

QUANTUM

Quantifying the nutrient enrichment, pathogenic, and ecotoxicological impacts of livestock farming on UK rivers

Penny Johnes, Richard Evershed, Ian Bull (University of Bristol)

Davey Jones, Dave Chadwick (Bangor University)

Barbara Kasprzyk Hordern (University of Bath)

Charles Tyler (University of Exeter)

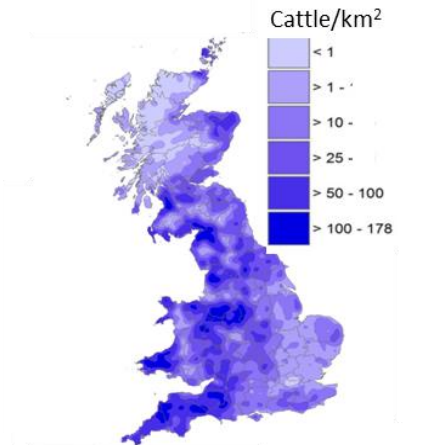
Andrew Binley (Lancaster University)

and our regulatory, industry and academic Project Partners:

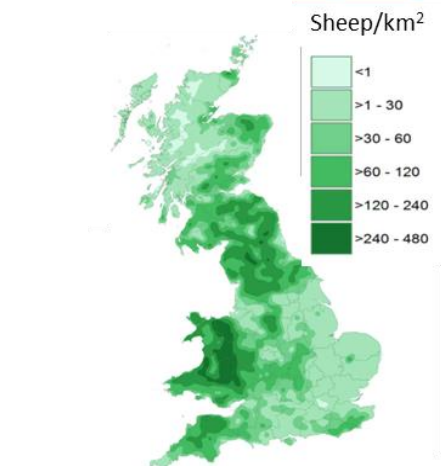
Livestock farming as a key driver of changing quality in UK rivers

- Cattle and sheep farming is concentrated in the wetter north and west of the UK on 10M hectares of grassland (57% of all UK agricultural land).
- There were 9.65M cattle, 32.7M sheep in the UK in 2020, excreting 4 x as much N and 3 x as much P as people in UK catchments.
- 80% of oestrogen in the UK environment derives from livestock, with cattle excreting an order of magnitude more oestrogen than humans.
- Livestock-derived pathogens, veterinary pharmaceuticals and other ecotoxins, their processing, critical concentrations and ensemble impacts in UK river ecosystems remain to be established, as do their interactions with livestock-derived organic nutrient loading.
- The role of environmental character and function in transforming these contaminant mixes and their impacts on UK rivers is unknown, creating uncertainty in the efficacy of both current mitigation and management strategies, and their likely efficacy under future climate change.

UK Cattle stocking density 2019
(www.apha.defra.gov.uk)



UK Sheep stocking density, 2019
(www.apha.defra.gov.uk)



The QUANTUM focus: livestock farming in UK catchments



Sources - practices - pathways - impacts

The QUANTUM programme

Theme 1: exploring how climate and catchment changes affect the sources (WP1) and processes (WP2) by which pollutants **from livestock farming**, enter, mix, are transported through and leave river systems

WP2 Investigating how manure management, environment and instream processing transform the contaminant pool instream

