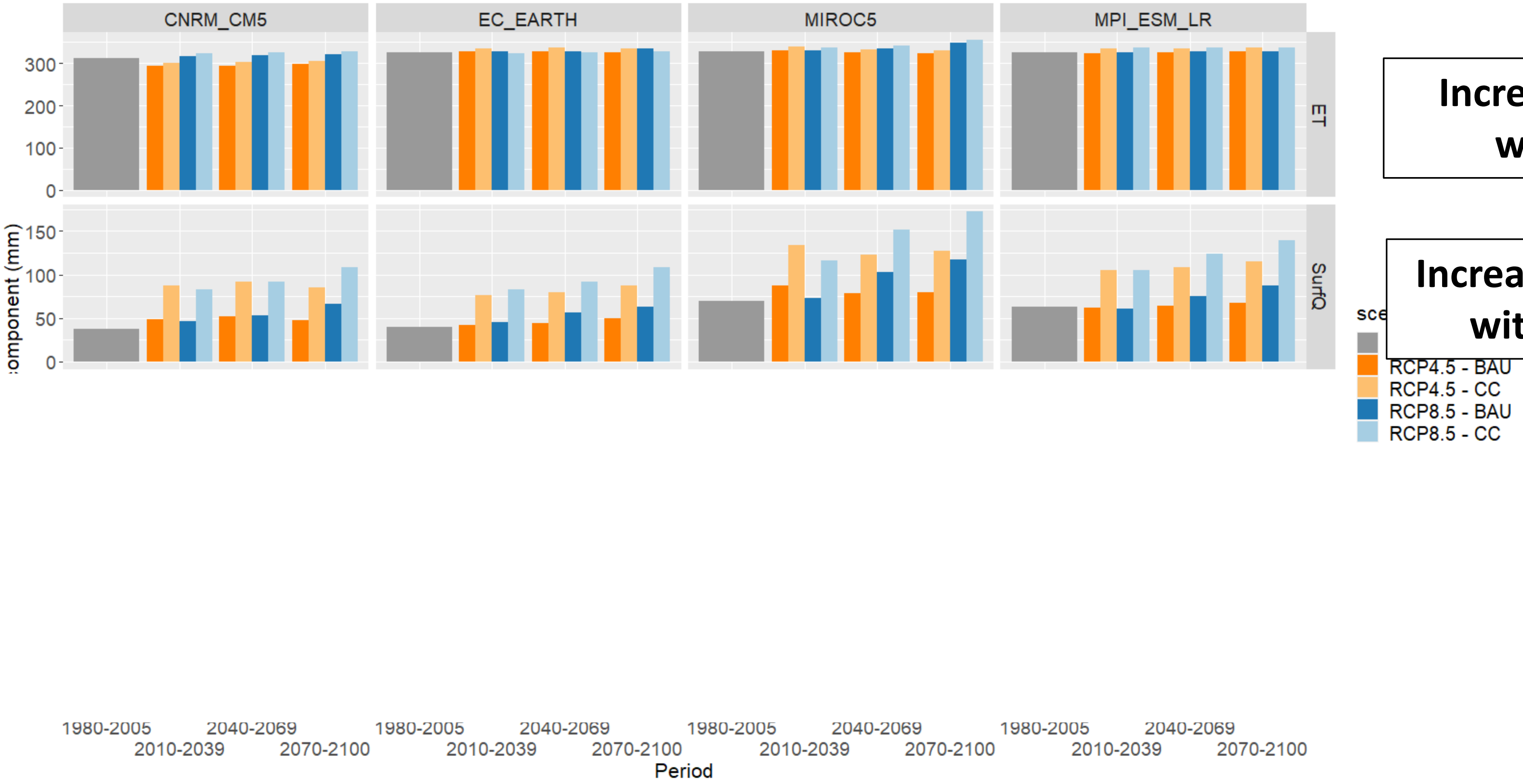
Water Balance Impacts



Increase in ET, more so with cover crops

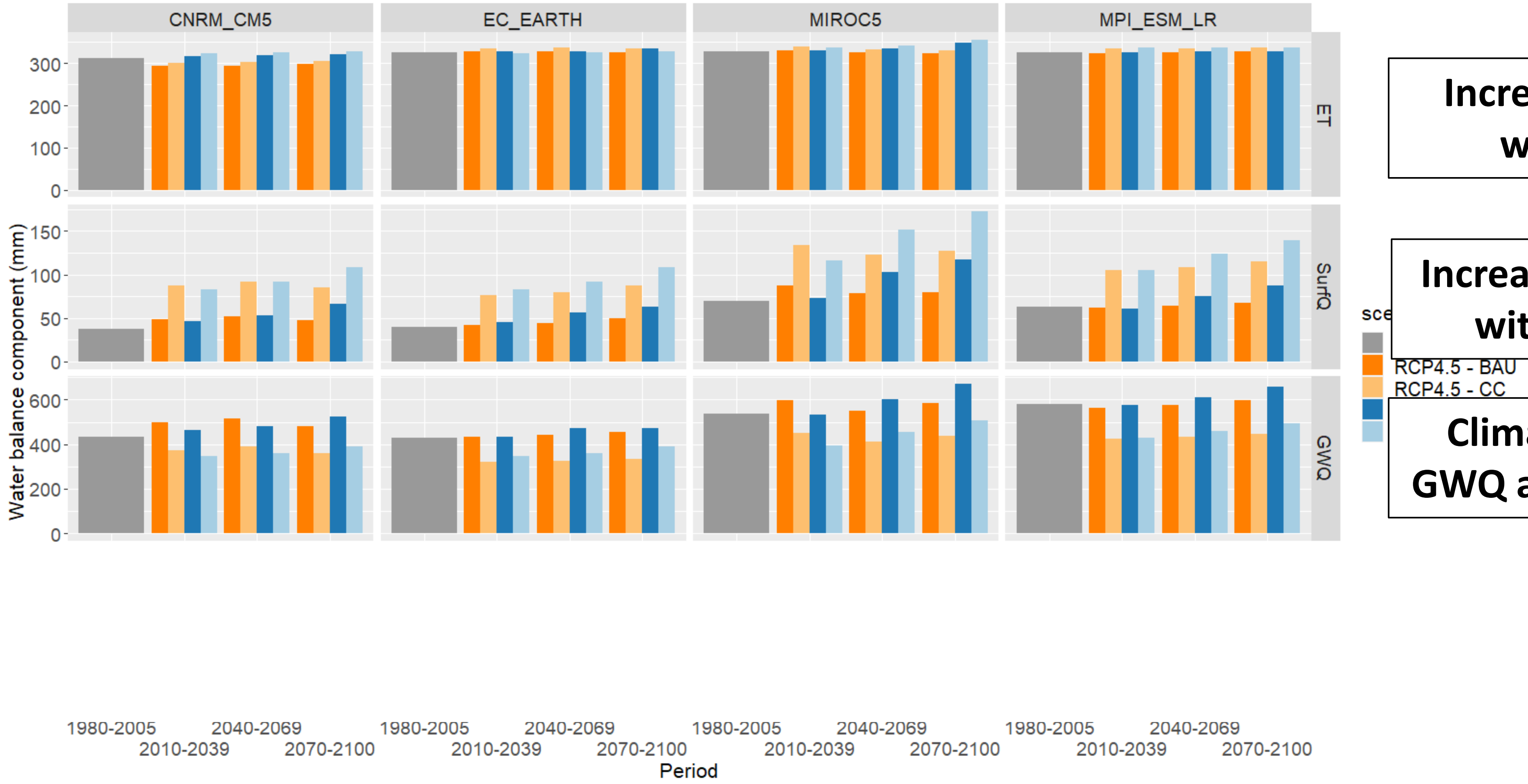
Water Balance Impacts



Increase in ET, more so with cover crops

Increase in SurQ, more so with cover crops (?)

