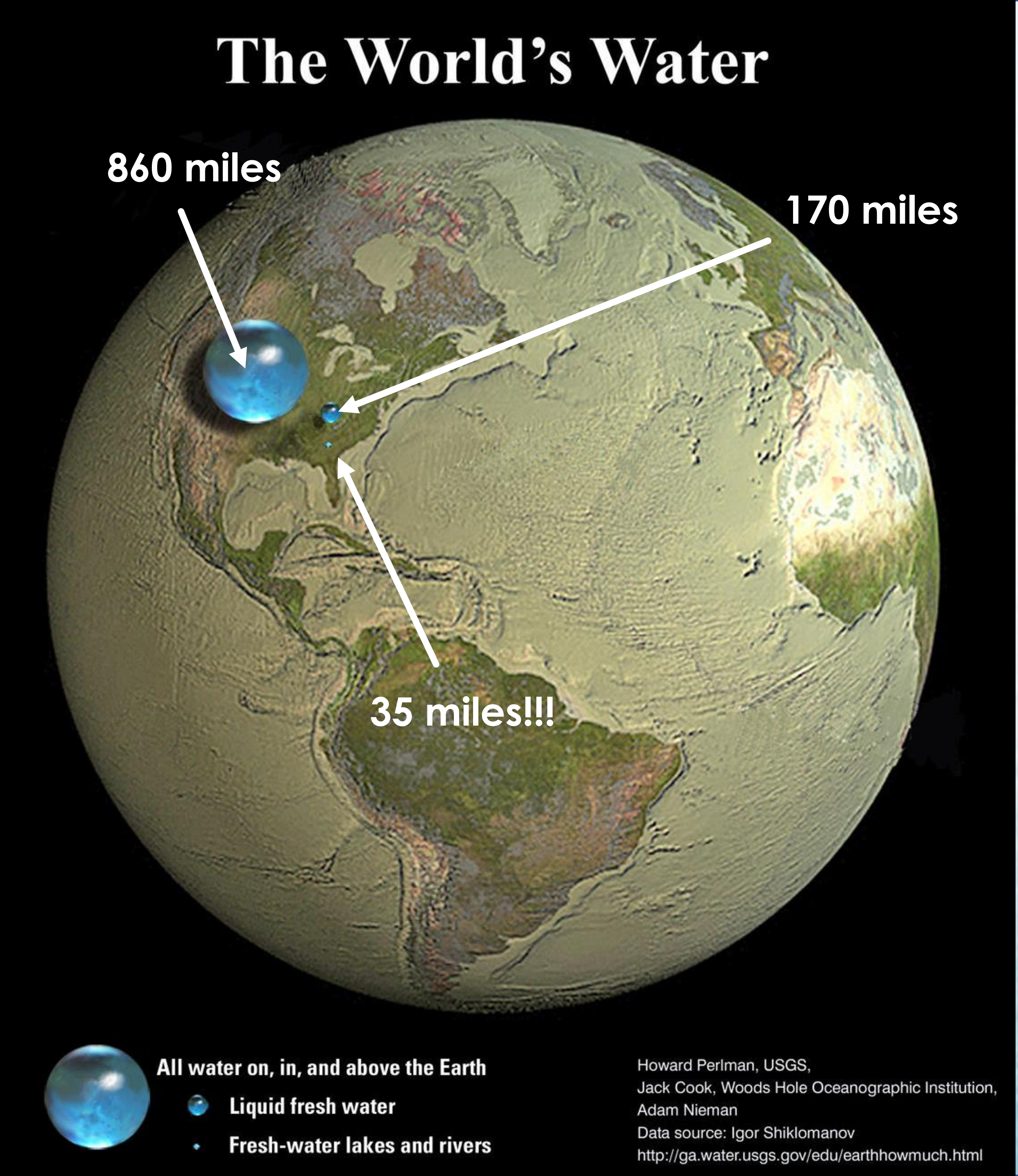
# Giving Our Rivers a Voice

*the current state of rivers in the UK and why we should all care*


Professor Darren Reynolds

*University of the West of England, Bristol*


Earthrise, NASA (1968)

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**Big bubble = all of Earth's water**
[332,500,000 cubic miles]

**Medium Bubble = Liquid fresh water**
[2,551,100 cubic miles]

**Tiny Bubble = Lakes and rivers!**
[22,339 cubic miles]

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# Fresh waters are hotpots for Life on Earth