WP1 Defining the chemical and microbial character of different livestock excreta

WP3 Tracking the ecotoxicological impacts of livestock excreta in UK rivers

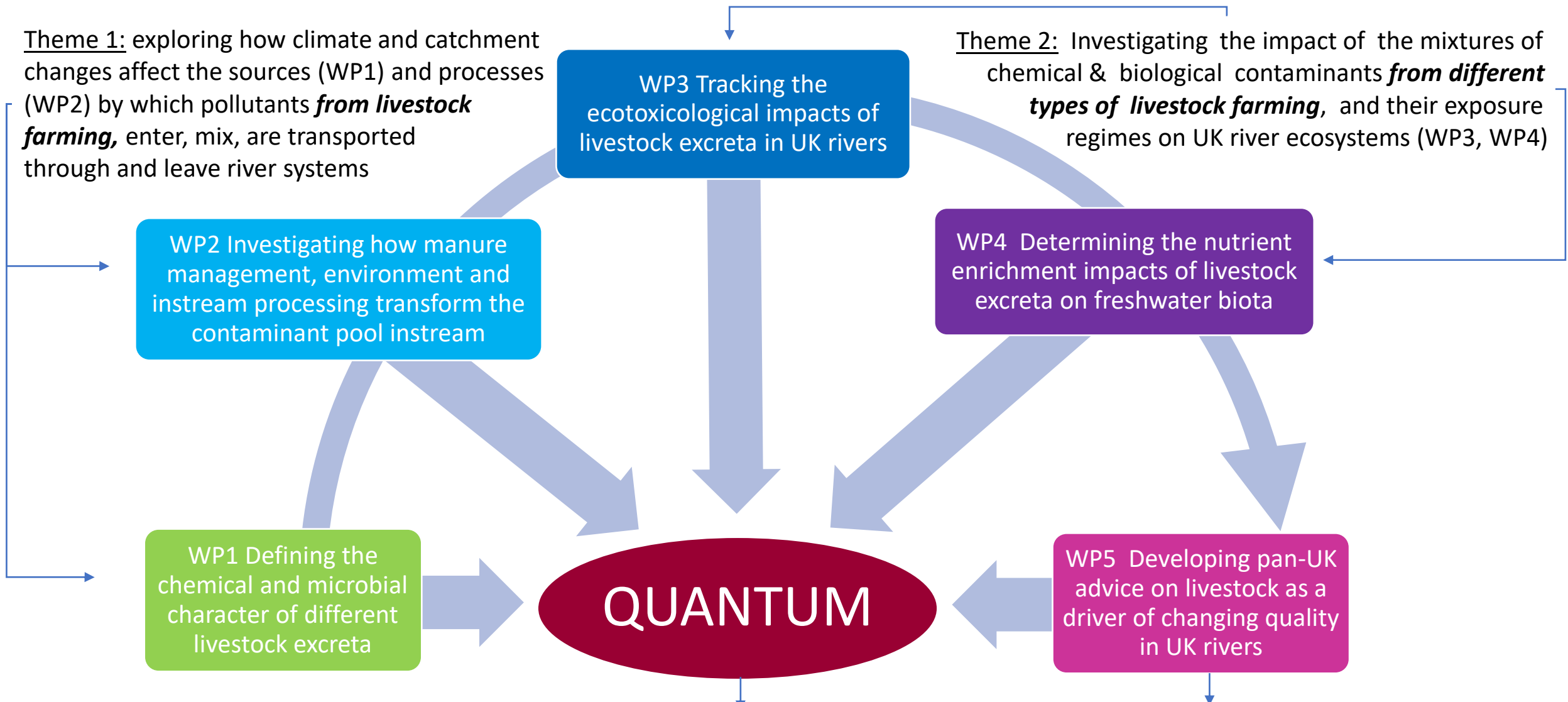
Theme 2: Investigating the impact of the mixtures of chemical & biological contaminants **from different types of livestock farming**, and their exposure regimes on UK river ecosystems (WP3, WP4)

WP4 Determining the nutrient enrichment impacts of livestock excreta on freshwater biota

WP5 Developing pan-UK advice on livestock as a driver of changing quality in UK rivers

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Theme 3: Enabling and informing the development of better plans for adaptation, mitigation and detection of the risks **of livestock farming** as a key driver of declining river quality, both now and in the future (WP1-4, WP5).