Water Balance Impacts



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Climate change increases GWQ and cover crops reduce

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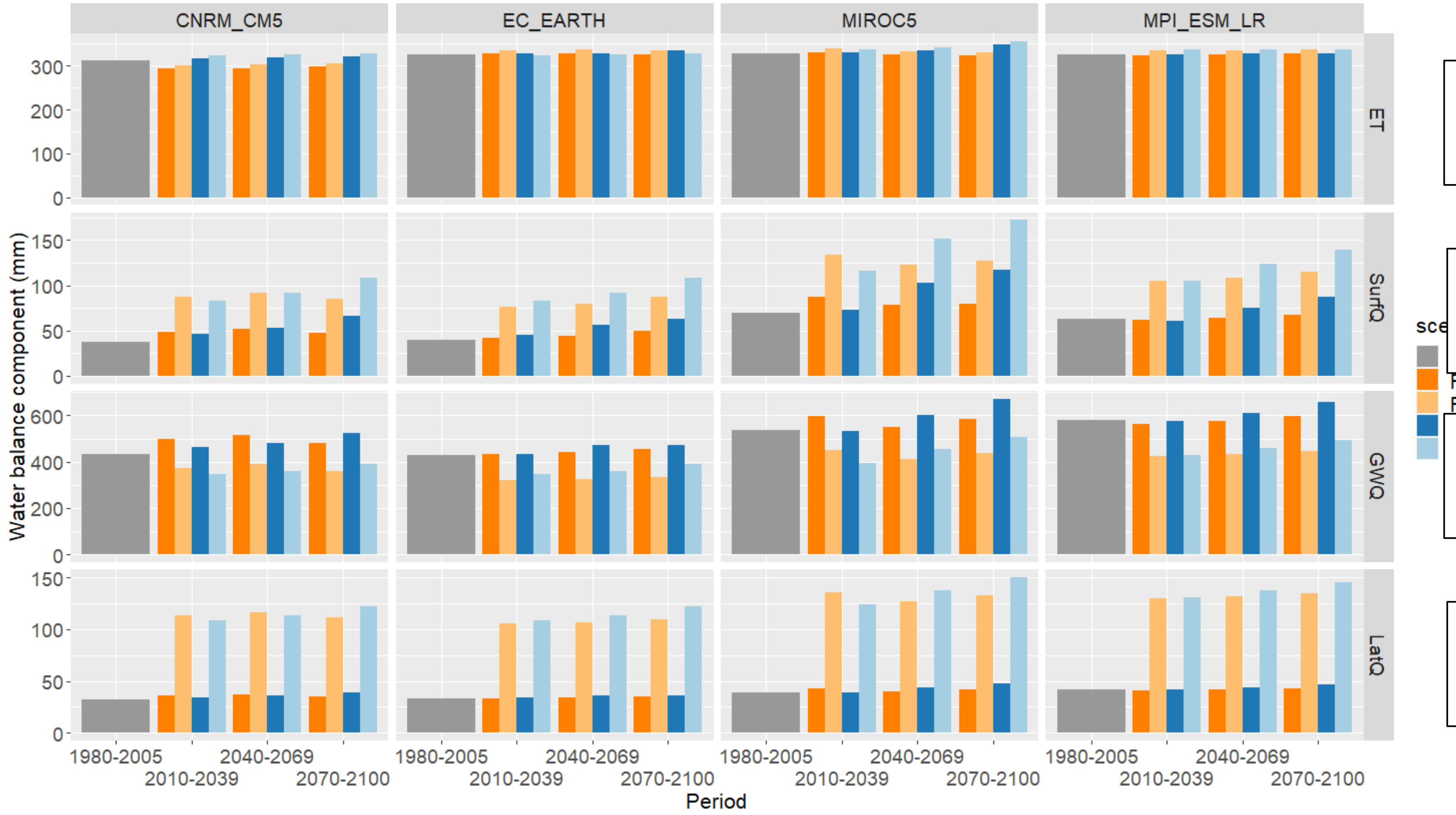