# Freshwater Ecosystems are important

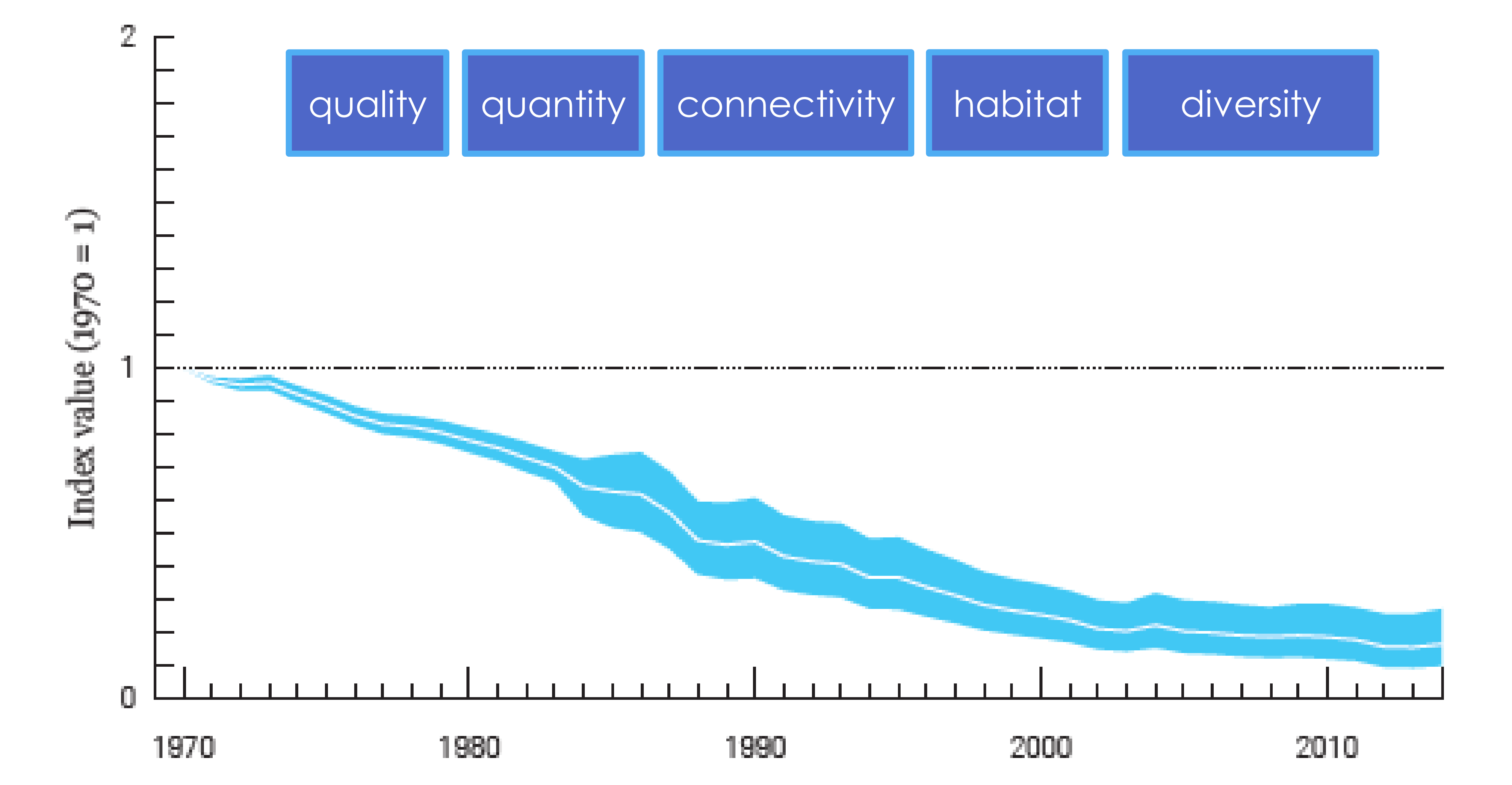


- Freshwater ecosystems contain disproportionately more species per unit area than marine and terrestrial ecosystems.
- Freshwater systems cover less ~ **1% of the Earth's surface**,
- Freshwater habitats are home to more than **10% of known animals** and about **one-third of all known vertebrate species**.
- In the 20th century freshwater fishes have had the highest extinction rate worldwide among all vertebrates



WWF Living Planet Report 2018

# Freshwater ecosystem health is in crisis




Average abundance of 3,358 freshwater populations monitored across the globe ~ 84% decline

WWF Living Planet Report 2018

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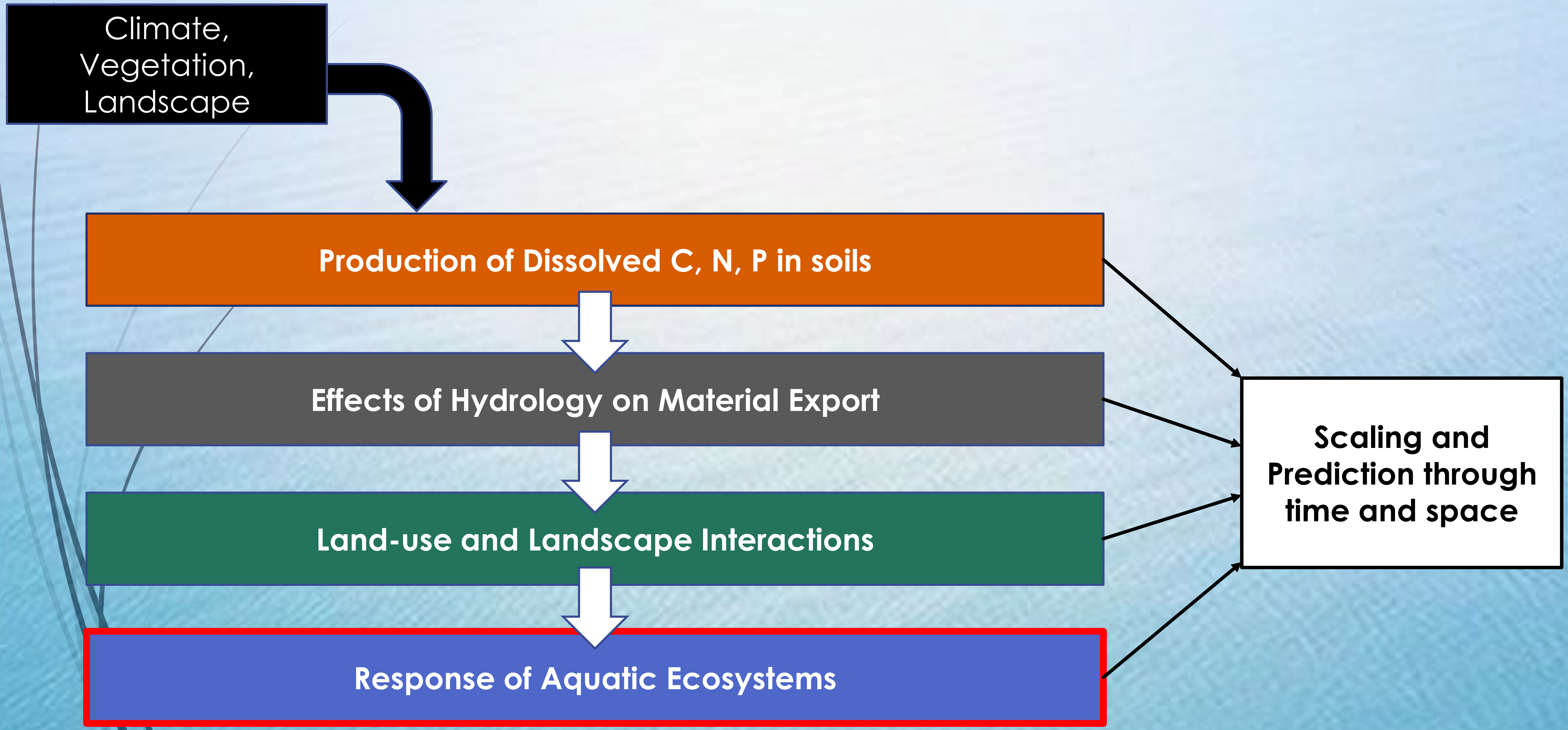
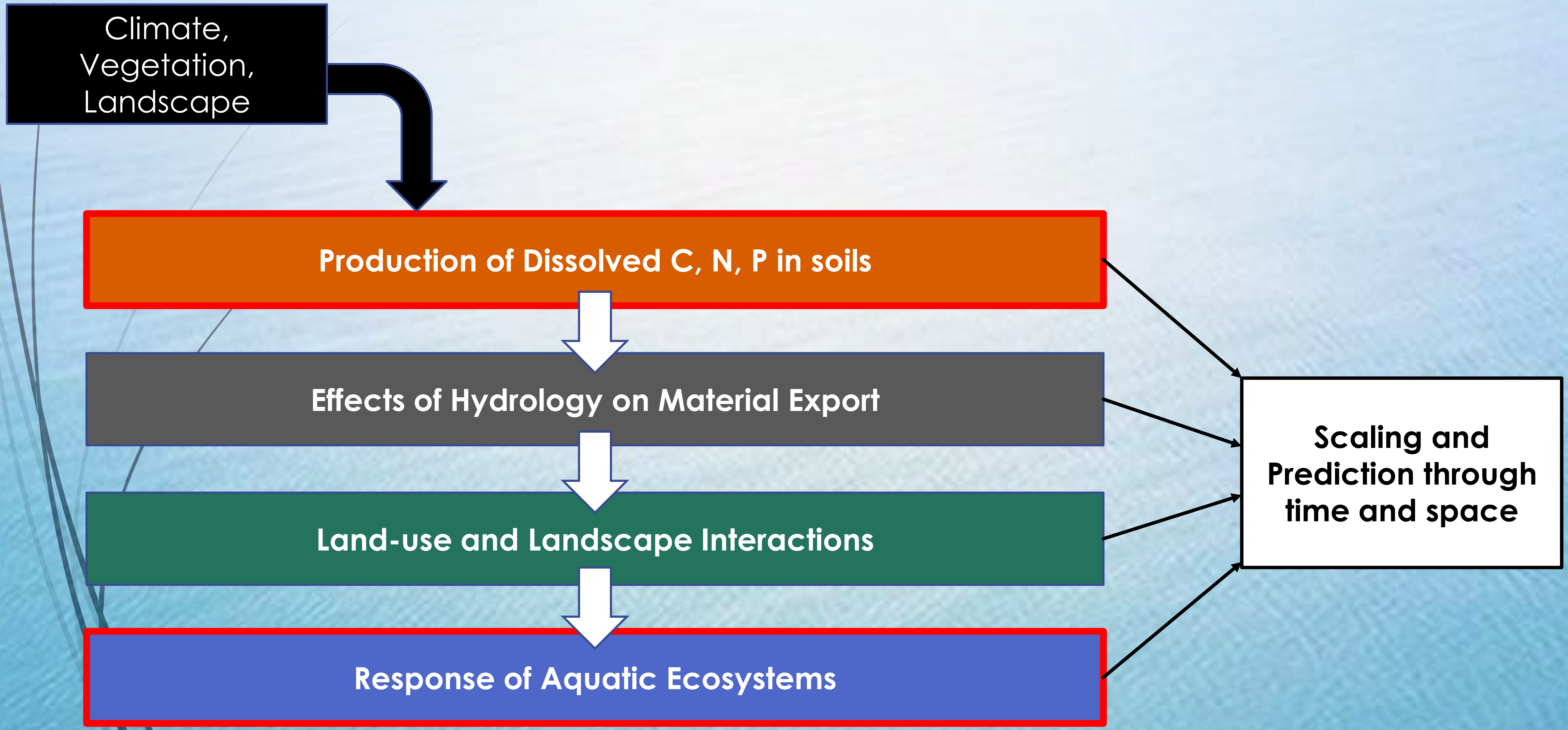
# Conceptual Model for Freshwater Ecosystems