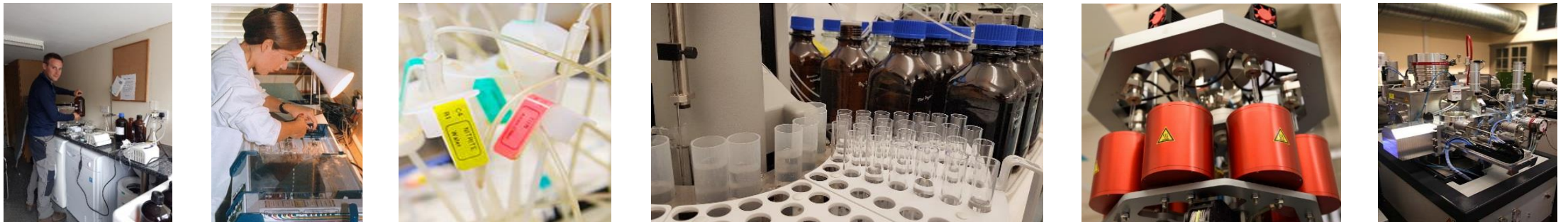
Novel sensing, sampling and analytical approaches

Capitalises on novel approaches for DOM characterisation using targeted and non-targeted methods, together with bulk and compound specific stable isotope probing developed in our prior UKRI funded research.

(a) Automated water samplers, telemetered sensor networks and novel chemical monitoring techniques (e.g. POCIS)



(b) Sample analyses using our suite of novel high resolution mass spectrometry, stable and radio isotope techniques



WP1 - Defining the chemical and microbial character of different livestock excreta

Henfaes Farm Research Centre,
Bangor University (sheep)



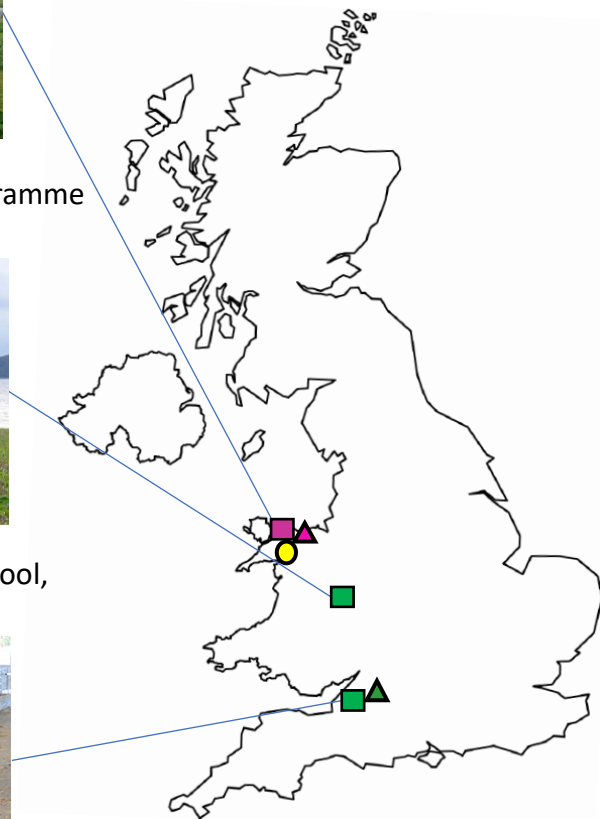
Innovate UK/Defra Slurry Management programme
Harper Adams Agricultural University (cattle)



John Oldacre Dairy Research Centre, Vet School,
University of Bristol



- University farms
- ▲ Farms in Tier 1 catchments
- DOMAINE field site farms



Research questions:

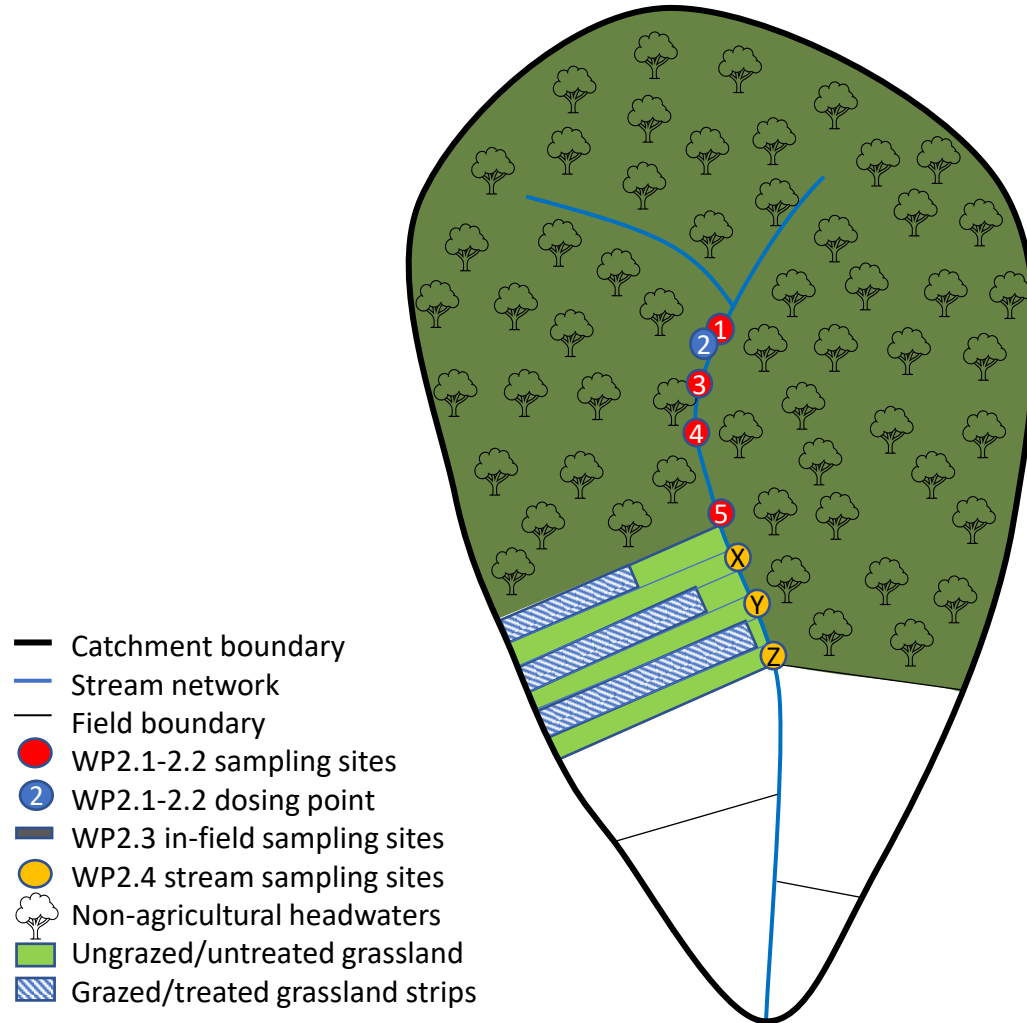
- 1.1 What is the chemical and pathogen composition of livestock excreta of differing type?
- 1.2 How does the composition of the livestock-derived OM (LDOM) pool vary according to production system/ management?

Approach:

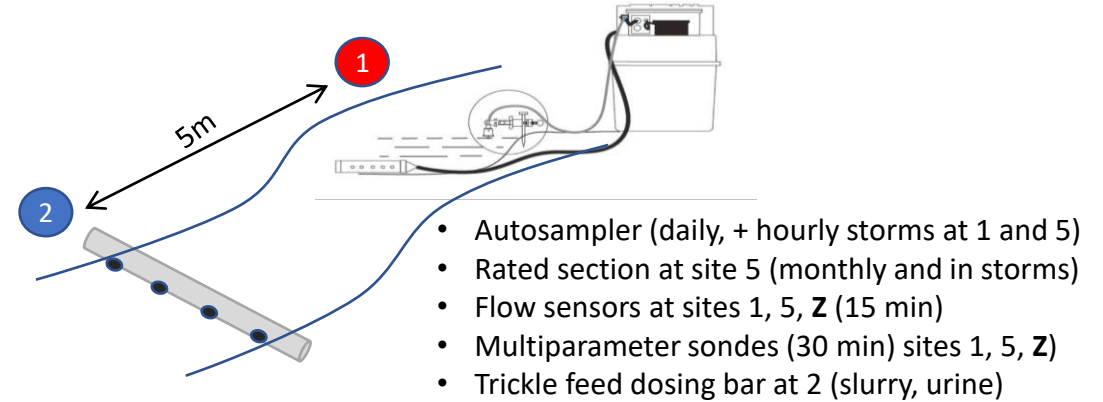
1. Collect representative samples from sheep, dairy and beef cattle farms (Tier 1 catchments, university farms)
2. Link up with the Innovate UK and Defra funded slurry management programme ongoing at Harper Adams
3. Analyse samples to determine nutrient profile, organic matter composition including 6 key organic nutrient and 6 ecotoxin compounds, faecal biomarkers, microbes.
4. Subsamples sent to NRM (Cawood Ltd) for nutrient analysis to allow comparison under RB209.
5. Include at least one target identified in WP1 samples from each of the following in our WP2-4 experiments:
 - a. nutrients (urea, amino acids, amino sugars, nucleotides);
 - b. ecotoxins (antibiotics, antifungals, NSAID, antiparasiticides/ antihelminthics, natural oestrogens).

WP2 - Investigating how manure management, environment and instream processing transform the (L)DOM pool instream

(a) WP2 field experimental platform (Hiraethlyn, Chew)



(b) WP2.1 – 2.2 installation detail, sites 1, 3-5, dosing at site 2



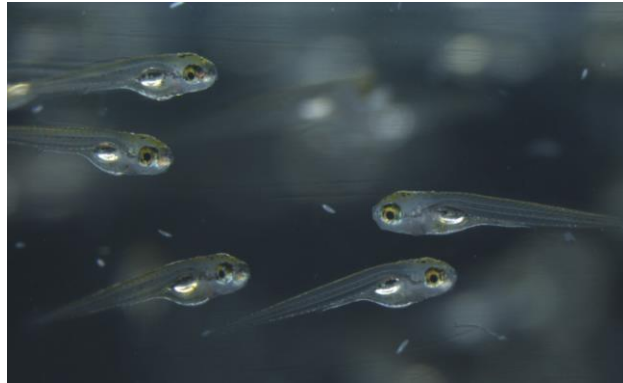
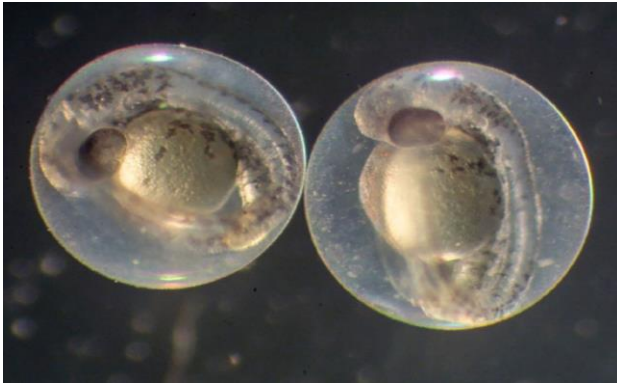
Research questions:

- 2.1 How does the composition of LDOM delivered to streams transform due to instream processing?
- 2.2 How does the stream OM pool composition transform in response to hydrology and climate?
- 2.3 How does LDOM composition transform according to in-field management practices?
- 2.4 What are the exposure rates for LDOM targets under contrasting flow and management?