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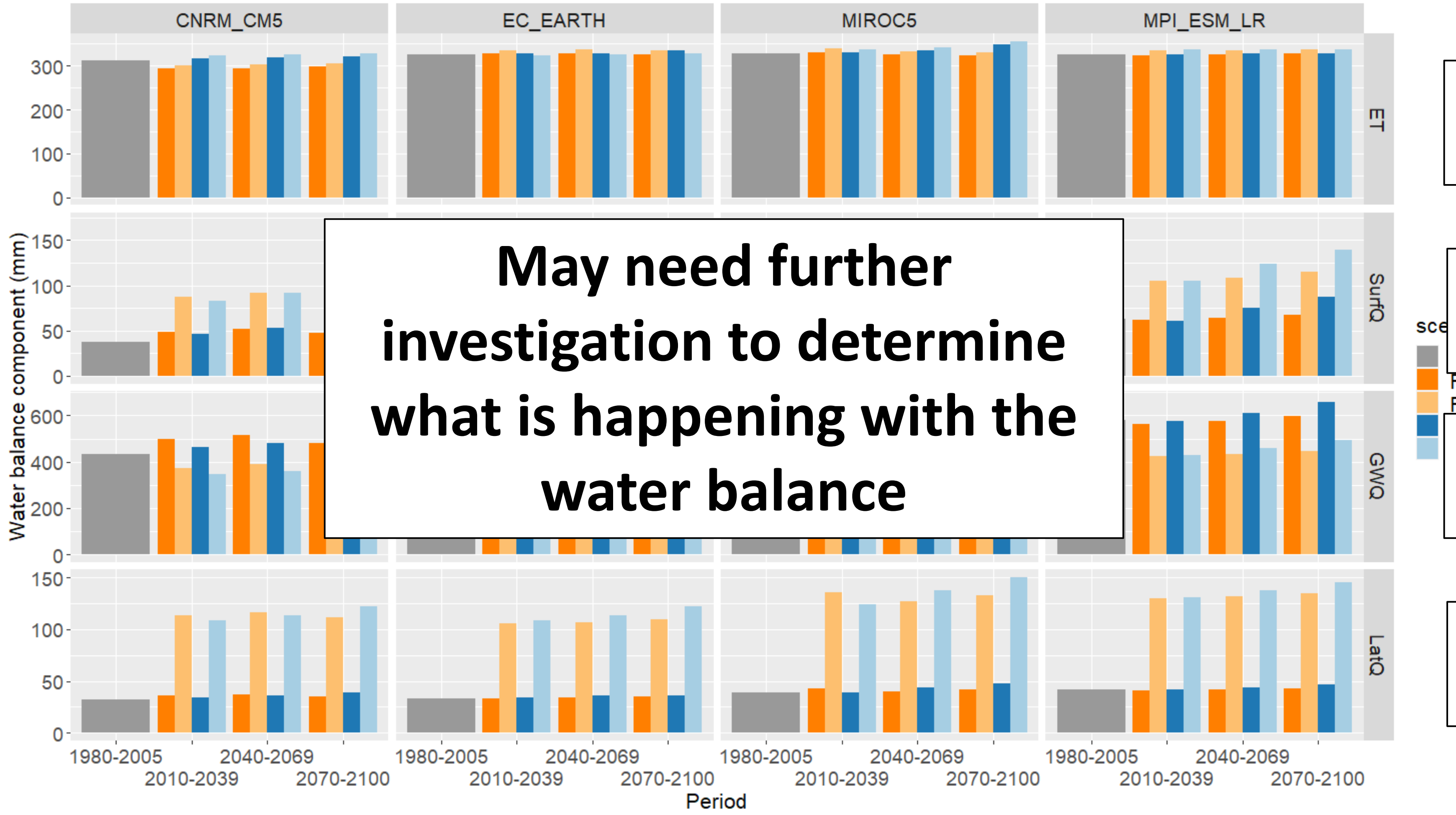
Climate change increases GWQ and cover crops reduce

Cover crops lead to much more LatQ

Water Balance Impacts



May need further investigation to determine what is happening with the water balance

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Increase in SurQ, more so with cover crops (?)

Climate change increases GWQ and cover crops reduce

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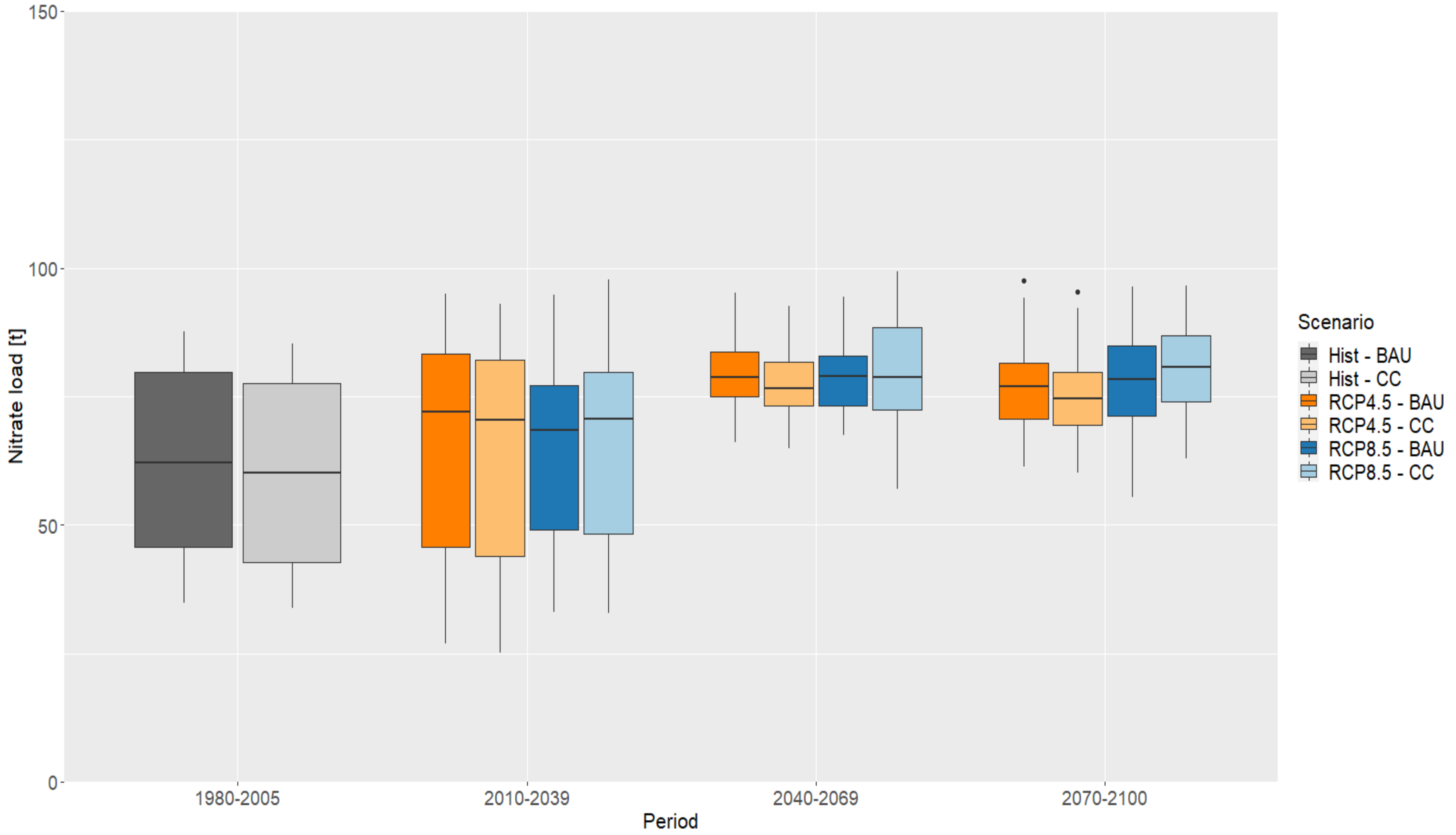
Nitrate Load Impacts



