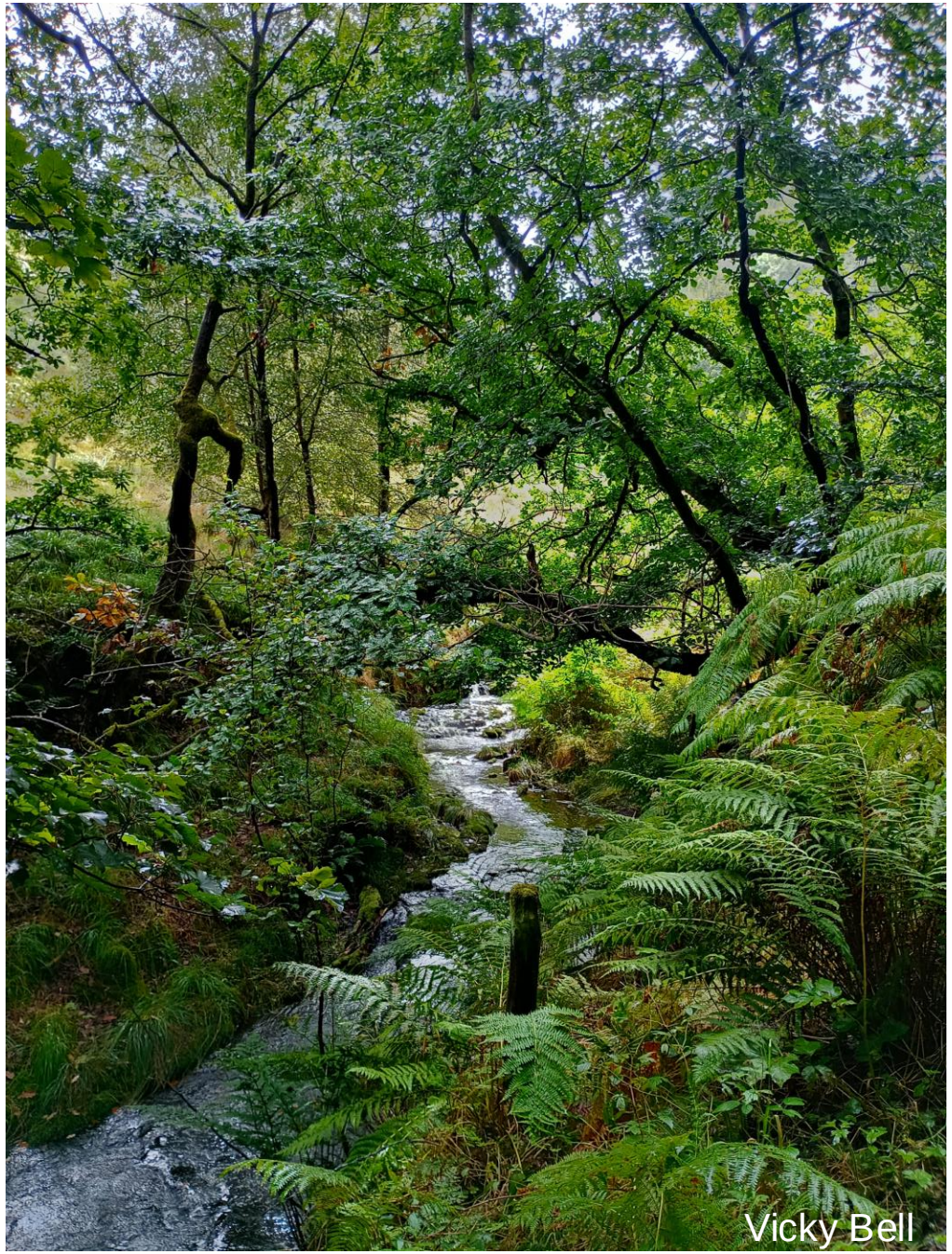
03.07.24

LTLS FRESHWATER ECOSYSTEMS

Freshwater Quality Programme Webinar: July 2024

Vicky Bell, Steve Lofts (UKCEH)
Ian Vaughan (Cardiff University)

- Introduction and freshwater quality modelling (VB)
- Pollutants: source and future change (SL)
- Putting the ‘FE’ into LTLS-FE (IV)
- What will the project deliver? (VB)



Meet the project team

- **UKCEH:**
  Vicky Bell and Steve Lofts (co-leads), Mark Rhodes-Smith, Nathan Missault, Gemma Nash, Bryan Spears, Hongyan Chen, Sam Harrison, Richard Ellis, Jacky Chaplow
- **Rothamsted Research:**
  Andy Whitmore, Alice Milne, Theo Jackson
- **Cardiff University:**
  Ian Vaughan, Will Perry
- **Bowburn Consultancy:**
  Martyn Kelly
- **BGS:**
  Dan Lapworth, Lei Wang, Matt Ascott, Ben Marchant, Barbara Palumbo-Roe

LTLS-FE kick-off meeting, January 2023

Cyfoeth Naturiol Cymru Natural Resources Wales
The Coal Authority
Scottish Government Riaghaltas na h-Alba gov.scot
defra Department for Environment Food and Rural Affairs
Environment Agency
UKWIR UK Water Industry Research
NATURAL ENGLAND
National Trust
Department of Agriculture, Environment and Rural Affairs
Sustainability at the heart of a living, working, active landscape valued by everyone
The Riverfly Partnership
FRESHWATER BIOLOGICAL ASSOCIATION
sepa

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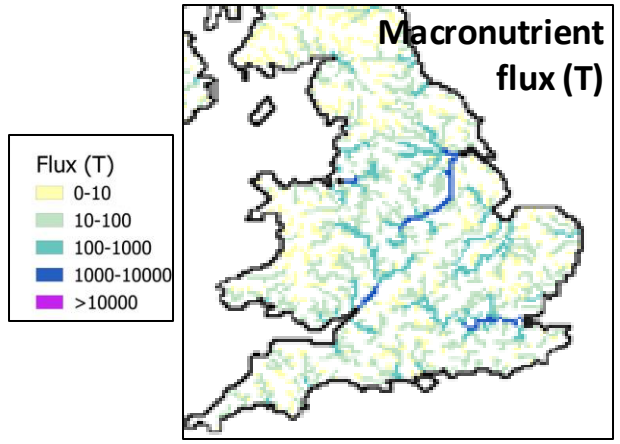
Background: Previous NERC research has explored how carbon, nitrogen and phosphorus in UK rivers changed since 1800…

Over this period the UK landscape has been transformed by the growth of agriculture, atmospheric pollution, and by human waste.

As part of a NERC Macronutrient Cycles-funded project called "**LTLS**", (Long Term Large Scale) we modelled how these changes contributed to the quality of our rivers, over the **last 200 years** and at a **national scale**.



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In the new project, LTLS-FE, we will use this modelling approach to explore *future projections* of freshwater quality and biodiversity for UK rivers

- We will use **newly-available climate and socioeconomic scenarios** to drive an innovative national-scale hydrological model of the potential futures of all the UK's rivers.

- We will show how the combination of **multiple contaminants and a changing climate** might impact on our freshwater ecosystems.

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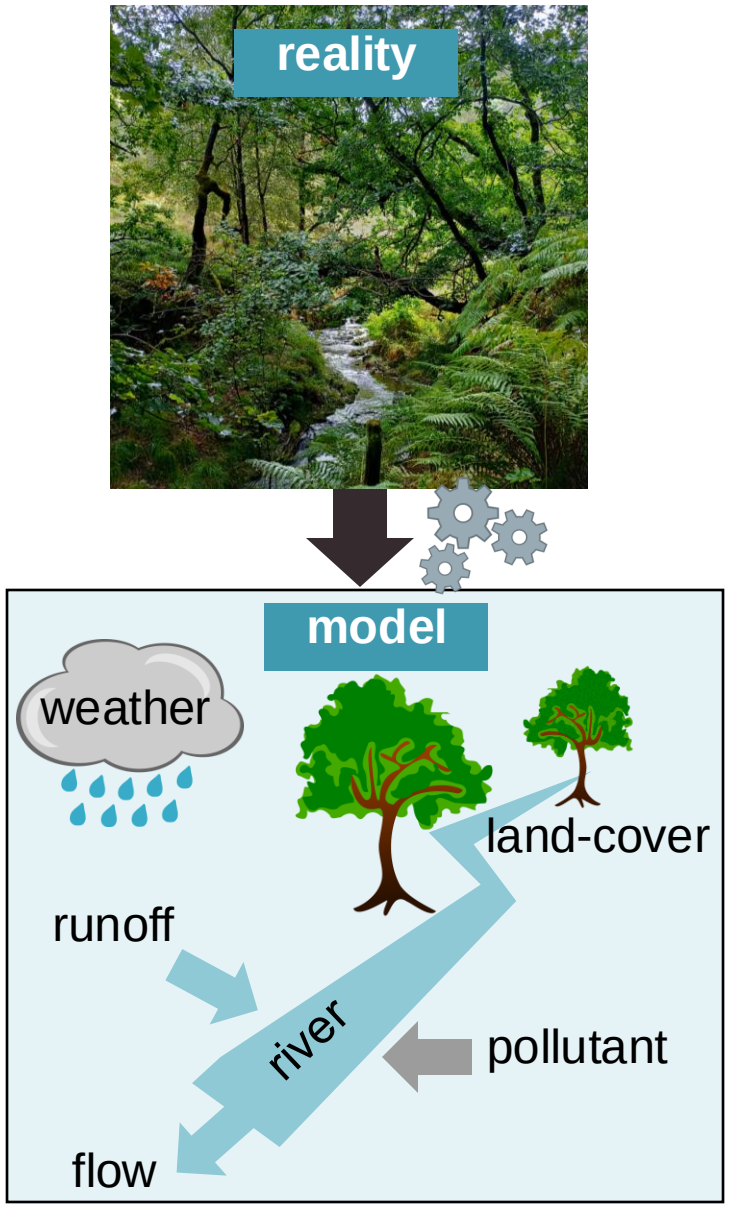
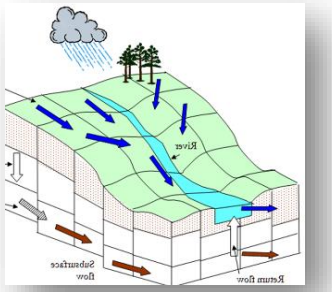
What do we mean by a “model” and why are we using one?

- Models summarise our understanding of how the world works, usually in mathematical equations (and computer code).
- The world is complex and models typically need to focus on the most important parts… and of course they need to make simplifications.
- But models are useful for understanding the past or future (without having to time travel) and they let us explore places we can’t measure. We can also test scenarios…
- *Checking the model against the measurements helps us test and improve our understanding of the world*



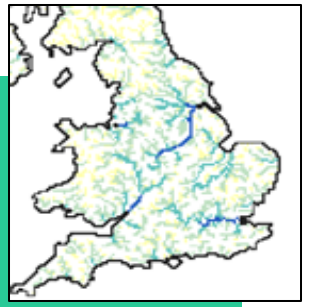
How are we making a national scale freshwater model ?