WP3: Tracking the ecotoxicological impacts of LDOM on freshwater biota under laboratory and ambient conditions

Research questions:

- 3.1 What are the toxicities of key compounds in livestock excreta (from WP1) to freshwater biota?
- 3.2 What are the bioaccumulation rates and effects of key compounds in invertebrates and fish?
- 3.3 How does ecotoxicological impact on stream biota vary according to environmental character and function?



WP4: Determining the nutrient enrichment impacts of LDOM on freshwater biota using stable isotope probing

Research questions:

- 4.1 How does LDOM nutrient uptake vary between different livestock excreta and chemistries?
- 4.2 How does bioavailability of LDOM to vary according to environmental character and function?
- 4.3 How is LDOM uptake modified by the matrices and interacting stressors in livestock excreta?



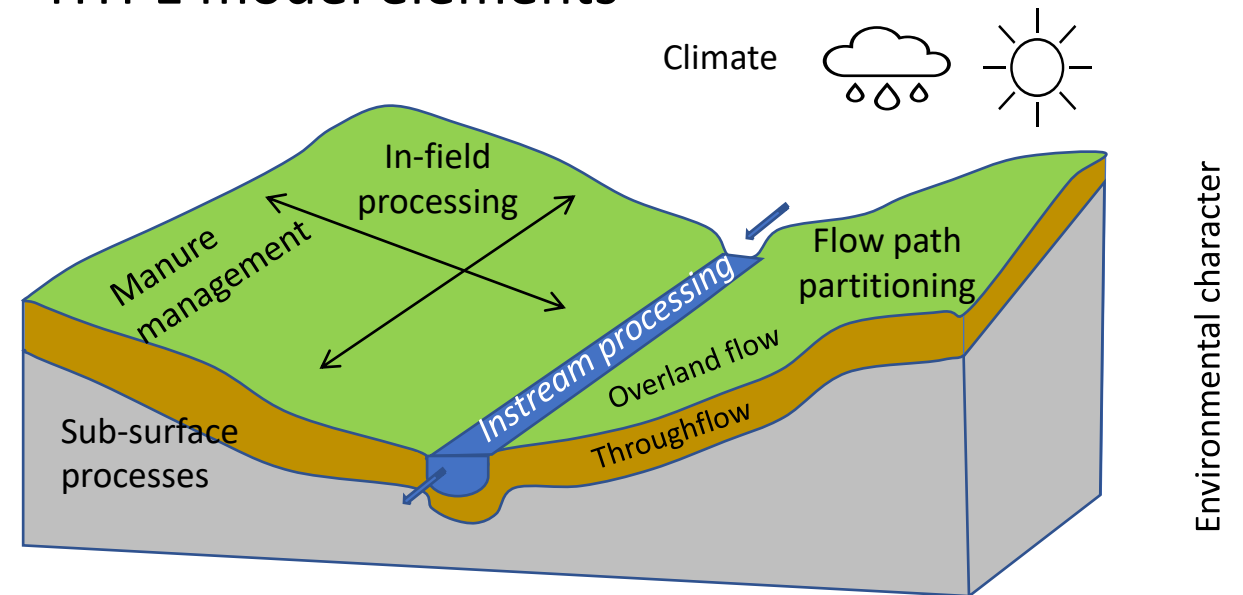
WP5 - Developing pan-UK understanding and advice on livestock as a driver of changing quality in UK rivers

Research questions:

- 5.1 Are there generic livestock impacts on UK rivers, linked to livestock type and environment?
- 5.2 How might impacts across UK conditions alter in response to a changing hydrological cycle?
- 5.3 Can we produce transferable evidence to improve policy and management for UK rivers?