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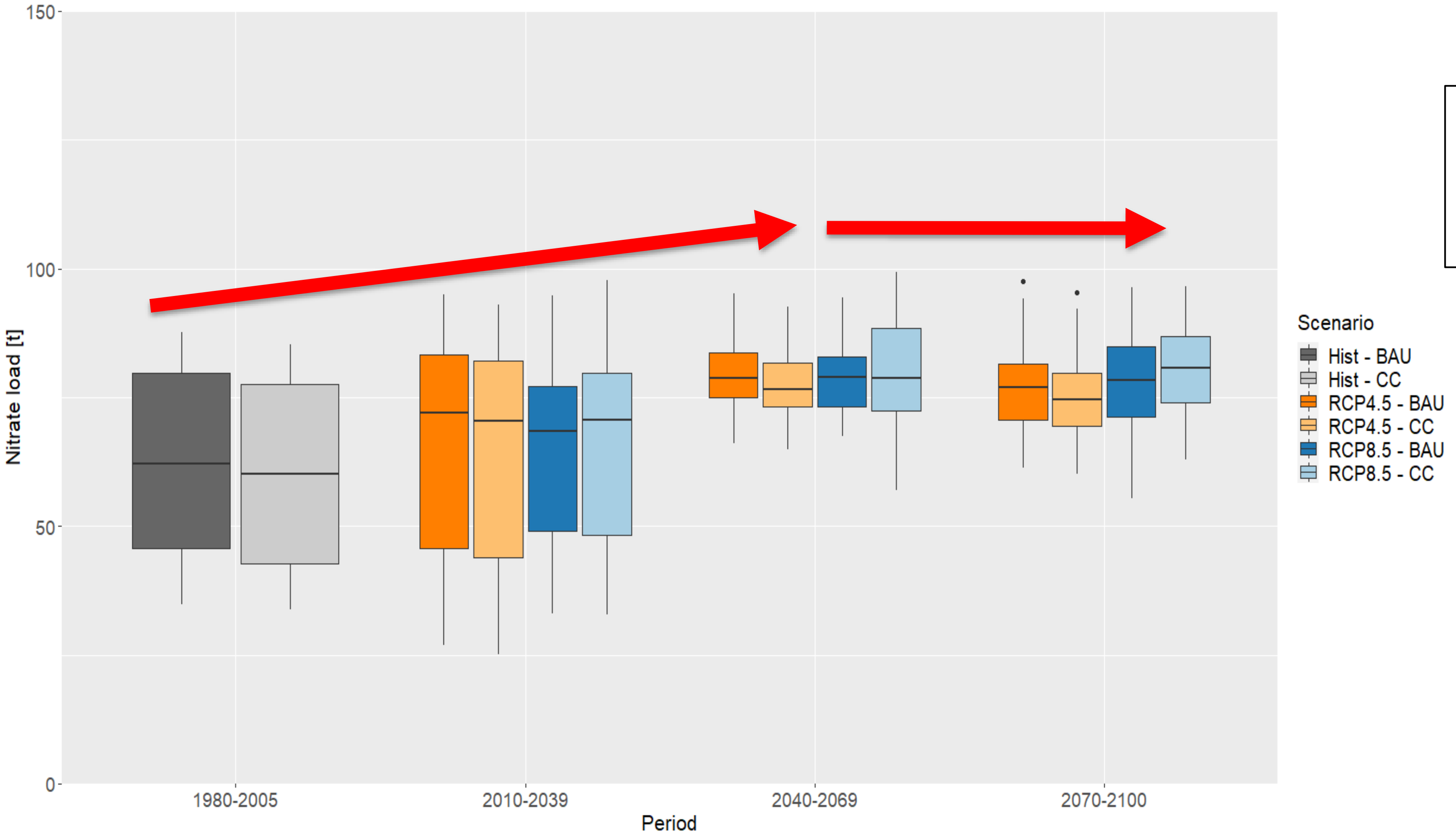

Increased N export under climate scenarios (but stabilized)