# The health of rivers are shaped by biological and physical processes.



# Deforestation leads to the degradation of soils



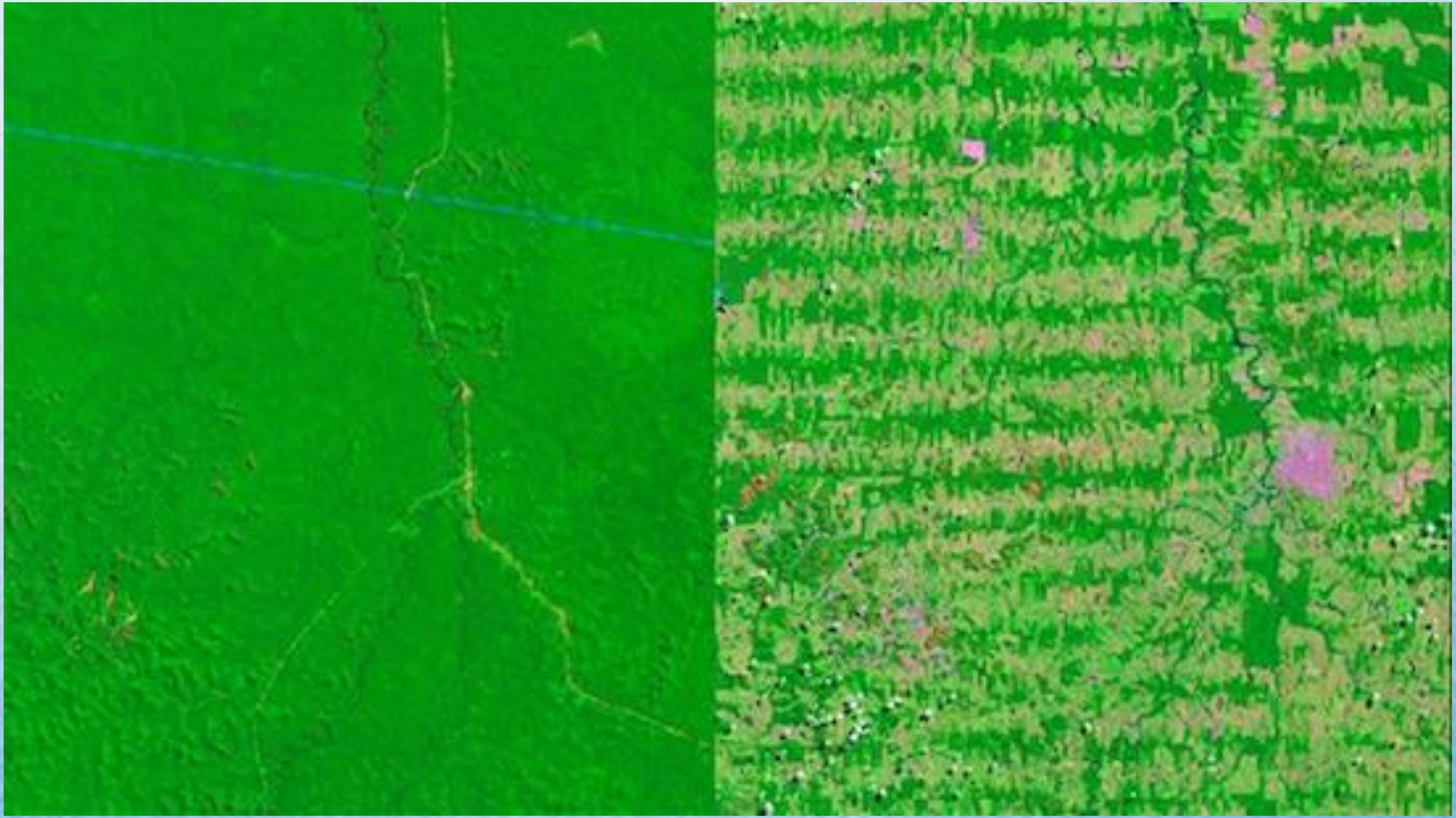
1975 ~ 208K km$^2$

1978 –4200 km$^2$

1988 –30,000 km$^2$

1998 –53,300 km$^2$

2003 –67,764 km$^2$



The state of Rondônia in western Brazil. Left from 1975 and right from 2012. Photo credit: NASA