We use existing models, datasets and expert knowledge as much as possible:



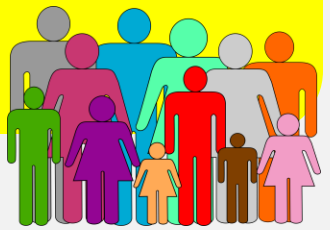
G2G hydrological model for UK simulated river flows on a 1km grid

LTLS added macronutrients C,N&P, lakes, geology and chemistry: UK 5km grid



LTLS-FE has introduced metals and micropollutant expertise

Add UKCP18 climate scenarios and SPEED socio-economic scenarios



Work with ecologists to introduce the **FE** (**Freshwater Ecology**) into LTLS-FE

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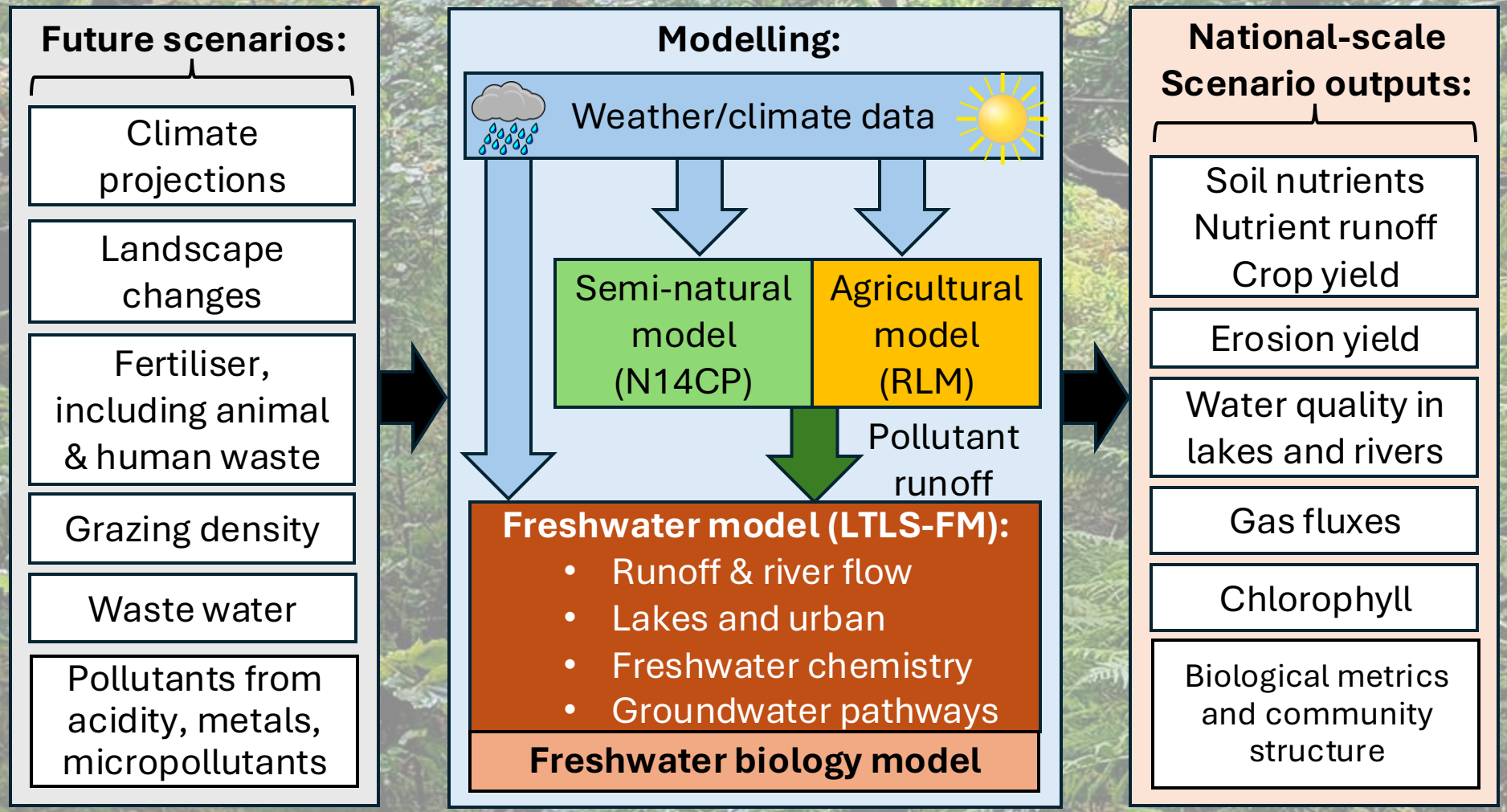
What processes are included in the freshwater model?



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What freshwater (physical) variables are we modelling?

Water

Macro-nutrients

Carbon
Nitrogen
Phosphorus
Sulphur

Micro-pollutants

Pharmaceuticals
Personal care products
Industrial Chemicals

Polyaromatic Hydrocarbons
Banned Pesticides
Allowed Pesticides

Metals

Aluminium
Nickel
Copper
Zinc

Cadmium
Lead
Manganese

Water quality

pH
Temperature

Oxygen
Biomass (C,N,P)

and more to come…

For the full list, please go to our website: https://www.ceh.ac.uk/LTLS-FE

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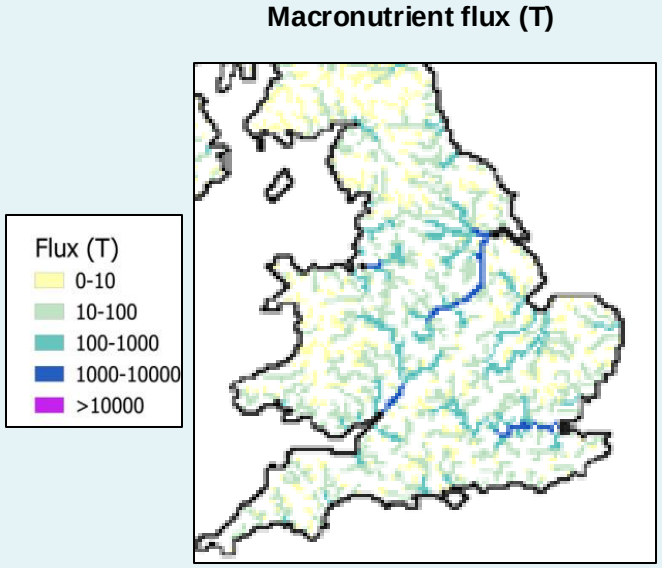
LTLS-FE project overview

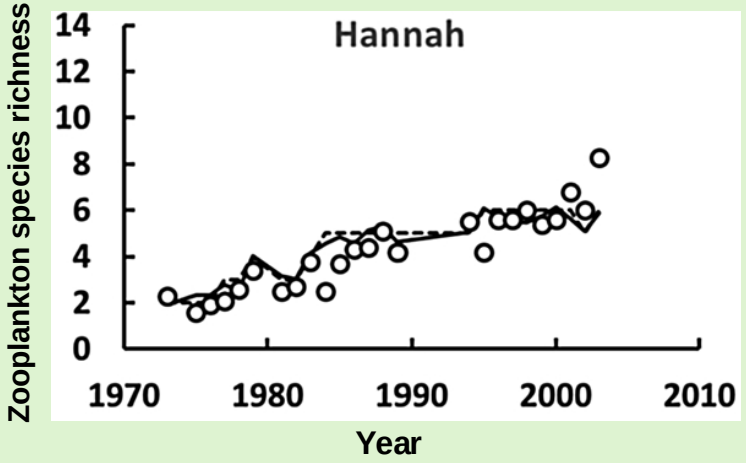
Model concentrations of chemical stressors in rivers for whole UK (5km x 5km)

Present day

Future (UK-SSPs; RCPs)



Model biological response to changing chemical stress

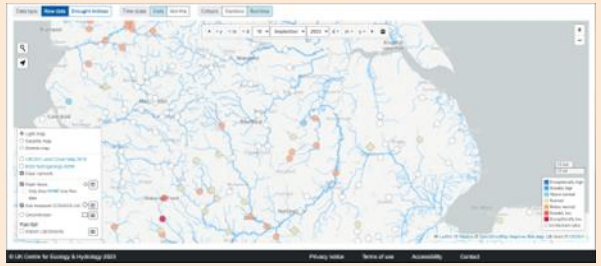


Recovery from acidification and metal stress, Ontario Canada

E. Tipping, S. Lofts and W. Keller, *Aquatic Toxicology, 2021,* ***231, 105708.***

Policy implications and dissemination of outcomes

Webtools and code



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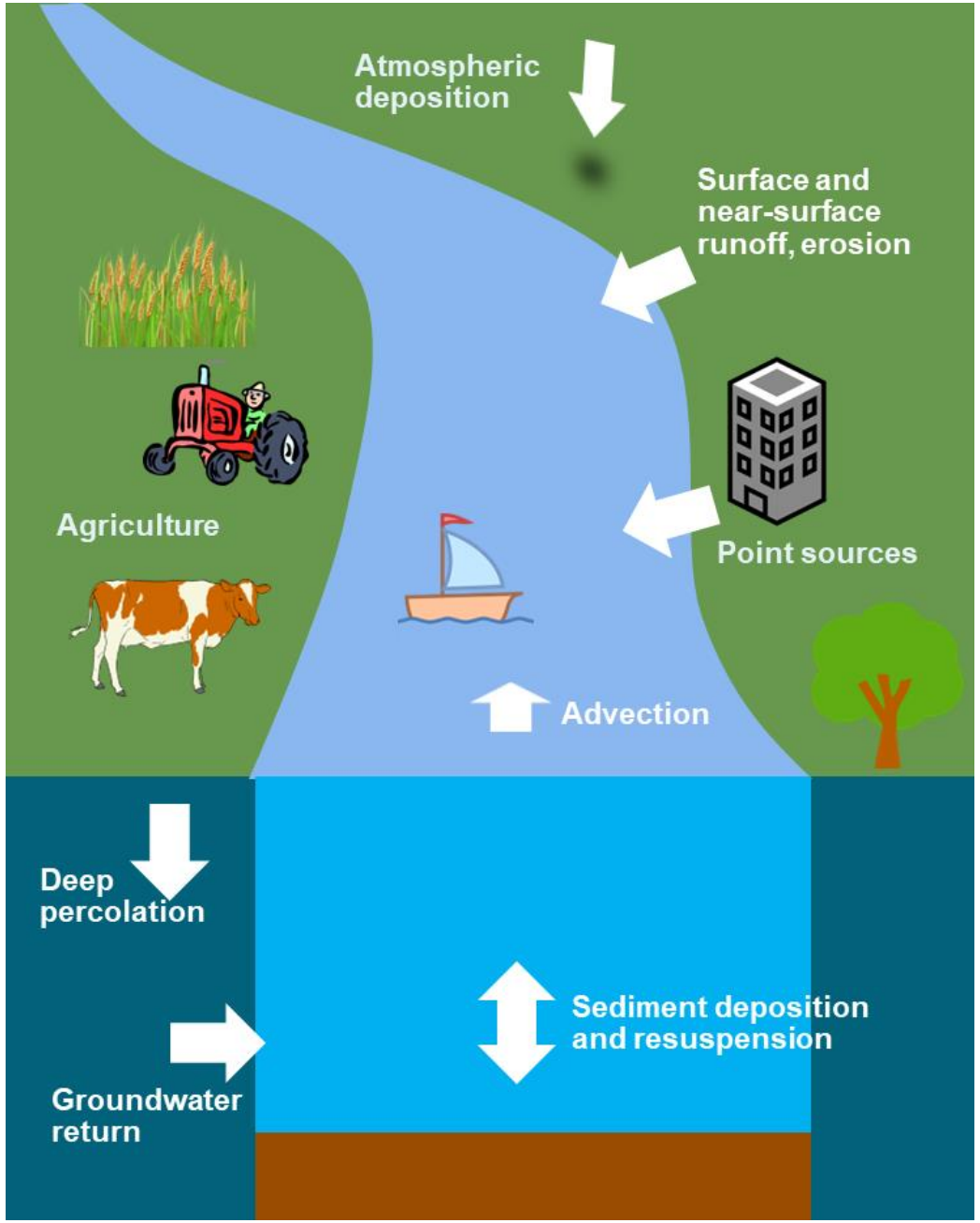
Pollutants: sources and future change