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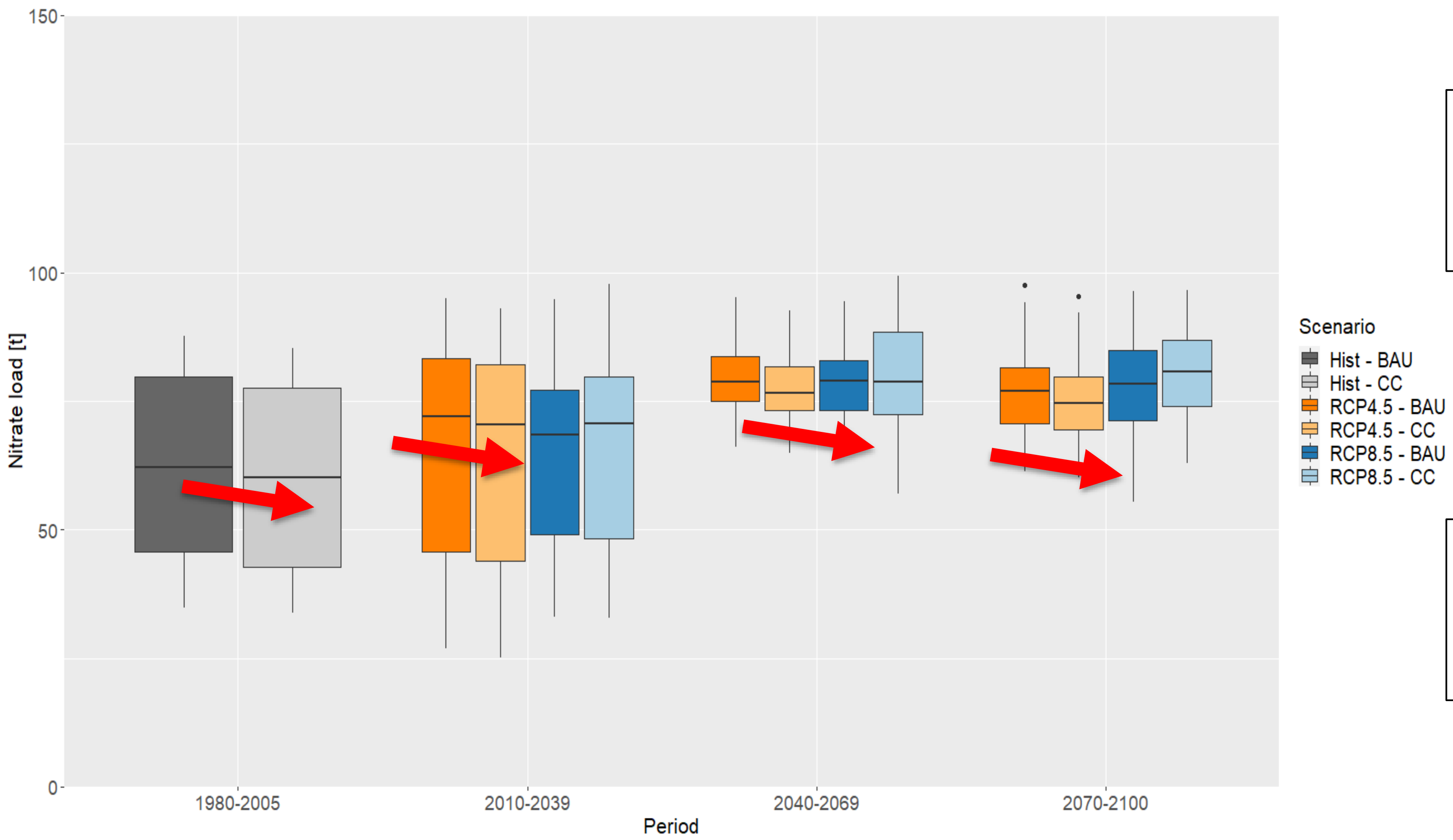
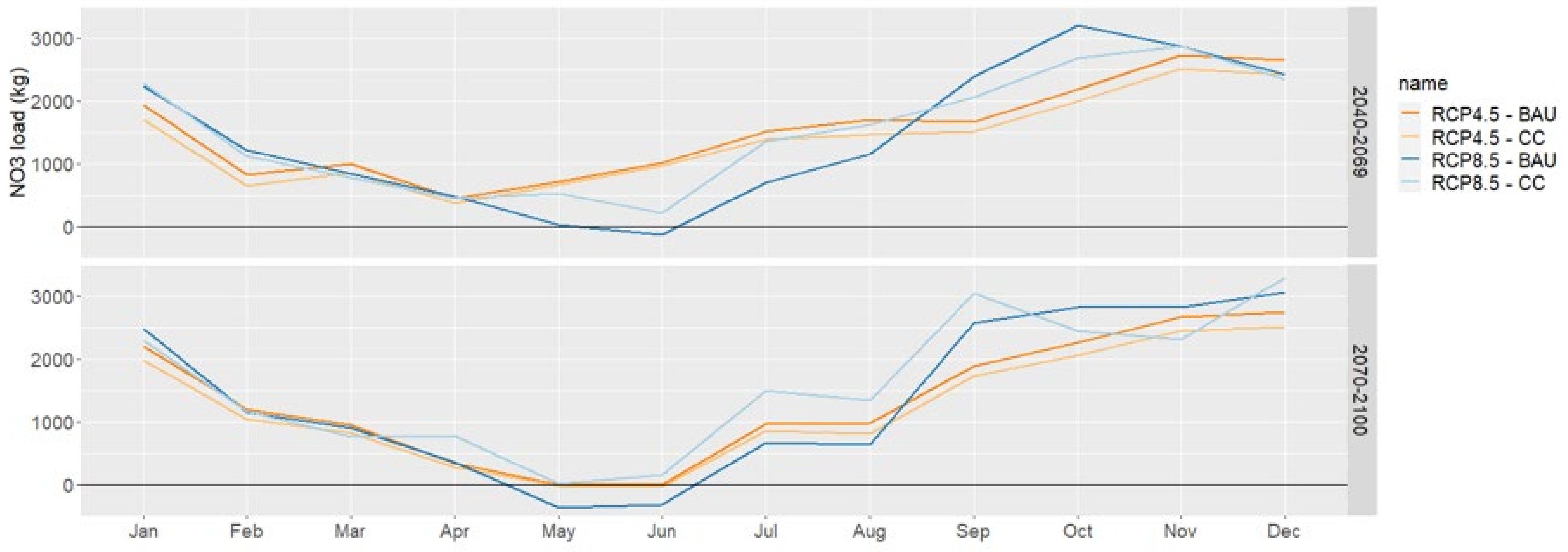