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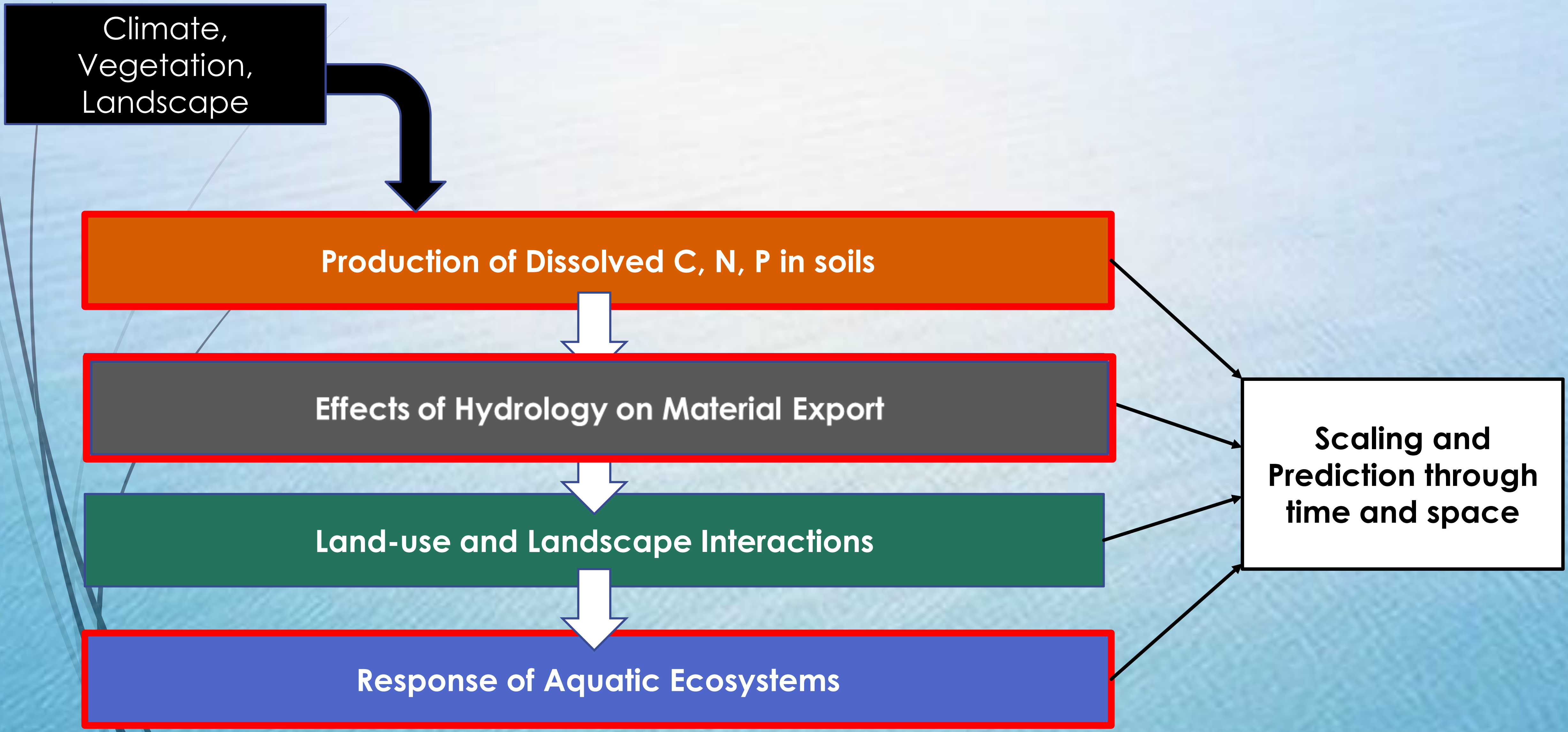
# Conceptual Model for Freshwater Ecosystems