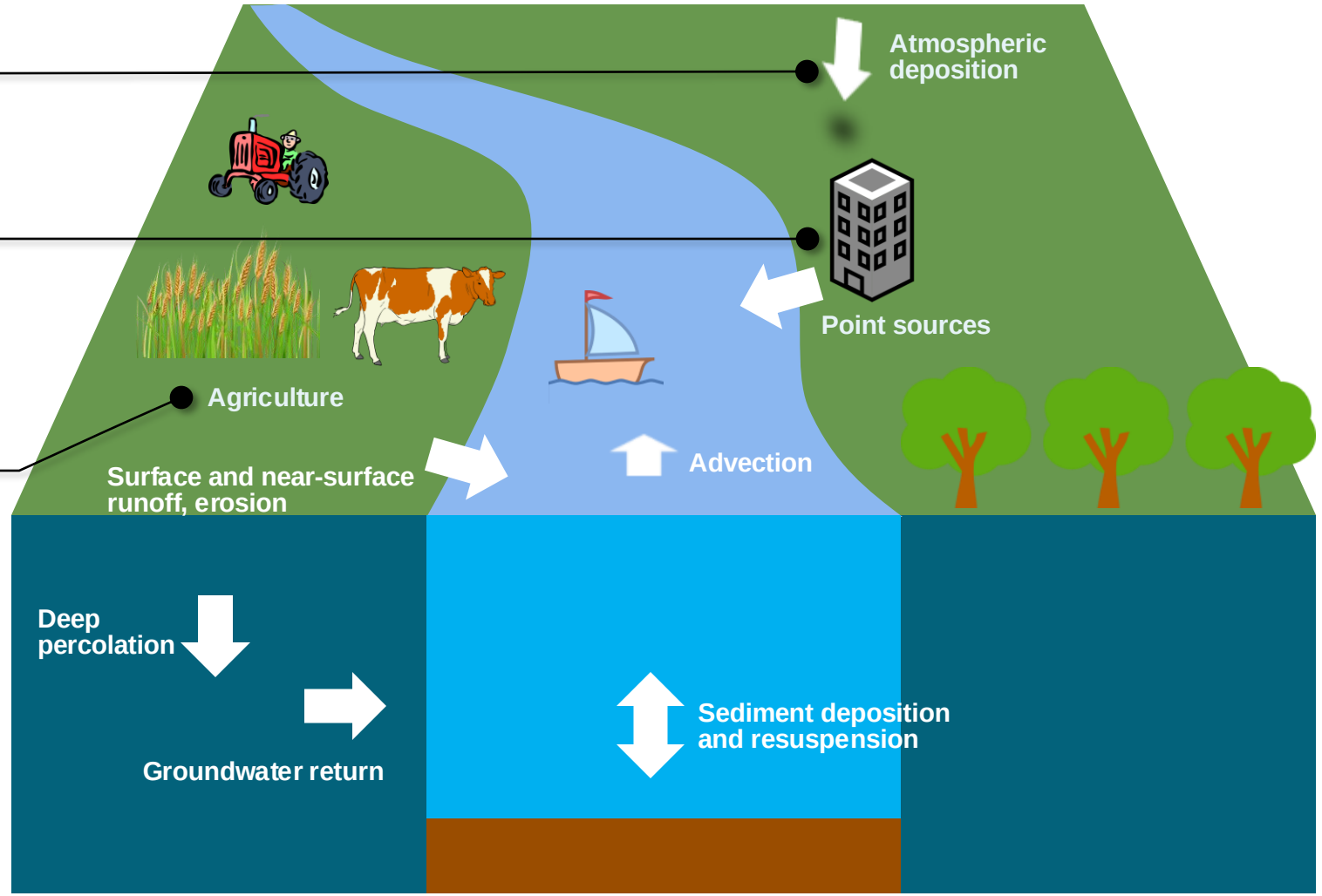


Key sources of pollutants

Atmospheric deposition **M H A N**

Domestic waste **Ph M H N**
Road runoff **M H**
Industrial emissions **M Ph H Pe**
Mines **M A**

Biosolids application **N M H Ph**
Pesticide use **Pe**
Manure application **N M Ph**
Fertiliser use **N M**



M	**metals**
H	**PAHs/organic industrial**
A	**acidifying contaminants**
N	**nutrients**
Ph	**pharmaceuticals**
Pe	**pesticides**

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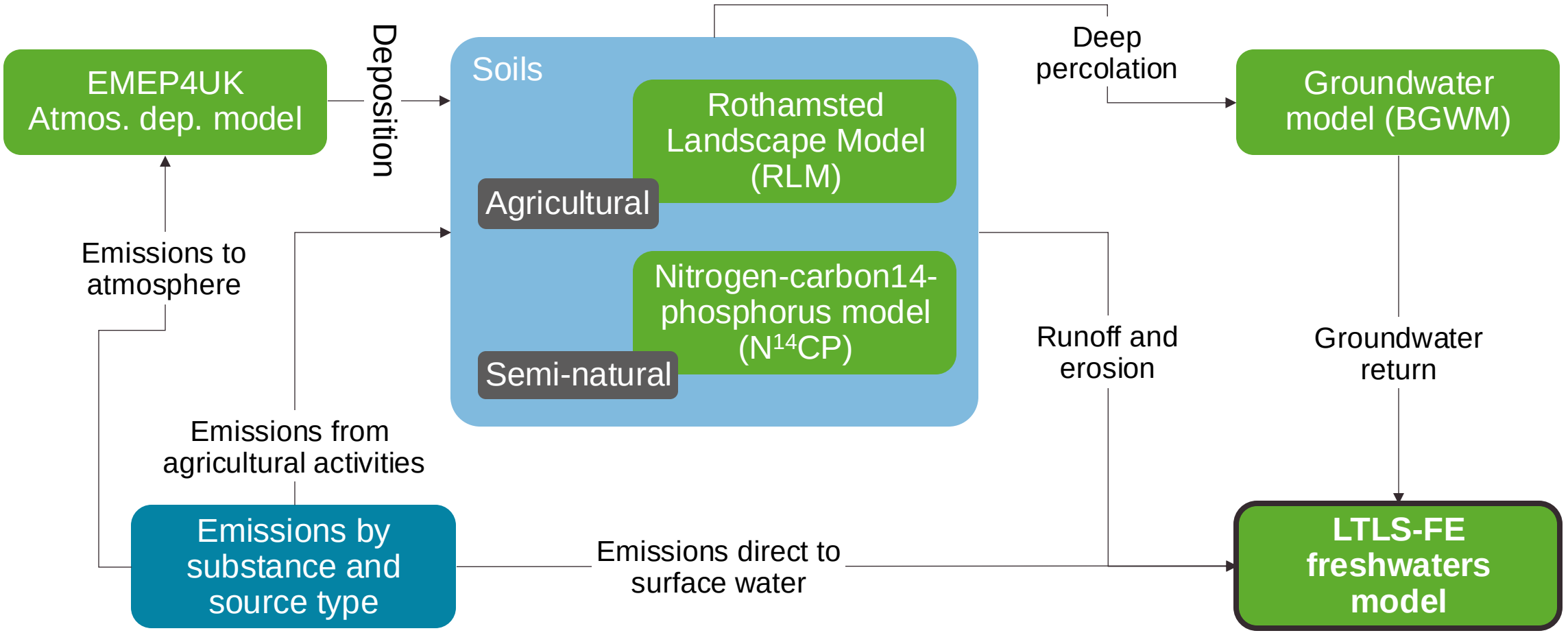
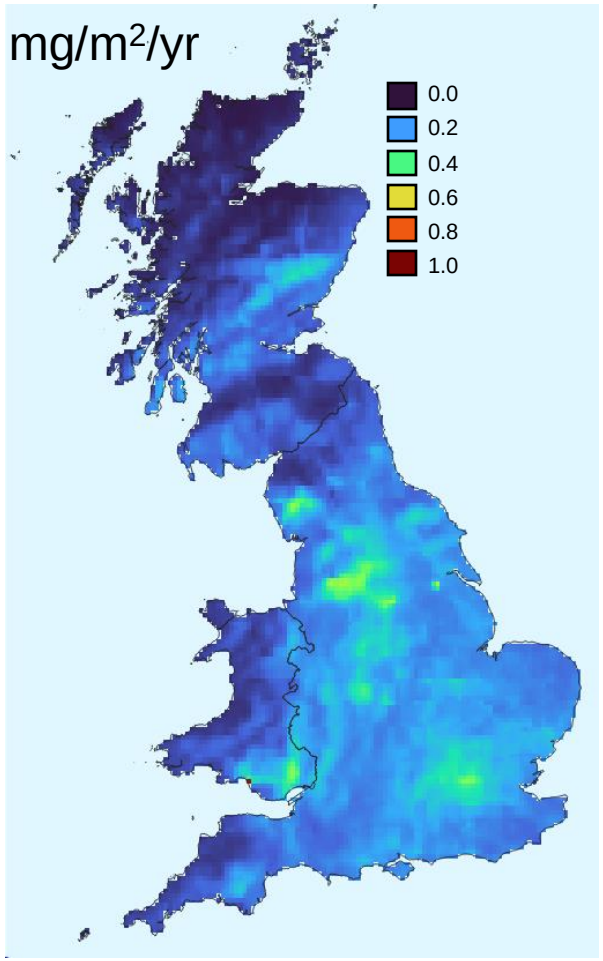
Data and model layout