Increased N export under climate scenarios (but stabilized)

Cover crops slightly reduce N exports under most scenarios

Nitrate Load – Seasonal Patterns

- Monthly anomaly plots for future periods– relative to historical values



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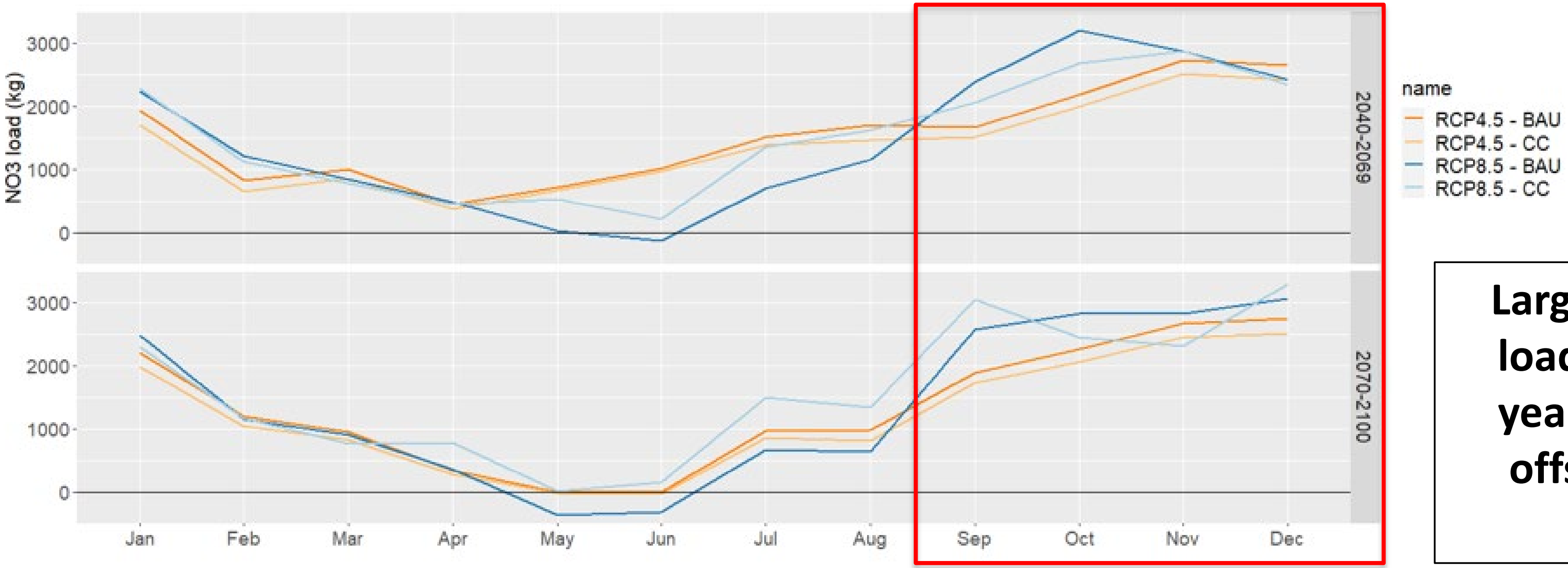

Large increase in loads late in the year (not nearly offset by cover crops)

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What did we learn given our objectives?

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- Use **SWAT** to quantify **future nitrate loads** under different **climate scenarios**.
  - How does this impact the water balance?
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- Initial scenario analysis indicates that climate change impacts outweigh the impacts of cover crops on N (i.e. increased N export)

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Conclusions

- Model is **very well-calibrated** to both streamflow and nitrogen loads in Castledockrell catchment (other ACP sites?)

- This is a very good starting point for further SWAT modelling in this catchment → more investigation into scenarios is needed

- This will compliment other nitrate leaching modelling work that is in planning → SWAT for upscaling

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Thank You for Your Attention!

Questions / Interest?