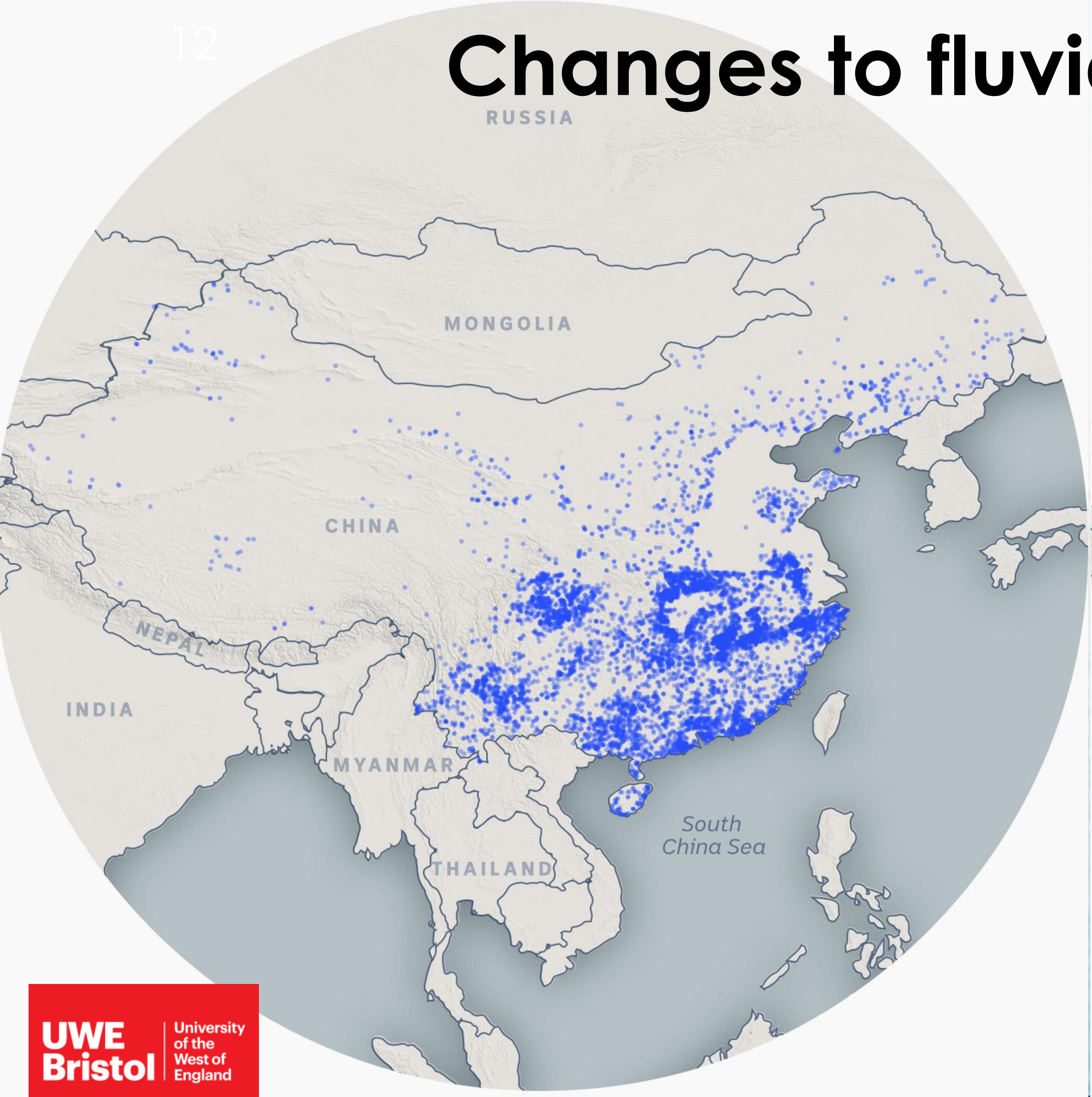


# Connected, flowing rivers are crucial

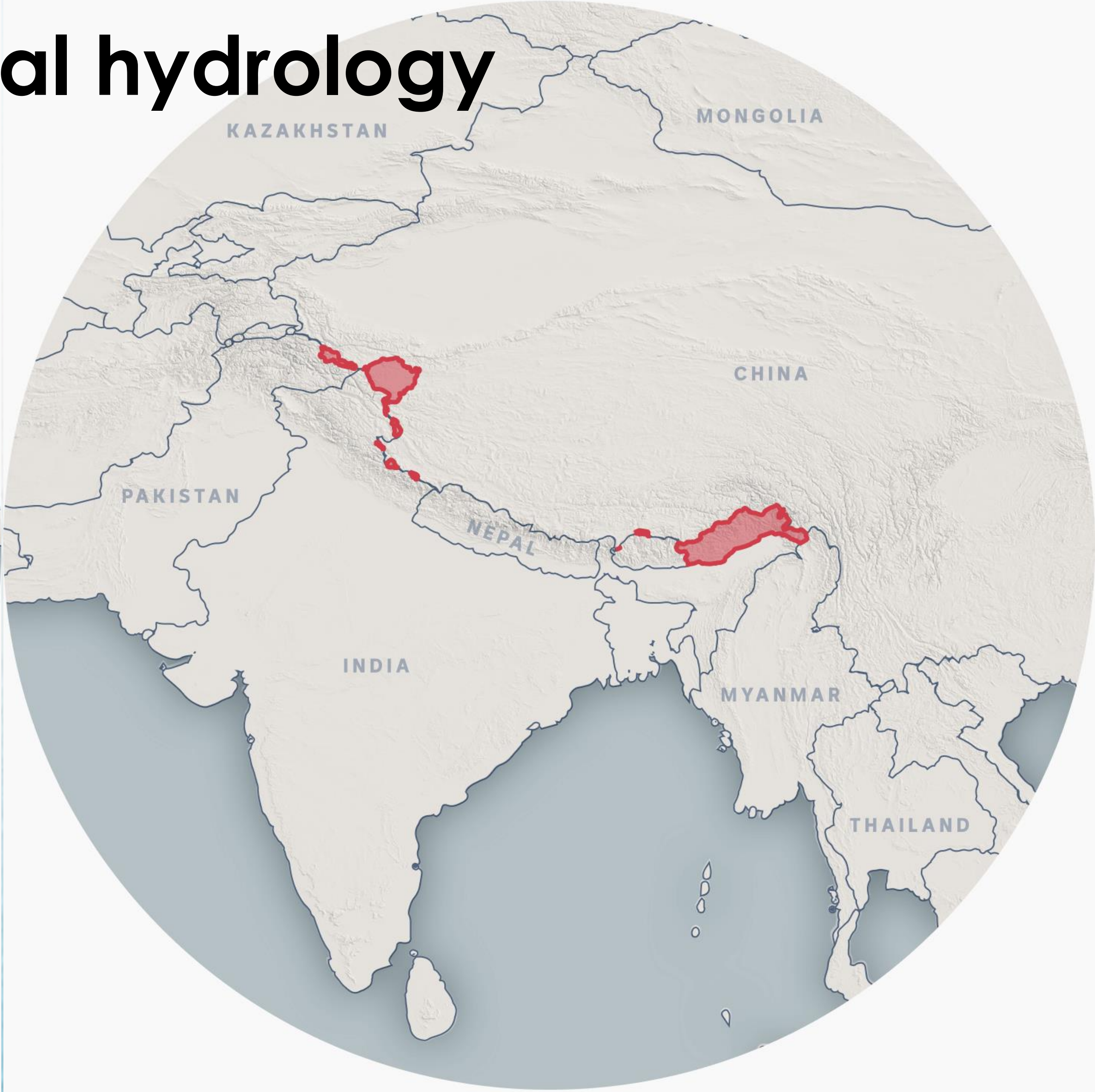

National Center for Atmospheric Research (NCAR), 2009

# Changes to fluvial hydrology

Thousands of dams dotted all across China




The disputed territory separating China and India

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# Yarlung Tsangpo River


It's the highest major river on Earth, running at an average elevation of 4,000 metres, and until recently was one of China's last major free-flowing rivers.

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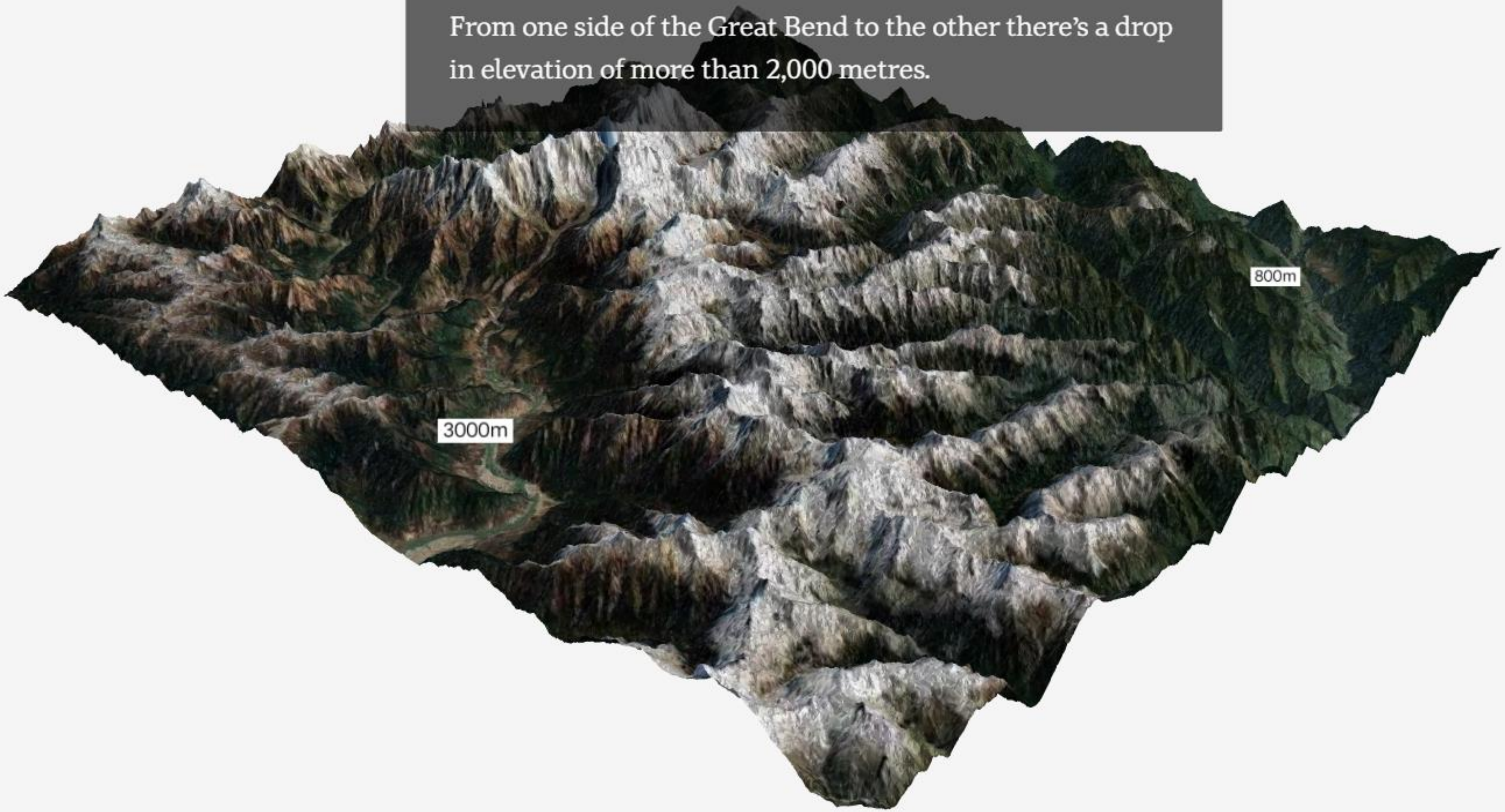
The Great Bend
Yarlung Tsangpo River
NAMCHA BARWA
But all of those projects pale in comparison to what it has planned here, at the most remote stretch of the river, known as the Great Bend.
UWE Bristol
University of the West of England

From one side of the Great Bend to the other there's a drop in elevation of more than 2,000 metres.