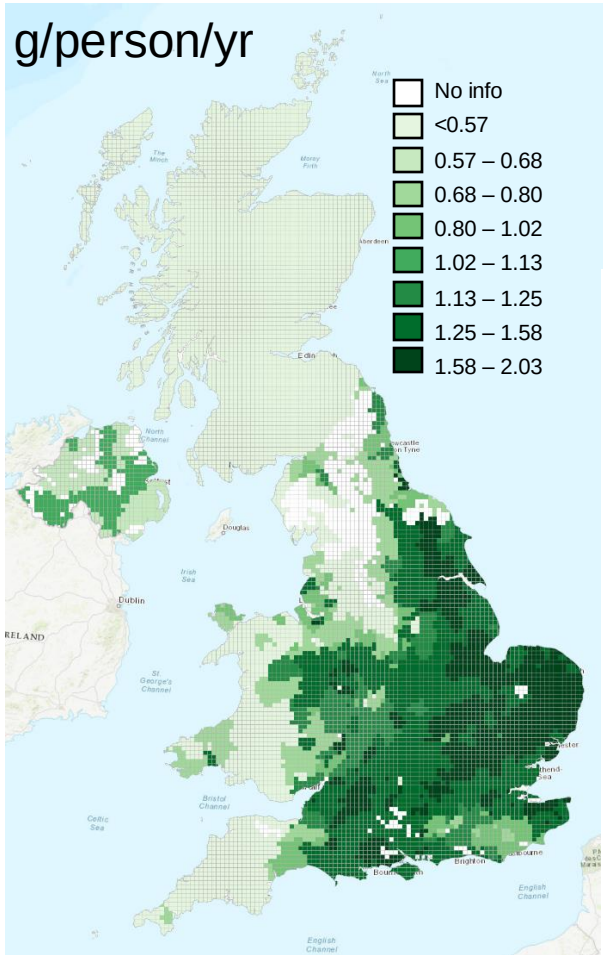


Present day emissions – copper example

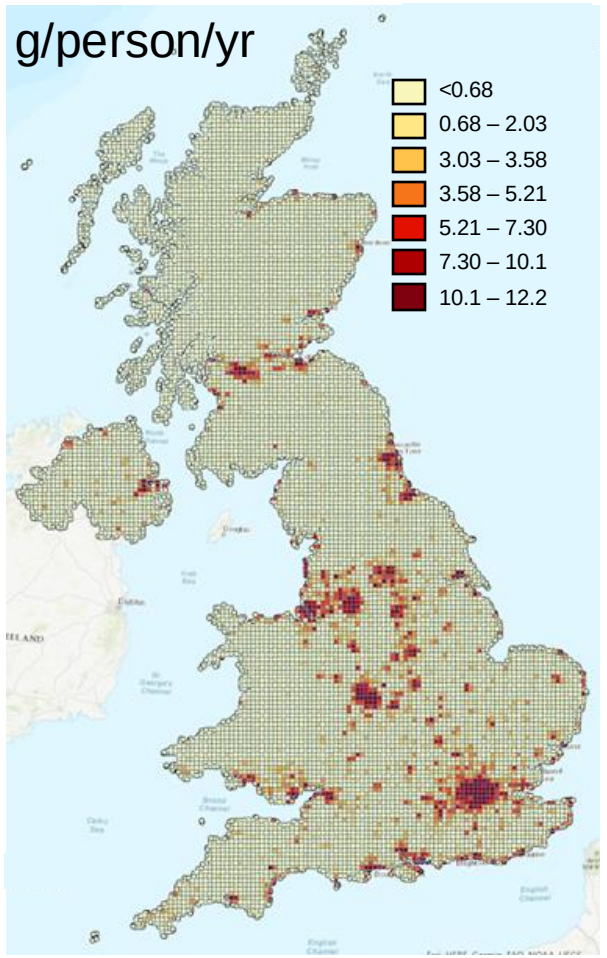
Wet atmospheric depn.



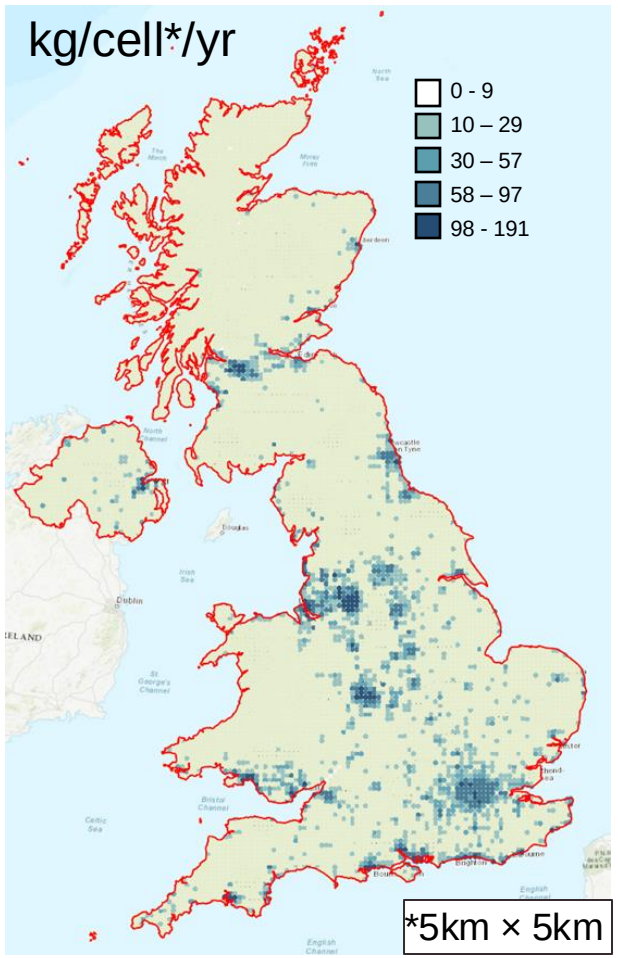
Domestic to wastewater



Services to wastewater



Urban runoff to wastewater



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Future scenarios: UK Shared Socioeconomic Pathways

UK-SSP1: **Sustainability**

UK-SSP2: **Middle of the Road**

UK-SSP3: **Regional Rivalry**

UK-SSP4: **Inequality**

UK-SSP5: **Fossil-fuelled Development**

"Stories about what happened in the future"

Exploratory scenarios, downscaled from global and European SSPs

Five plausible but contrasting future societal directions

Elements co-developed with UK stakeholders

Used to identify key drivers of outcomes and impacts, challenge policy development

NARRATIVE

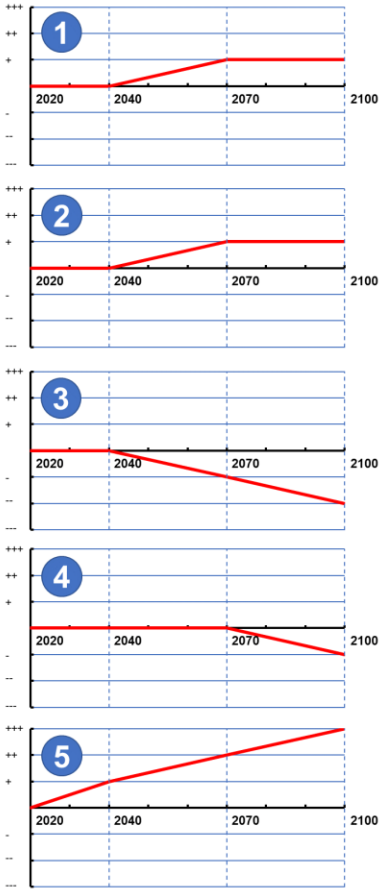
a prose description of key events and trends

SEMI-QUANTITATIVE TRENDS

in 50 socio-economic variables

trend in seven categories (no change, sml/med/lrg ↑, sml/med/lrg ↓)

Example is for population



QUANTIFIED PROJECTIONS

27 variables many spatial

Population
Demography
Health
Healthcare
Inequality
GDP
GVA
Food consumption
Employment
Household Income
Food Production
Land Use
CO_2 emissions
Energy
Electricity
Environmental values
RD transfers
Road infrastructure
Rail infrastructure
R&D expenses
Education
Social Cohesion
Produced Capital
Savings
Urbanisation
Land Use intensity

Not all projections go to 2100. **We will model to 2080.**

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Future scenarios

Substance

Use profile

Source-freshwater pathways

Proxy drivers

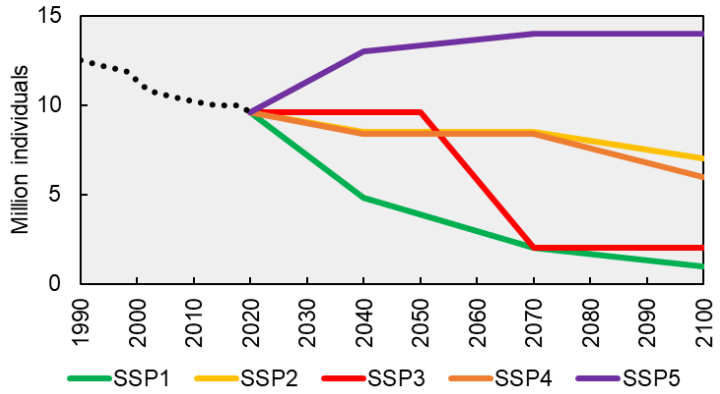
Semiquantitative trends

Quantitative trends

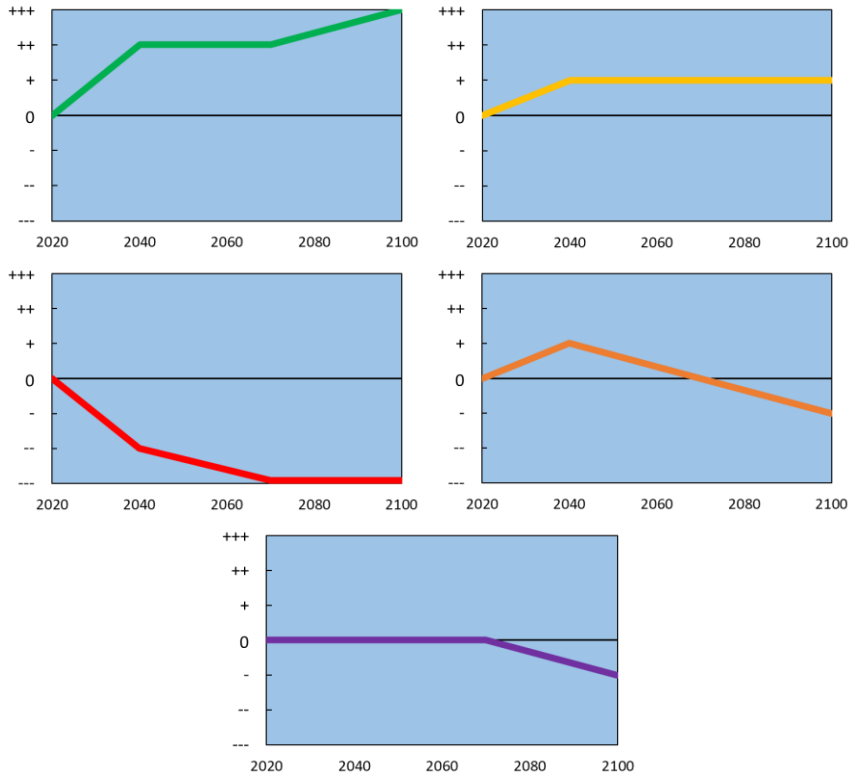
Copper

Source type	Applications
Domestic/services/ light industry	Copper piping
Industrial	Electrical Renewable energy Recycling
Runoff	Car brakes Roofing
Agriculture	Biosolids Feed additives Fungicide
Mining	Extraction Smelting Abandoned workings