Please contact me at:
daniel.hawtree@teagasc.ie

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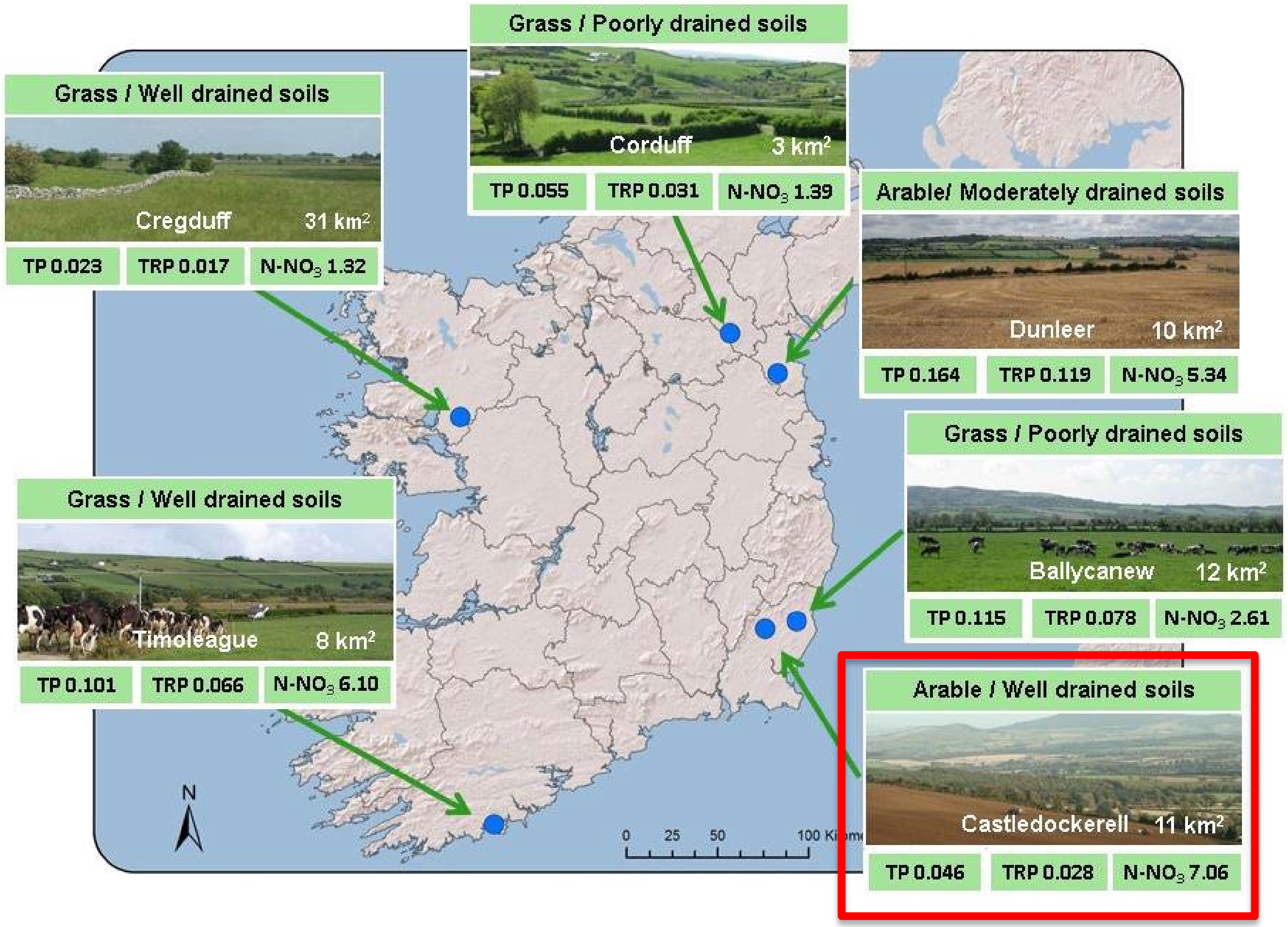
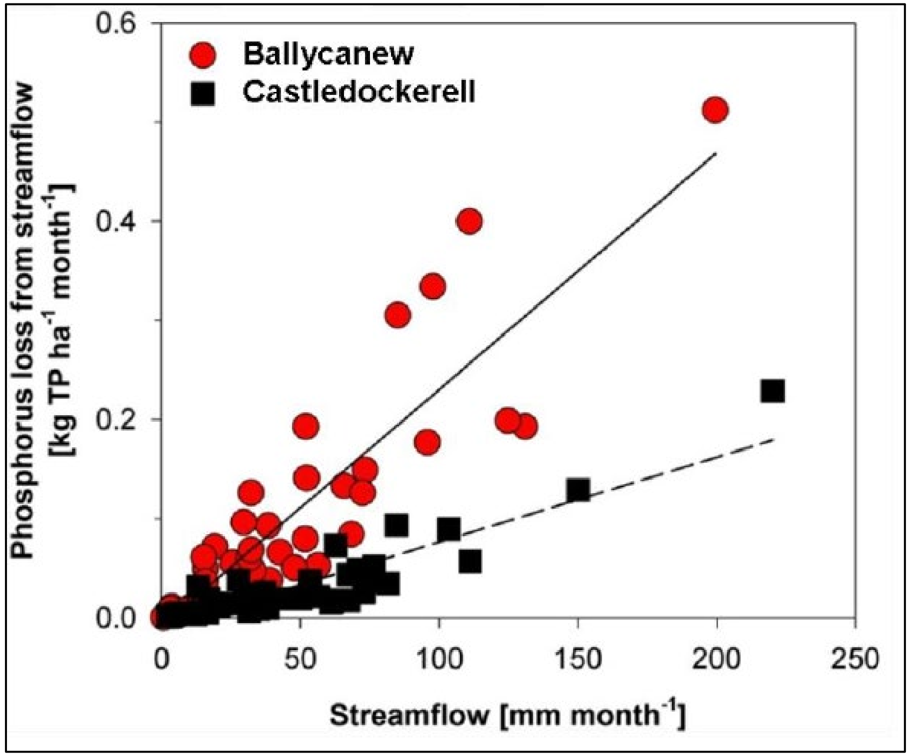
N-Risky & P-Risky Sites