Water Research 211 (2022) 118054

ELSEVIER

Contents lists available at ScienceDirect

Water Research

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

IWA WATER RESEARCH

Check for updates

# A systematic approach to understand hydrogeochemical dynamics in large river systems: Development and application to the River Ganges (Ganga) in India

Laura A. Richards[a,*], Bethany G. Fox[b], Michael J. Bowes[c], Kieran Khamis[d], Arun Kumar[e], Rupa Kumari[e], Sumant Kumar[f], Moushumi Hazra[g], Ben Howard[d], Robin M.S. Thorn[b], Daniel S. Read[c], Holly A. Nel[d], Uwe Schneidewind[d], Linda K. Armstrong[c], David J.E. Nicholls[c], Daniel Magnone[h], Ashok Ghosh[e], Biswajit Chakravorty[i], Himanshu Joshi[g], Tapan K. Dutta[j], David M. Hannah[d], Darren M. Reynolds[b], Stefan Krause[d], Daren C. Gooddy[k], David A. Polya[a]

# Our rivers are alive, metabolising through biological processes. An intricate digestive network for carbon.

- Climate, Vegetation, Landscape
- Production of Dissolved C, N, P in soils
- Effects of Hydrology on Material Export
- Land-use and Landscape Interactions
- Response of Aquatic Ecosystems
- Scaling and Prediction through time and space

# Land use and landscape interactions

Agriculture equates to around 70% of all withdrawals

# Increasing urbanisation

Science of the Total Environment 842 (2022) 156848

Contents lists available at ScienceDirect

Science of the Total Environment

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

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## A case study: The deployment of a novel *in situ* fluorimeter for monitoring biological contamination within the urban surface waters of Kolkata, India

Check for updates

B.G. Fox [a], R.M.S. Thorn [a], T.K. Dutta [b], M.J. Bowes [c], D.S. Read [c], D.M. Reynolds [a,*]

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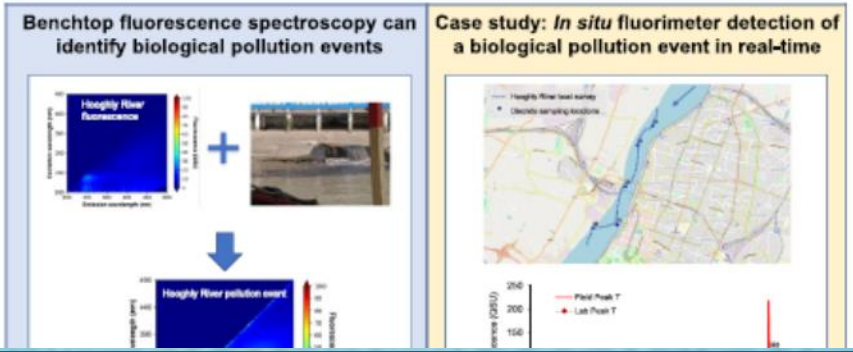
[c] *UK Centre for Ecology & Hydrology (UKCEH), Benson Lane, Crowmarsh Gifford, Wallingford OX10 8BB, UK*

### HIGHLIGHTS

- Better water quality monitoring requires more appropriate water quality parameters.
- Peak T fluorescence could be used to monitor microbial activity in aquatic systems.
- *In situ* Peak T fluorimeter was deployed in urban surface waters in Kolkata.
- Fluorimeter response was compared to other traditional water quality analyses.
- Sensor able to detect biological pollution

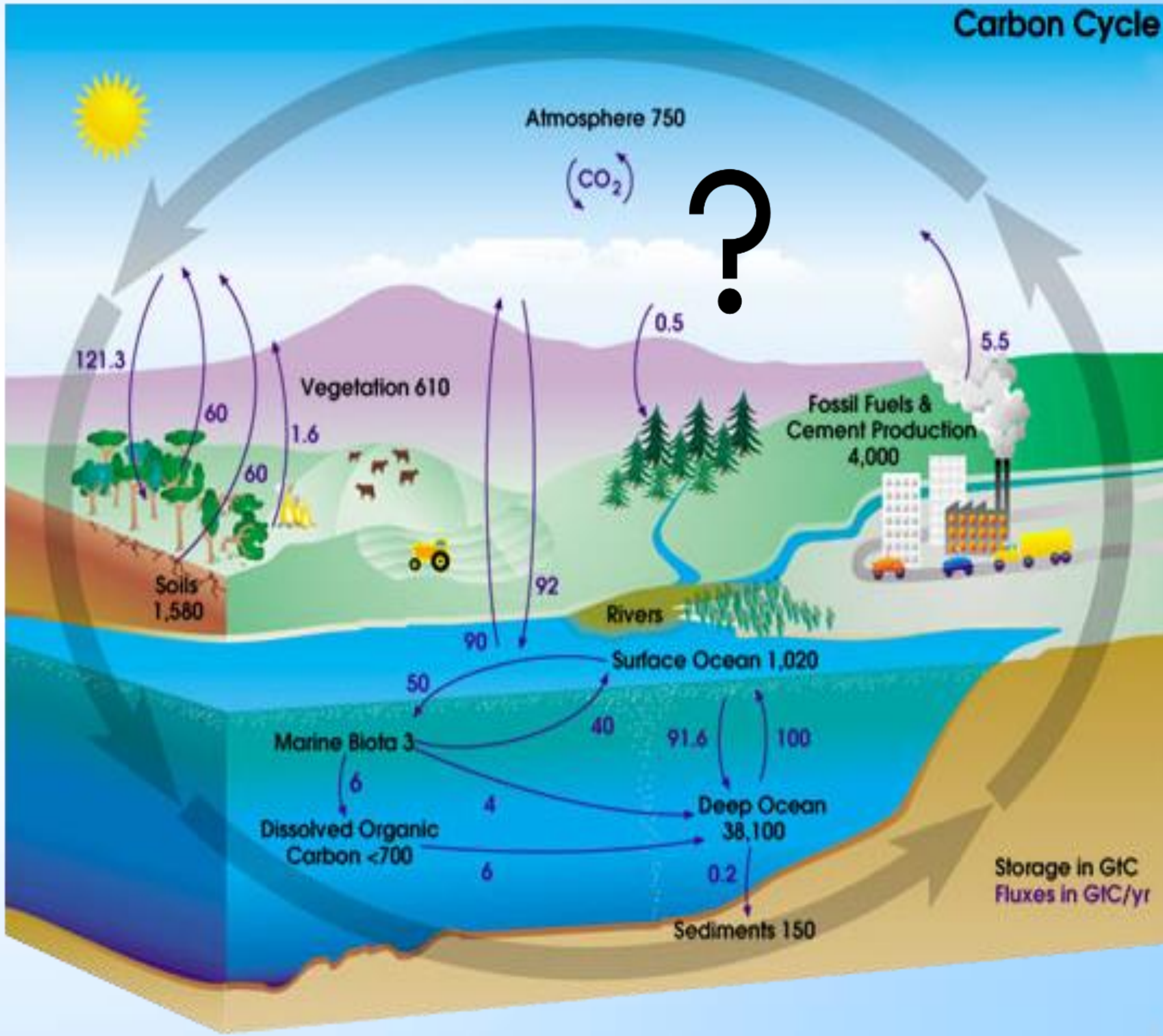
### GRAPHICAL ABSTRACT



# Rivers are Alive: An intricate digestive network for carbon.

- The largest absorber of carbon are land-based ecosystems (120 billion metric tonnes of $CO_2$ per year) releasing back 115 billion, This leaves 5 billion tonnes: *Net Primary Production*.

- This land carbon is mobile. Around 2.7 billion ends up in rivers, getting respired ($CO_2$), sediments or oceans



# Emerging Role of Freshwater in the Global Theatre



- The ***amount*** of carbon that ***inland*** waters emit is comparable to the net amount of carbon absorbed by ***living organisms*** on Earth's land surface and ***in*** its oceans!

- Fresh water bodies ***bury more carbon*** in sediments each year that the vast ocean floor.

- There is ***large uncertainty and many unknowns*** in these estimates.