Total number of livestock - cows



SQ trend 'Efficiency and capacity of wastewater treatment system'



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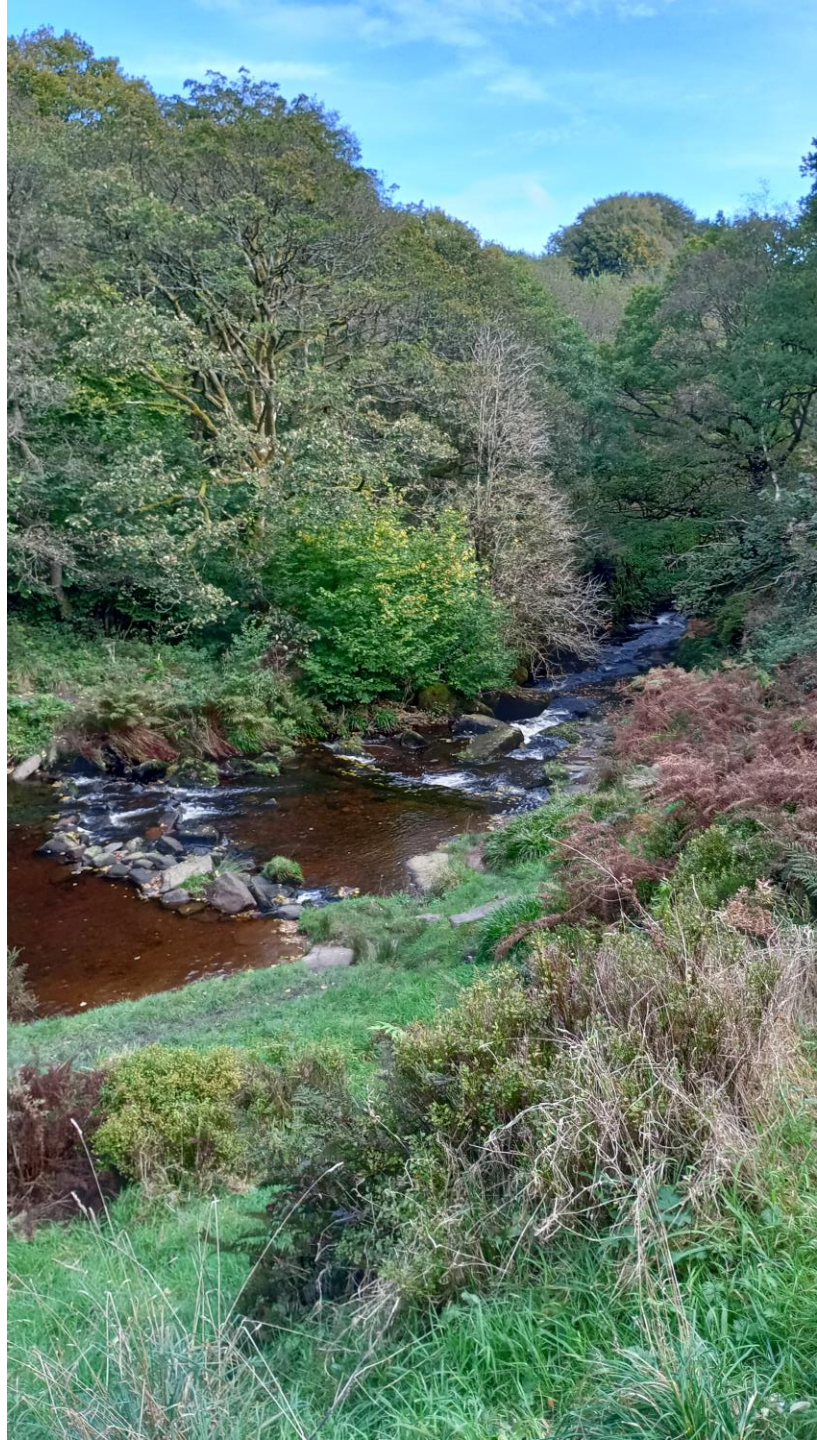
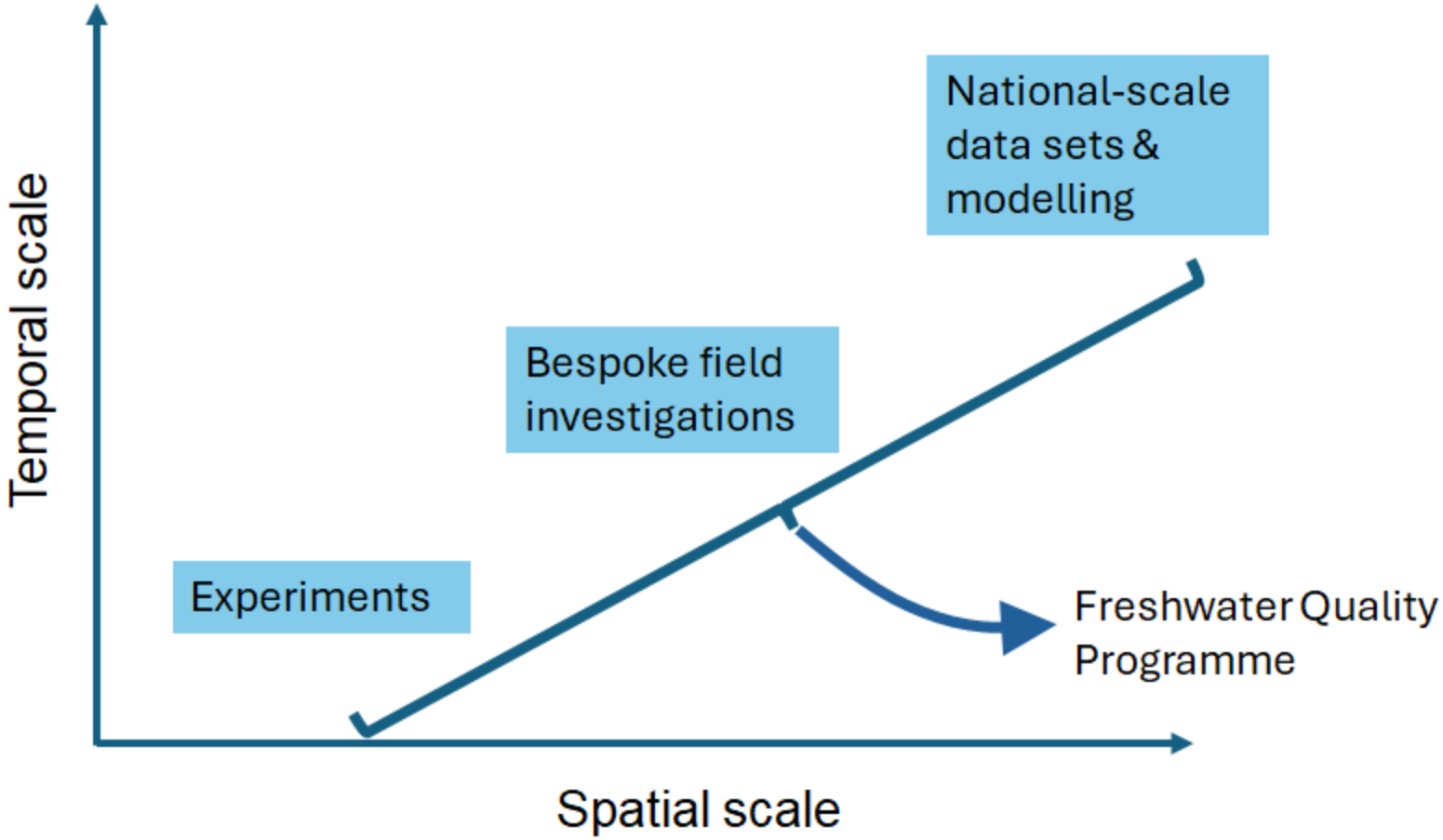
Putting FE into LTLS-FE



Understanding multiple stressor effects



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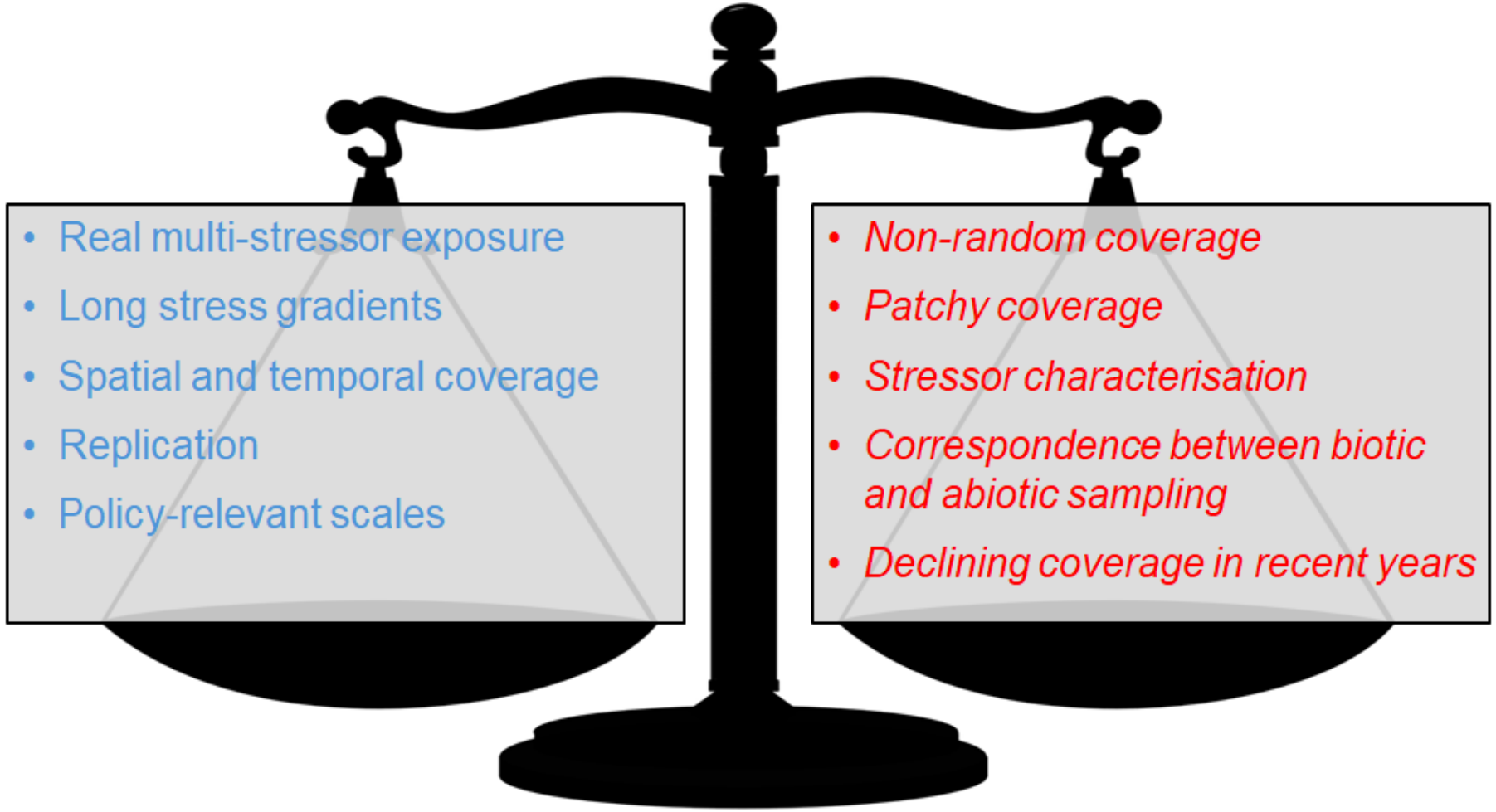
Re-purposing national monitoring data to study multiple stressors