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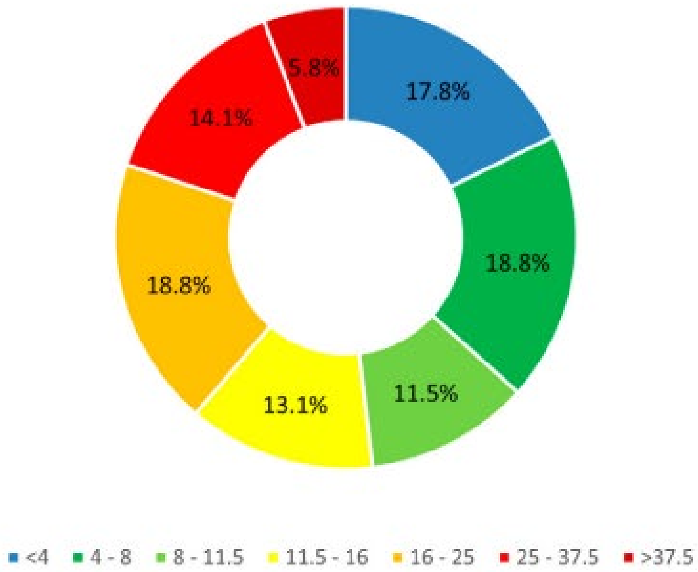
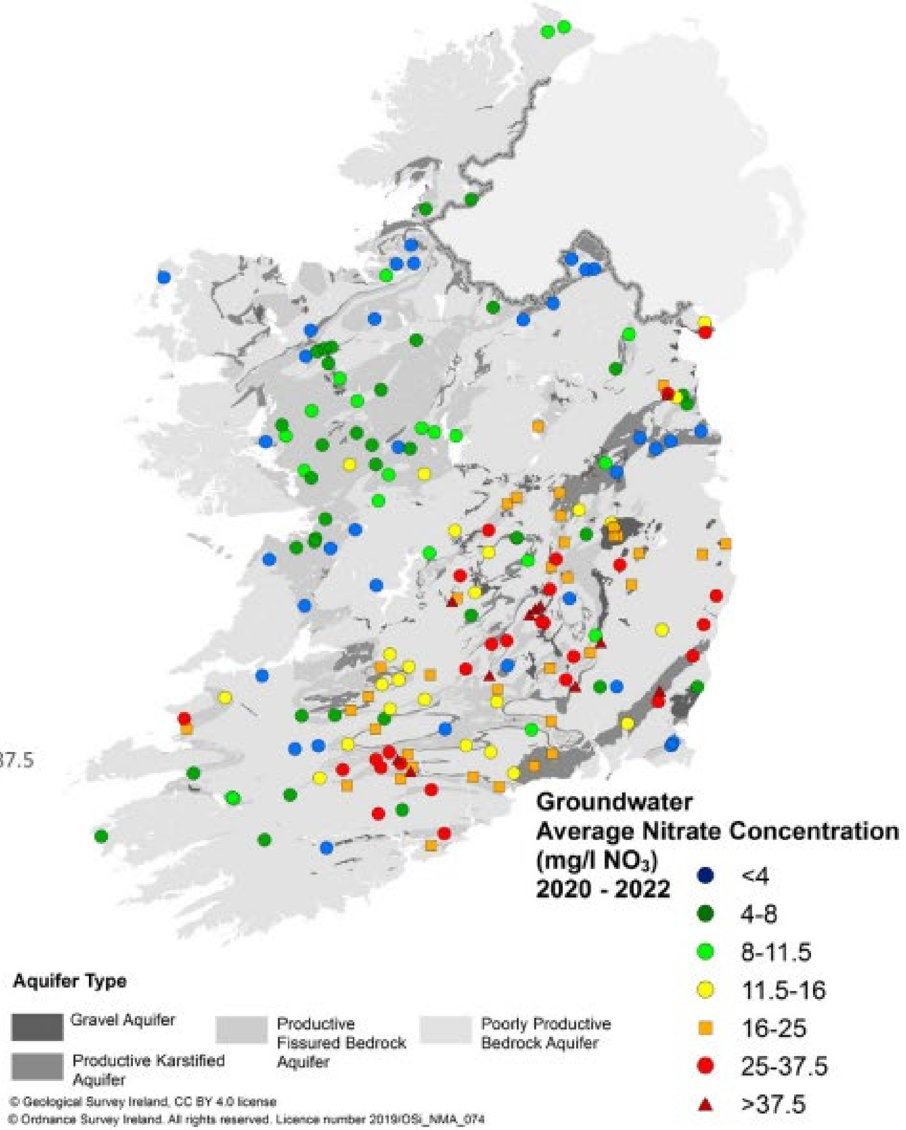
Nitrate in Groundwater
(mg/l NO_3)
2020-2022





Variable	Description	Units	Calibration range	Calibrated value
GW_DELAY	Groundwater delay time	days	1 - 31	2
ALPHA_BF	Baseflow recession constant	1/days	0.1 – 0.95	0.25
RCHRG_DP	Deep aquifer percolation fraction	-	0 – 0.15	0
DEP_IMP	Depth to impervious layer in soil profile	mm	1500 - 6000	5000
SURLAG	Surface runoff lag coefficient	-	1 - 6	1
CN2	Initial SCS runoff curve number for moisture condition II	-	-30 - 0	-20
Sol_K	Saturated hydraulic conductivity	mm/hr	-0.6 - 0	-0.5
Sol_AWC	Available water capacity of the soil layer	mm H2O/ mm soil	0 – 0.5	+0.3

Variable	Description	Units	Calibration range	Calibrated value
RCN	Concentration of nitrogen in rainfall	mg N/L	0 -15	15
CMN	Rate factor for humus mineralization of active organic nutrients (N and P)	-	0.0001 – 0.03	0.0001
CDN	Denitrification exponential rate coefficient	-	0.001 – 1.6	0.001
SDNCO	Denitrification threshold water content	-	0.1 - 1.9	0.2
NPERCO	Nitrate percolation coefficient	-	0.1 – 1	1
N_UPDIS	Nitrogen uptake distribution parameter	-	0 – 100	100
RCN_SUB	Atmospheric deposition of nitrate	mg/l	0 – 0.4	0.2
DRYDEP_NH4	Atmospheric dry deposition of ammonium	kg/ha/yr	0 – 8.2	8.08
DRYDEP_NO3	Atmospheric dry deposition of nitrates	kg/ha/yr	0 – 1.2	1.12
HLIFE_NGM	Half-life of nitrate in the shallow aquifer	Days	0 – 700	500

Climate Scenarios

- Climate scenarios were provided by the **WaterFutures** Project
  - 5 downscaled Global Climate Models: CNRM-CM5, ECEARTH, MIROC5, and MPI-ESM-LR (4 km horizontal resolution)
  - 2 emission pathways: Intermediate (RCP4.5) and intensive (RCP8.5)
  - 3 temporal intervals: 2010-2039 (NF), 2040-2069 (MF), and 2070-2100 (FF).

- Key Expected Impacts (w/ respect to nutrient export)
  - Mean daily precipitation is projected to increase
  - Precipitation will mainly increase in the period August to February
  - Increase in the number and intensity of extreme events

Nitrate Load – Seasonal Patterns