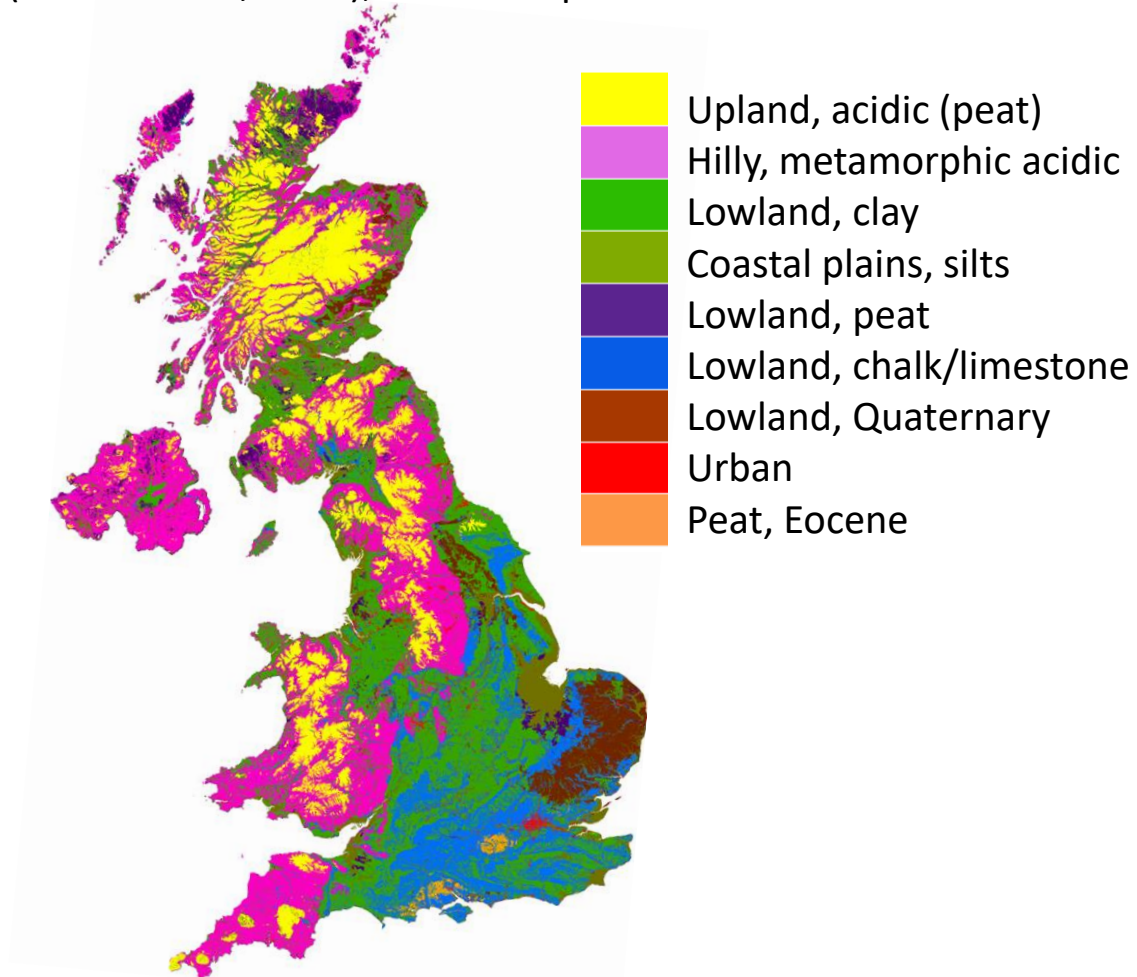
- Sampling and analysis as in Tier 1, for 20 catchments of comparable environmental character
- HYPE model parameterisation linking specific chemistries from sheep versus cattle farming in differing environments, under ambient and climatically altered conditions to ecological and ecotoxicological impacts using Tier 1 outcomes
- Model validation using Tier 2, published and project partner data
- Scenario testing in consultation with our regulatory, industry and academic partners
- Will generate pan-UK understanding and advice on the impacts of livestock farming on freshwater quality under ambient conditions, in response to climate change, and mitigation targeting manure management.