Changing status – but drivers are less well understood…

Article

The recovery of European freshwater biodiversity has come to a halt

Haase et al. (2023) *Nature*

Abundance trends for river macroinvertebrates vary across taxa, trophic group and river typology

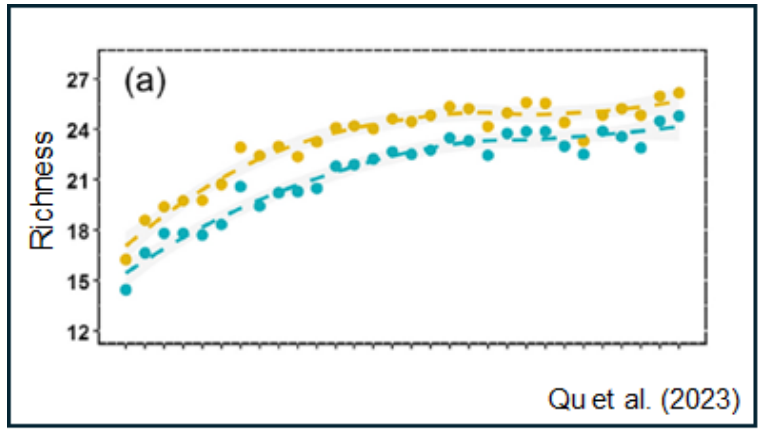
Powell et al. (2023) *Glob. Change Biol.*

Evidence of biological recovery from gross pollution in English and Welsh rivers over three decades

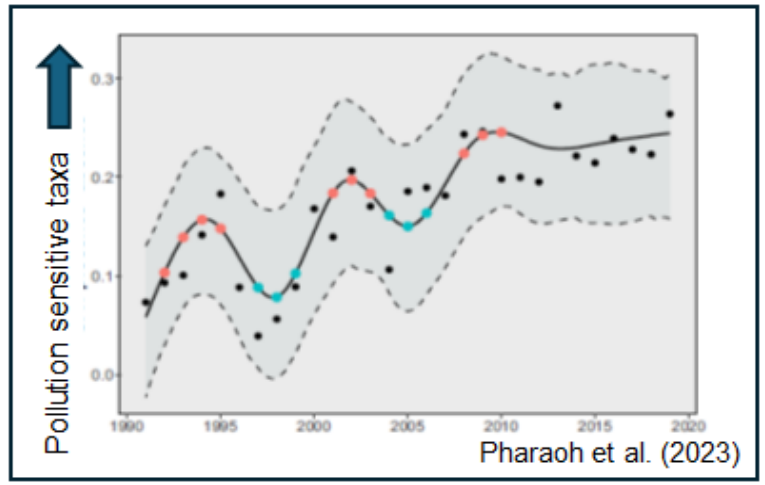
Pharaoh et al. (2023) *STOTEN*

Significant improvement in freshwater invertebrate biodiversity in all types of English rivers over the past 30 years

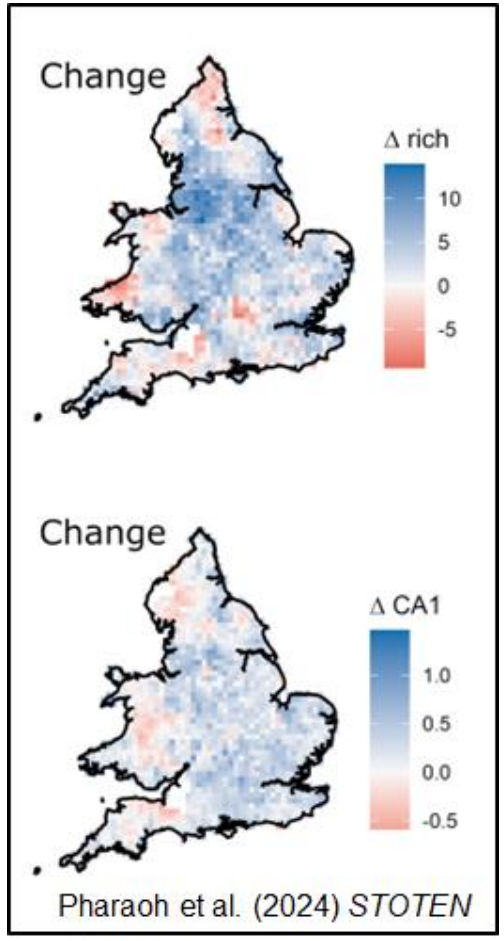
Qu et al. (2023) *STOTEN*



Qu et al. (2023)



Pharaoh et al. (2023)



Pharaoh et al. (2024) *STOTEN*

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LTLS-FE's contribution

- Expand the range of stressors
- Provide complete spatial and temporal coverage for selected stressors
- UK-wide
- Produce biodiversity forecasts under future scenarios

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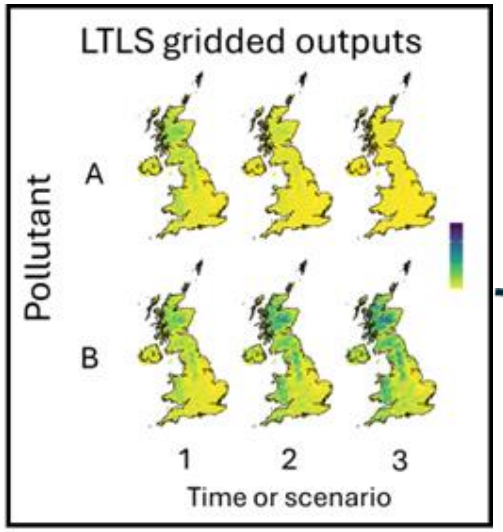
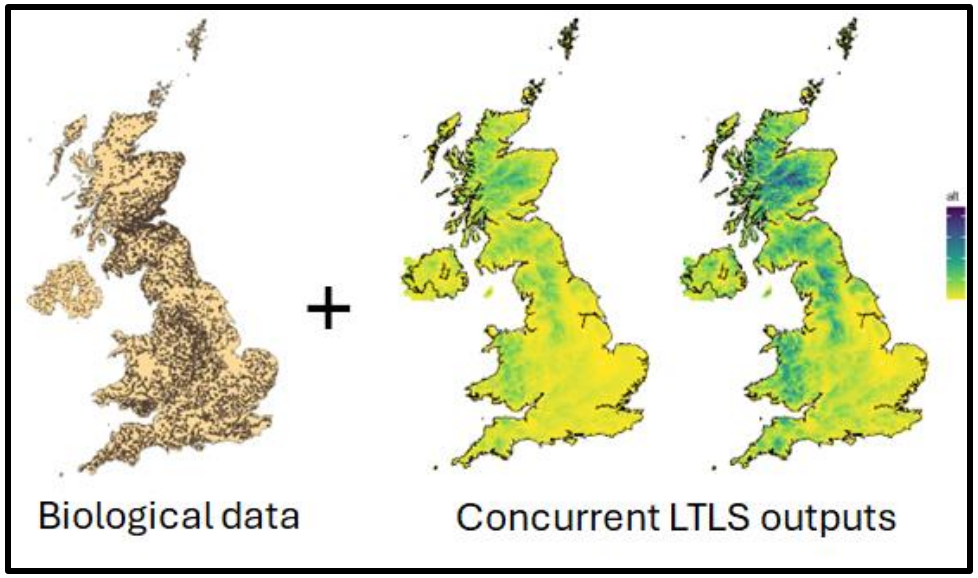
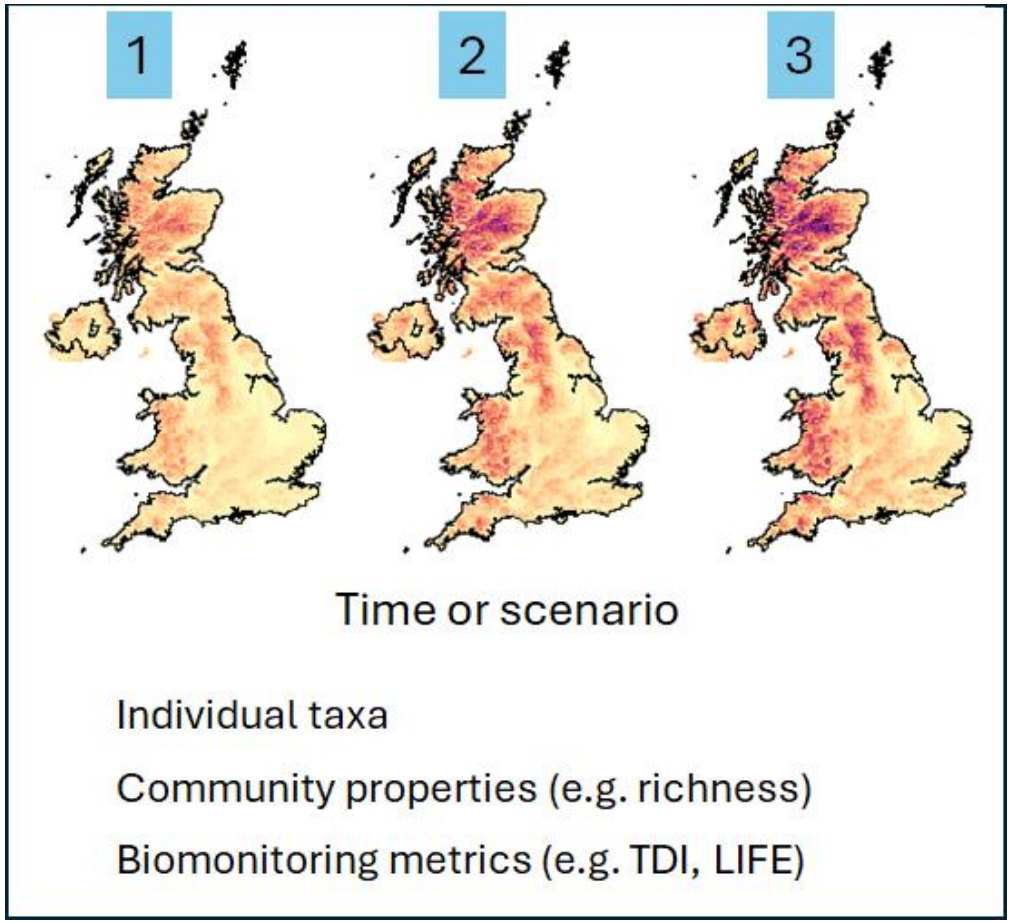
Biodiversity forecasts