# What are we missing?

We lack adequate data and proper models to evaluate how our changing world will affect the ways that freshwater systems interact with the land, atmosphere, and oceans

Among these key uncertainties is our understanding of carbon transformations, productivity and storage. Especially in freshwater ecosystems.

Especially uncertain is how much human activity— like land use changes, pollution discharges (fertilizers and sewage) into freshwater ecosystems— will effect these beautiful and complex carbon emission and storage process.

# What's missing?

- Inland waters' role in carbon emissions and burial were only official integrated into the Intergovernmental Panel on Climate Change in **2013**
- Even this description was brief – highlighting the lack of historical research in this area
- We don't fully understand yet how the impacts of pollution – sewage, fertilizers from agriculture, etc – are influencing these underpinning processes

# EU Water Framework Directive Ecological Status & UK Environment Bill (2020)

High

Good

Moderate

Bad

Poor

**Acceptable** – Meets WFD goals

**Unacceptable** – Does not meet WFD goals

Ecological status is defined as *'a measure of the quality of the structure and functioning of surface water ecosystems'*.

It is determined using the following:

**Physical and Chemical**
Nutrients ($NO_3$-, $PO_4$-), turbidity, conductivity, pH, temperature, DOC/TOC

**Macrobiological**
Fish, benthic invertebrates, macrophytes (BMWP scores)

Chemical

Ecological

# The State of UK Rivers

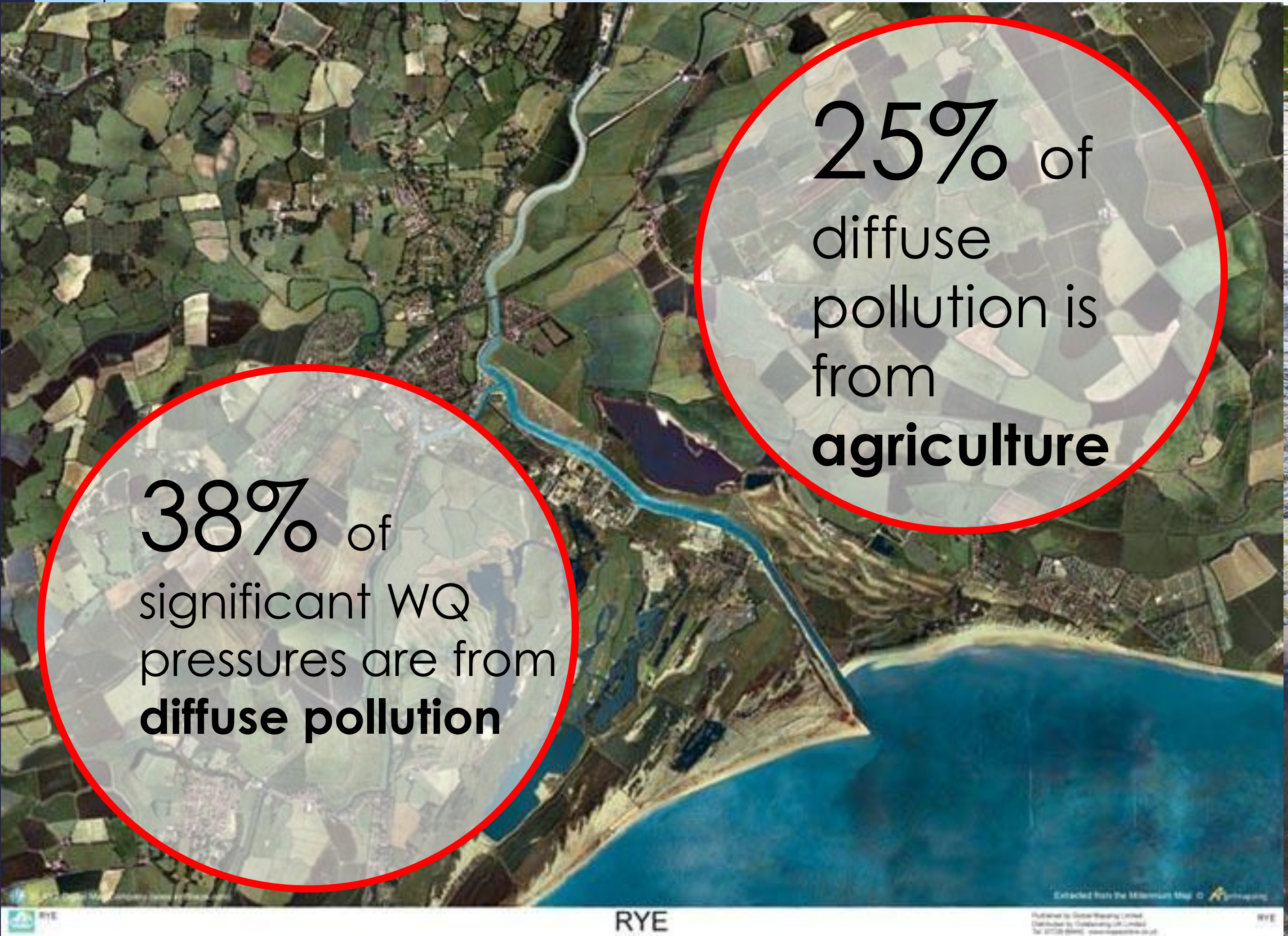
Of England's rivers, including 85% of the world's precious chalk streams, only **14%** are in good ***ecological health while*** every single river fails to meet good/chemical standards.

**66%** of rivers are in "good heath" in **Scotland** – but there growing concerns of sewage discharges

In **Wales 46%** of rivers are good health

Only 31% of rivers in **Northern Ireland** are classed as "good"

# Pressures on inland waters – anthropological stressors - *WFD European Waters Assessment, 2018*




38% of significant WQ pressures are from **diffuse pollution**

25% of diffuse pollution is from **agriculture**

Raw sewage was discharged into UK rivers **400,000** times in 2020

# The health of rivers is declining, because we are not listening



Science & Environment

## 'Total failure' on English river water quality

By Roger Harrabin
BBC environment analyst

17 September



## In-depth: EA insiders disclose river monitoring regime flaws

"It's become more important how we dispose of our teabags than how we monitor our rivers," the Environment Agency officer tells ENDS with palpable frustration. "We spend more time looking at how we do the job than on what we do."

by Rachel Salvidge

Concerns have been raised over the timing of water sampling. Photograph: ipa1999/Getty