HYPE model elements

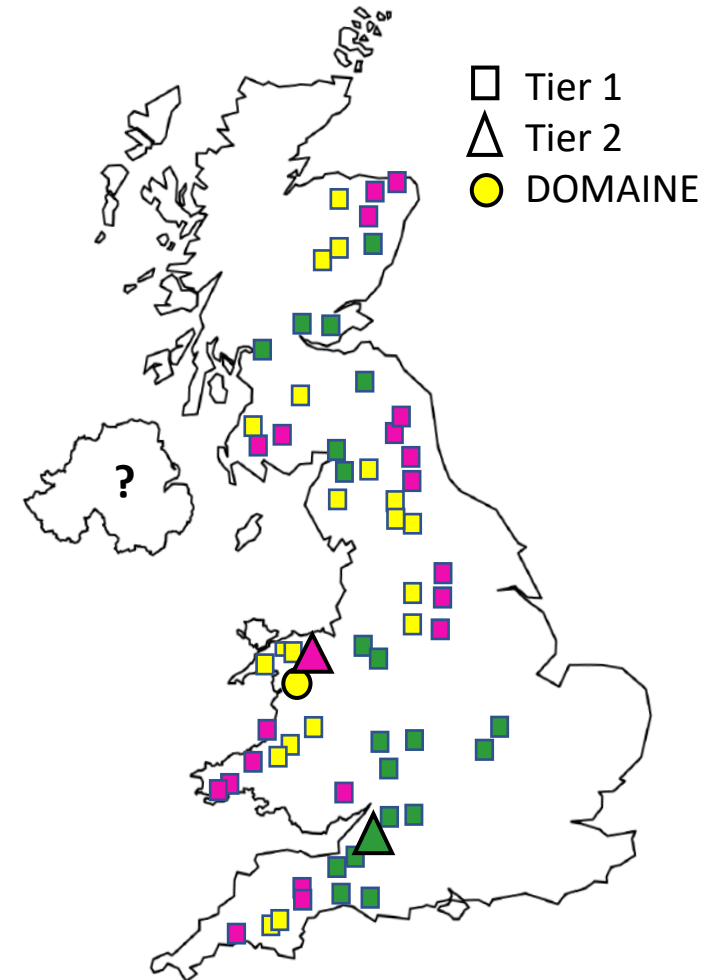


WP5 - Developing pan-UK understanding and advice on livestock as a driver of changing quality in UK rivers

(a) Biogeochemical Modelling Framework
(Greene *et al.*, 2015); NERC EVOp



(b) Tier 1 & 2 sampling sites



Anticipated outcomes: *highlights*

WP1

Diagnosis of the nutrient, pathogen and ecotoxin contaminant mixtures exported to UK rivers from different types of livestock farming, using state of the art field/lab techniques recently developed in our prior UKRI funded programmes.

e.g. NERC DOMAINE, 2014-19, EPSRC ReNEW, 2017-20, NERC AMR, 2016-18, NERC EMHH, 2012-15, 2015-18, NERC Urgent Grant, 2020-21

WP2

Evidence of the impact of livestock production methods on the stressor portfolio to which stream biota are exposed, under different environment environmental conditions, as it is processed instream, together with tools to distinguish between livestock- and human-derived faecal matter in UK rivers.

WP3

Evidence of the combined ecotoxicological impacts of livestock farming on cyanobacteria, macroinvertebrates and fish, under controlled laboratory (using standard methods) and ambient (and variable) environmental conditions

WP4

Evidence of the compound-, environment- and multi-stressor mix impacts of LDOM nutrient enrichment on stream biota under varying ambient and climatically-altered conditions, for epilithon, bryophytes, macroinvertebrates, fish.

WP5

Pan-UK understanding of the impacts of differing livestock production systems as drivers of changing quality in UK rivers, under ambient and climatically altered conditions.