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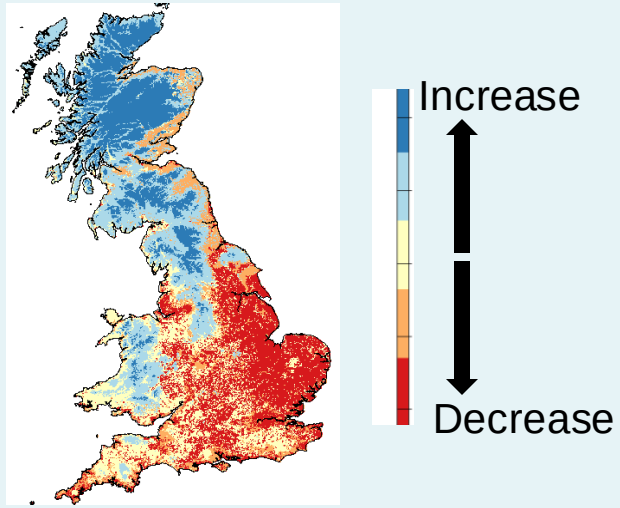
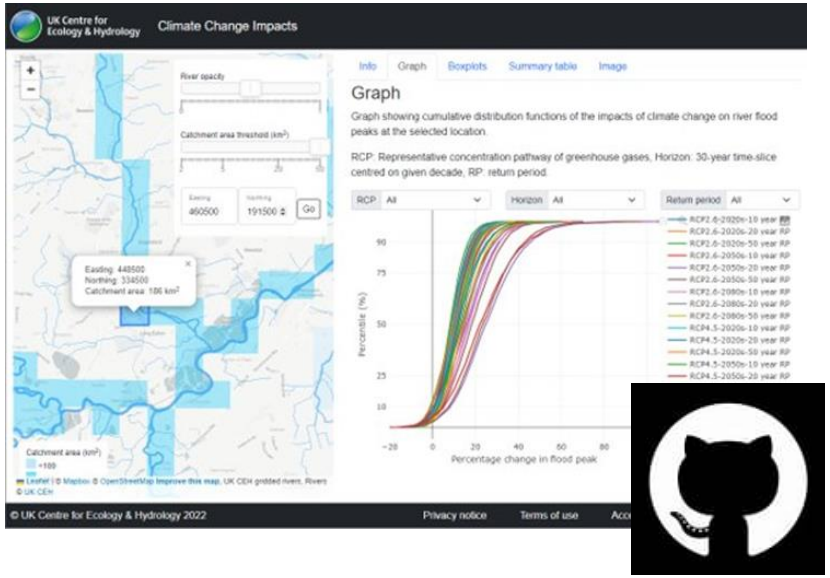
What will LTLS-FE deliver?

Change in indices e.g. ASPT, TDI



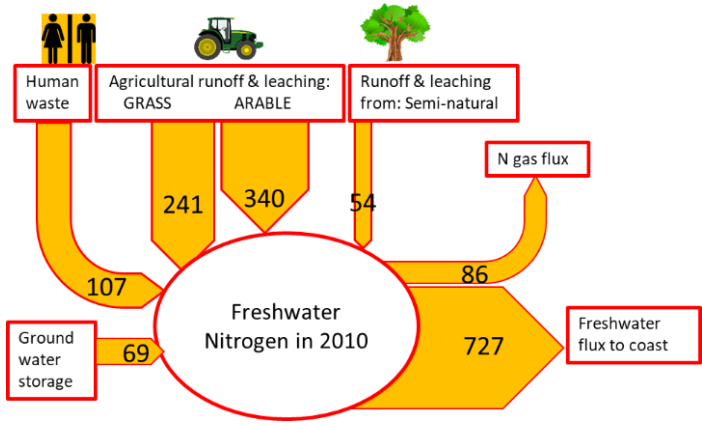
Webtools and code



Our goal is to provide information to support adaptation and mitigation of risks to Freshwater Quality

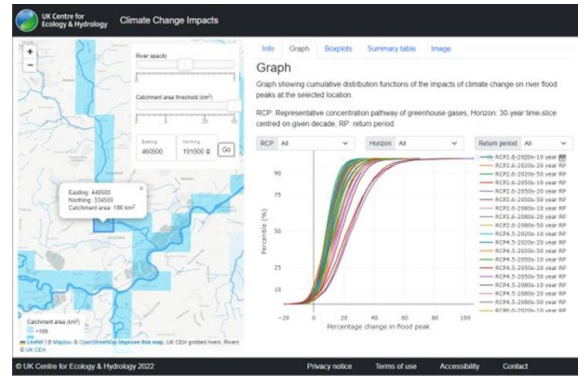
For stakeholders

- Impacts/information derived from the scenario outputs to help **develop plans for adaptation, mitigation and detection of risks** to river quality



For other researchers

- Models shared on Github
- Datasets published for use in follow-on projects
- Publish research in refereed journal publications



For everyone

- Website (https://www.ceh.ac.uk/LTLS-FE) and **web-dissemination tool** for exploring freshwater futures

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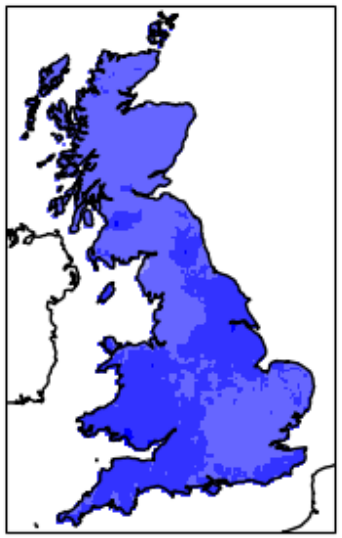
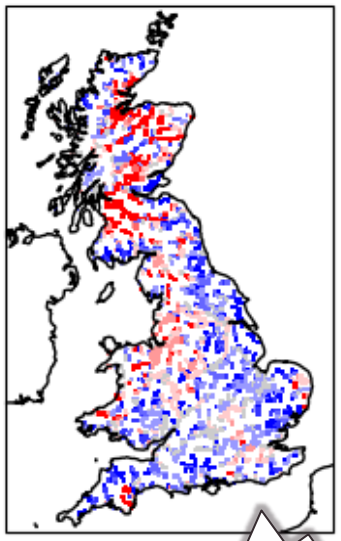
Prototype LTLS-FE scenarios: change in Cadmium (Cd) from 2000 to 2050

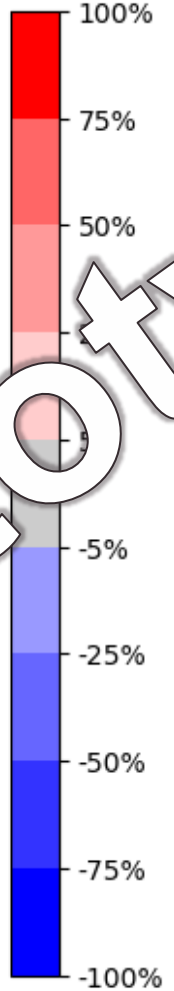
Green future:
SSP1
RCP2.6

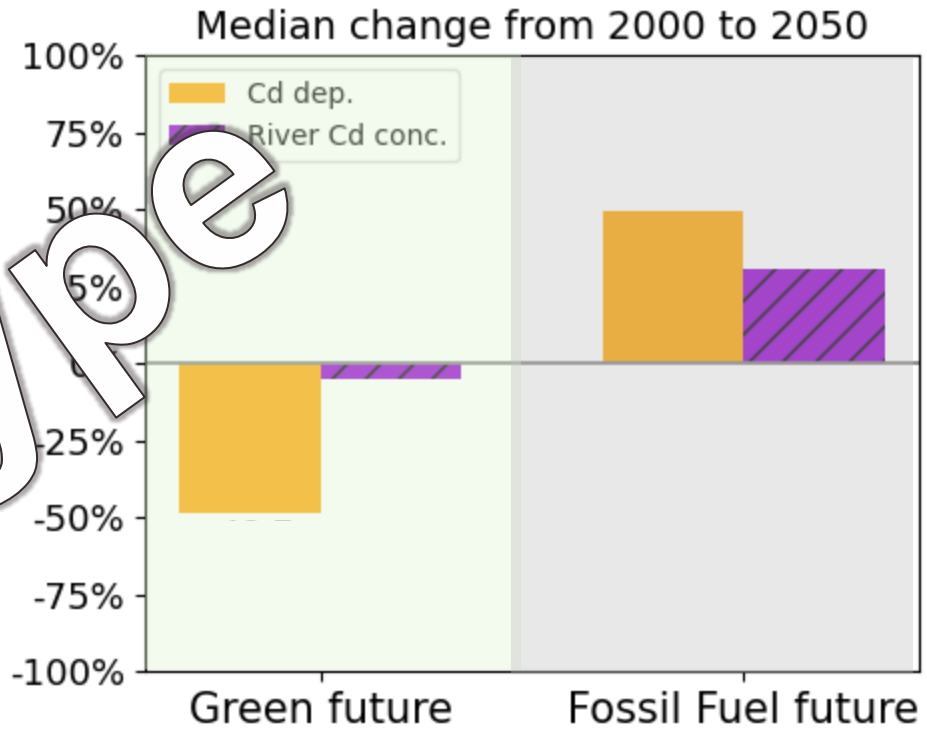


Cd deposition

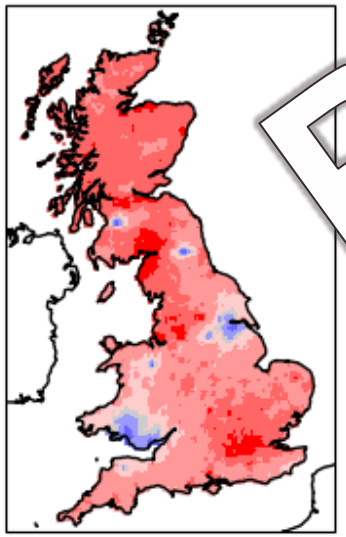


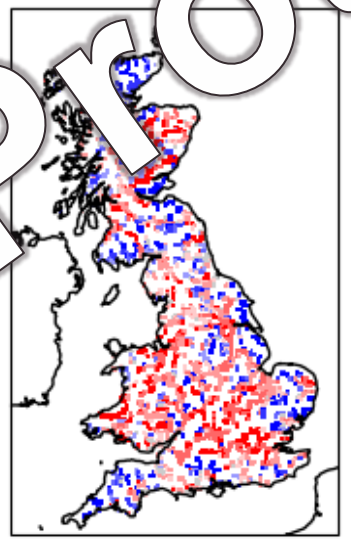
River Cd concentration





Fossil fuel future:
SSP5
RCP8.5



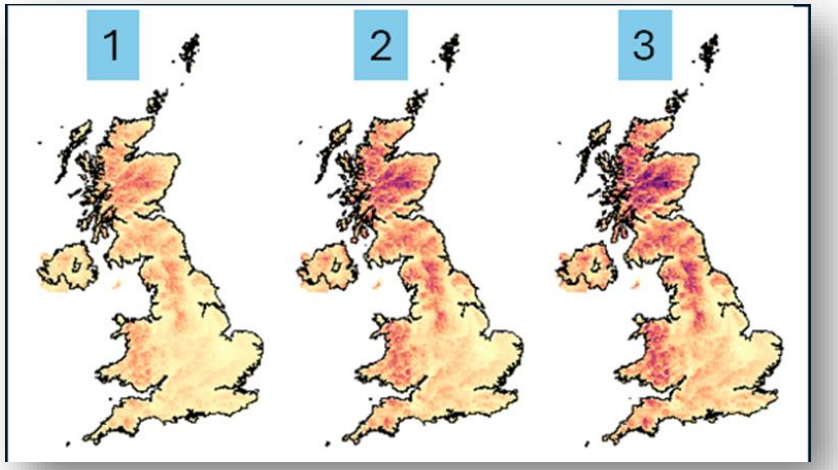


*Summary: Broadly, freshwater Cd **decreases** in the green future scenario and **increases** in the fossil fuel scenario*

What will the scenario analyses provide?