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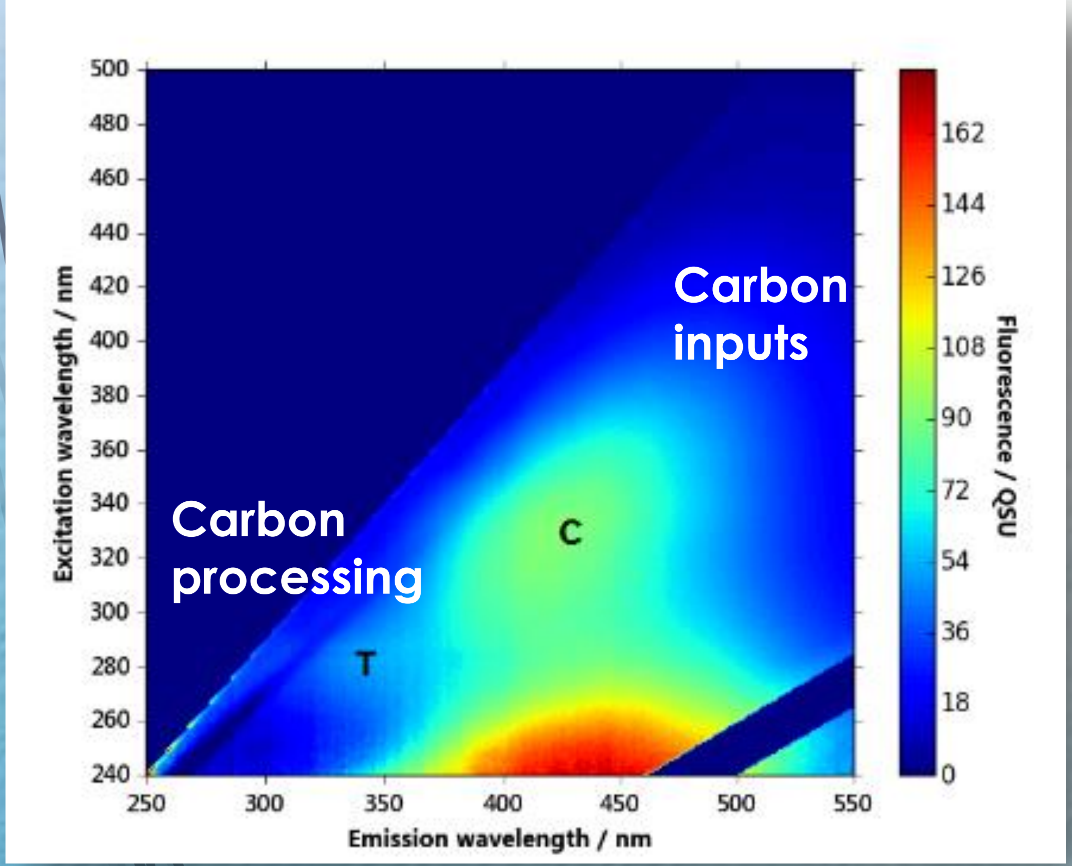
**Physical and Chemical**
Nutrients ($NO_3$-, $PO_4$-), turbidity, conductivity, pH, temperature, DOC/TOC

***Biogeochemical***
*Microbial processing, whole-stream metabolism, ecosystem respiration*

**Macrobiological**
Fish, benthic invertebrates, macrophytes (BMWP scores)

# We are developing a new water health parameter, based on fluorescence technology





# Fluorescence sensing technology at Taplow, Maidenhead

- Range of water quality parameters:
    - Nutrients (phosphate, nitrate)
    - Physico-chemical (DO, conductivity, pH, turbidity)
    - Microbiological (flow cytometry, total viable counts, *Escherichia coli*)
    - Fluorescence (V-Lux, EEMs)
    - Total/Dissolved organic carbon
- Real-time (every second) data outputs through the cloud
- Sensing the microbial processing of carbon, and how it changes as a result of pollution inputs

# Investigating carbon processing by bacteria in freshwater systems

frontiers in Microbiology

ORIGINAL RESEARCH
published: 24 February 2022
doi: 10.3389/fmicb.2022.817976

Check for updates

## The *in situ* Production of Aquatic Fluorescent Organic Matter in a Simulated Freshwater Laboratory Model

***Eva M. Perrin[1], Robin M. S. Thorn[1], Stephanie L. Sargeant[1], John W. Attridge[2] and Darren M. Reynolds[1]****

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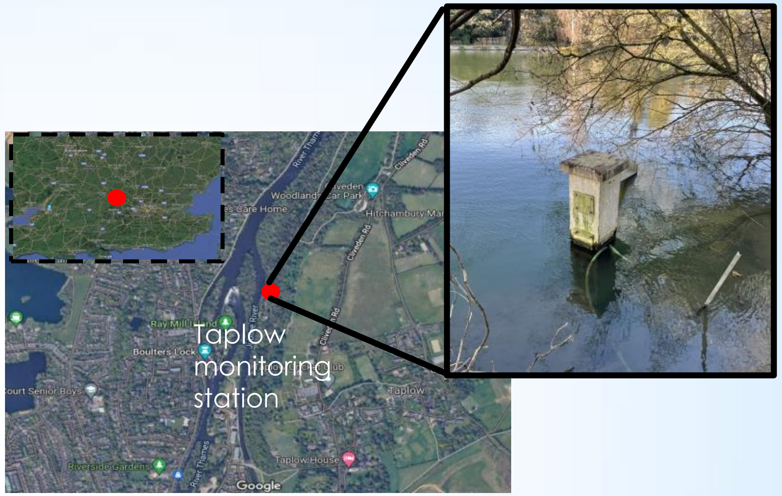
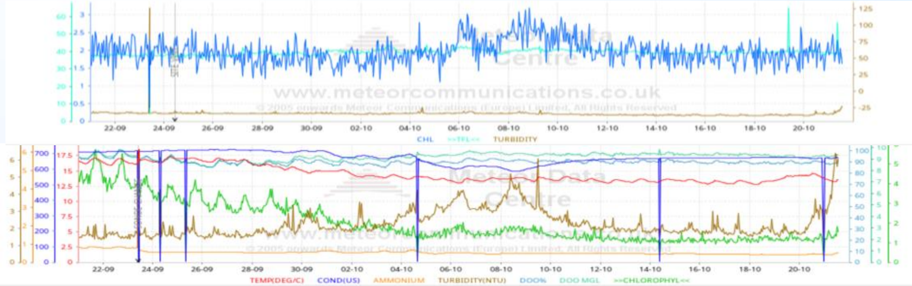
Dissolved organic matter (DOM) is ubiquitous throughout aquatic systems. Fluorescence techniques can be used to characterize the fluorescing proportion of DOM, aquatic fluorescent organic matter (AFOM). AFOM is conventionally named in association with specific fluorescence "peaks," which fluoresce in similar optical regions as microbially-derived proteinaceous material (Peak T), and terrestrially-derived humic-like compounds (Peaks C/C+), with Peak T previously being investigated as a tool for bacterial enumeration within freshwaters. The impact of anthropogenic nutrient loading on the processing of DOM by microbial communities is largely unknown. Previous laboratory studies utilizing environmental freshwater have employed growth media with complex background fluorescence, or very high nutrient concentrations, preventing the investigation of AFOM production under a range of more representative nutrient concentrations within a matrix exhibiting very low background fluorescence. We describe a laboratory-based model with

# Real-time sensing of river metabolism?

- Range of water quality parameters:
  - Nutrients (phosphate, nitrate)
  - Physico-chemical (DO, conductivity, pH, turbidity)
  - Microbiological (flow cytometry, total viable counts, *Escherichia coli*)
  - Fluorescence (V-Lux, EEMs)
  - Total/Dissolved organic carbon
- Long term (12+ months) networked commissioning of novel fluorescence sensor plus standard WQ parameters (both remote in-situ and laboratory-based)  for monitoring ecosystem health




*Location of Taplow monitoring station*




*Real-time telemetry output of in-situ fluorescence data alongside standard water quality parameters*

*Multi-channel fluorescence sensor*

LA Richards, DA Polya

E Perrin, BG Fox, S Sargeant RMS Thorn & DM Reynolds

A Ghosh, A Kumar, R Kumari, A Gaurav, S Kumar

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MJ Bowes, DS Read, DJE Nicholls, LK Armstrong

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TK Dutta

D Gooddy

D Magnone

Website: https://www.saptanadi.org/

# Thank you for listening

UWE Bristol University of the West of England

Westcountry Rivers Trust

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NERC SCIENCE OF THE ENVIRONMENT

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