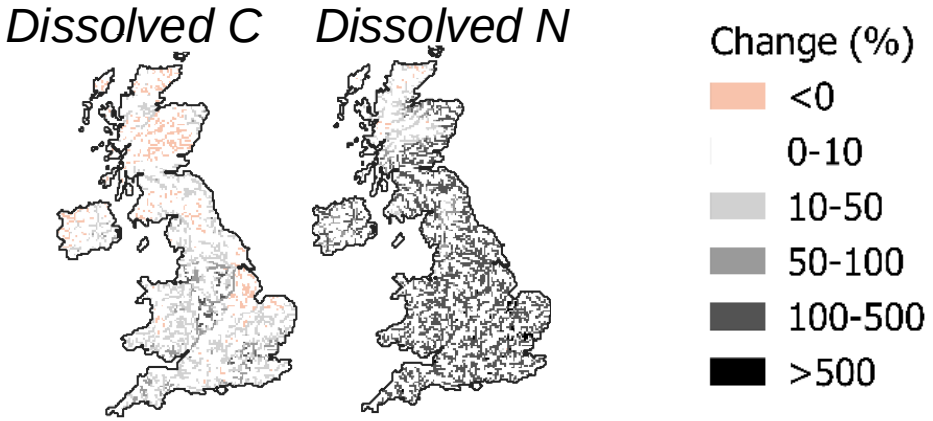
These examples of how future socio-economic scenario outputs might look are based on simulated historical trends or prototype output

Estimated future change in biodiversity indicators for different scenarios



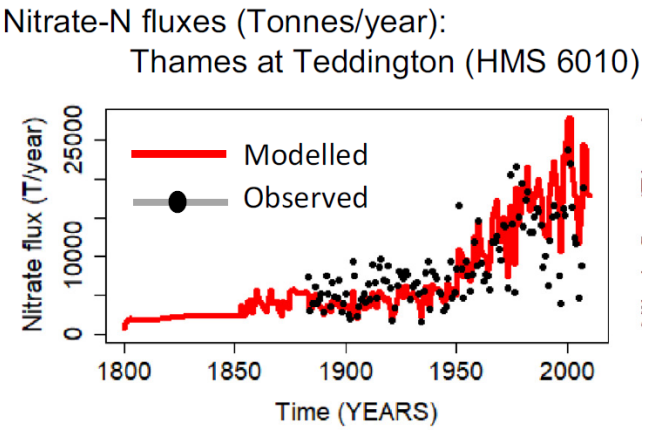
Estimated future change in freshwater quality

% change in annual flux from 1900 to 2000



Future trends in pollutants at monitoring sites

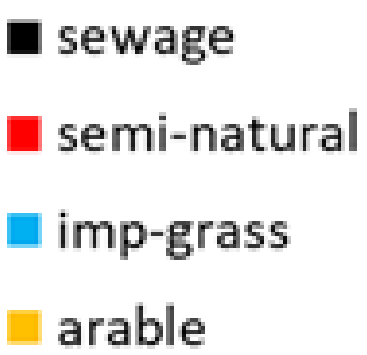
Change in annual flux of Nitrate from 1800 to 2010

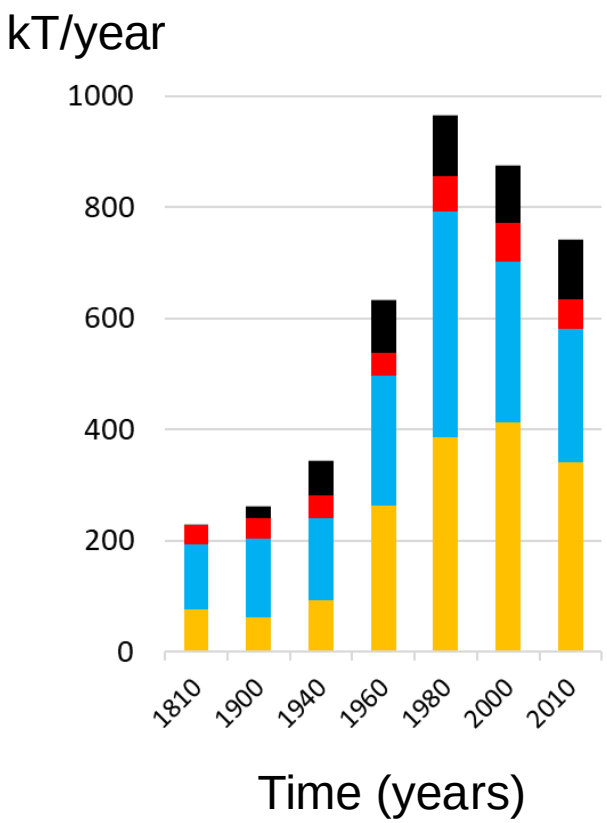


How can LTLS-FE outputs support decision-making?

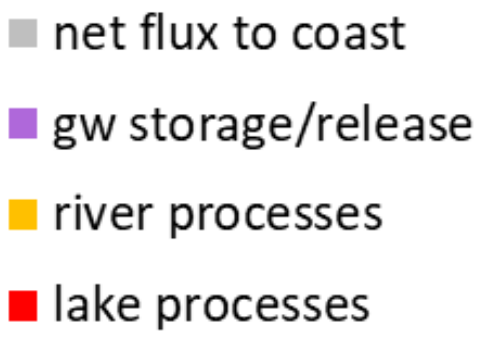
The process-based model approach allows us to add/remove pollutants from different sources (pollutant "inputs") and freshwater processes to understand where pollutants come from, and their fate:

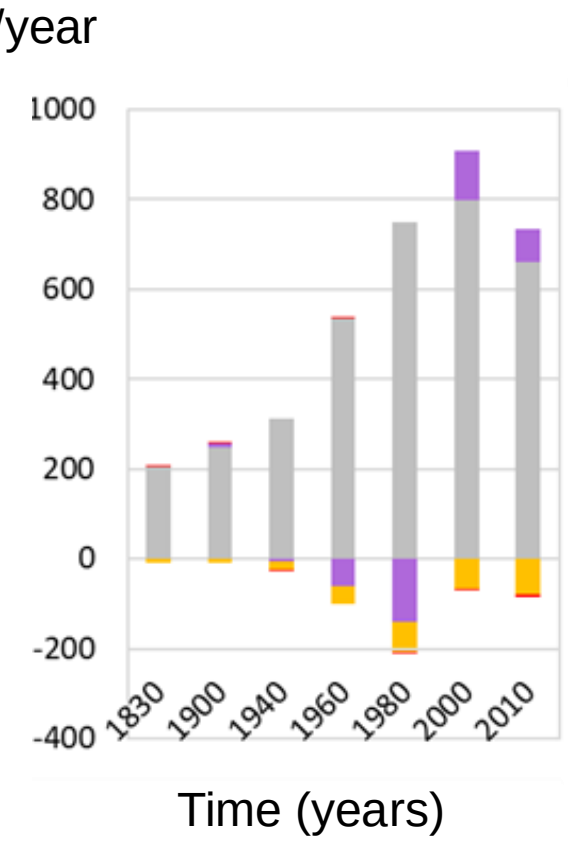
Terrestrial N sources (1810 – 2010)





Freshwater N Fate (1810 – 2010)





Scenario outcomes → policy challenge

Scenarios:
- Climate
- Socio-economic

Pressures
- Population growth
- Terrestrial pollution

LTLS-FE

(Freshwater) State
- Flow & quality
- Biodiversity

Human Impact
- Recreation
- Drinking water

Drivers → Pressures → State → Impact → Response

"What policies would you develop and implement to manage the FWQ situation in 2040?"

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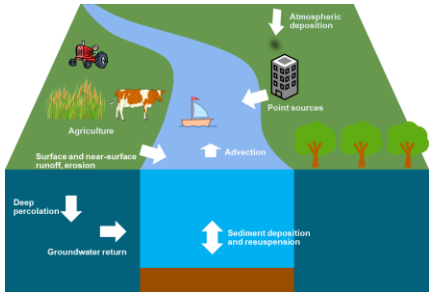
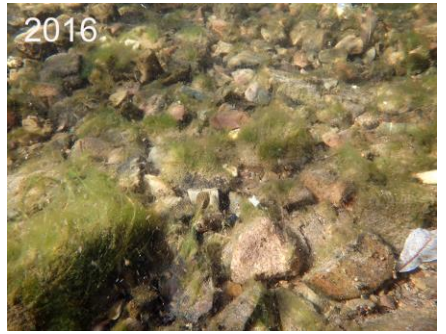
Next steps:



- Finish the model development phase and test freshwater model outputs against observations
- Continue the development of future scenarios of different pollutant inputs to UK freshwaters
- Link the LTLS-FE pollution scenarios with freshwater biology modelling
- Work with our stakeholders to understand how best to present and provide the future scenarios
- Outreach



Autumn algae: M. Kelly

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Thank you, questions welcome...

Further information: LTLS-FE website: **https://www.ceh.ac.uk/LTLS-FE**

Model and scenario references:

- ✓ UK-SSPs: https://www.ukclimateresilience.org/projects/uk-socioeconomic-scenarios-for-climate-research-and-policy/
- ✓ CHESS-SCAPE scenarios: https://uk-scape.ceh.ac.uk/our-science/projects/SPEED/future-climate-projections
- ✓ LTLS Freshwater Macronutrient Model: Bell, VA et al. (2021). *Sci. Tot. Environ*., 776, 145813, https://doi.org/10.1016/j.scitotenv.2021.145813
- ✓ Metal toxicity model (WHAM-FTOX): Stockdale, A. et al. (2010). Aquat. Toxicol. 100,112–119. https://doi.org/10.1016/j.aquatox.2010.07.018
- ✓ Soil metals model (IDMM): Lofts, S. et al. (2013) *Environmental Pollution*, 2013, **180**, 236-245. https://doi.org/10.1016/j.envpol.2013.05.030
- ✓ Agricultural Model (RLM): Coleman K et al. (2017), *Science of the Total Environment 609* (2017) 1483–1499, https://doi.org/10.1016/j.scitotenv.2017.07.193
- ✓ Groundwater model (BGWM): Bianchi, M et al. (2024). *Hydrological Sciences Journal*, *69*(5), 572–591. https://doi.org/10.1080/02626667.2024.2320847

Agricultural model