Environmental modelling and regulation in catchments – Bristol 2019

Modelling of agricultural impacts and their mitigation for policy support

Yusheng Zhang and Adie Collins

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Presentation outline

- Challenges of modelling agricultural impacts and their mitigation for policy support
- Approach to better quantification of agricultural impacts and their mitigation
- Updating agricultural impacts and mitigation efficacy using Farmscoper
- Current research: Soil to Nutrition strategic research programme

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Characteristics of agricultural impacts

- Less about dramatic damage, more about cumulative effects of multi-pollutants
- Result from interaction of natural environment / conditions and farming activities
- Knowledge gaps about the impacts and mitigation efficacies of available measures
- Numerous stakeholders: economically / financially separate but hydrologically connected
- Agricultural externalities are a key component of sustainable intensification

PILLAR 1

Efficient and resilient agriculture systems

Increase yields; reduce food loss; limit emissions from agriculture; raise water-use efficiency; reduce release of nitrogen and phosphorus.

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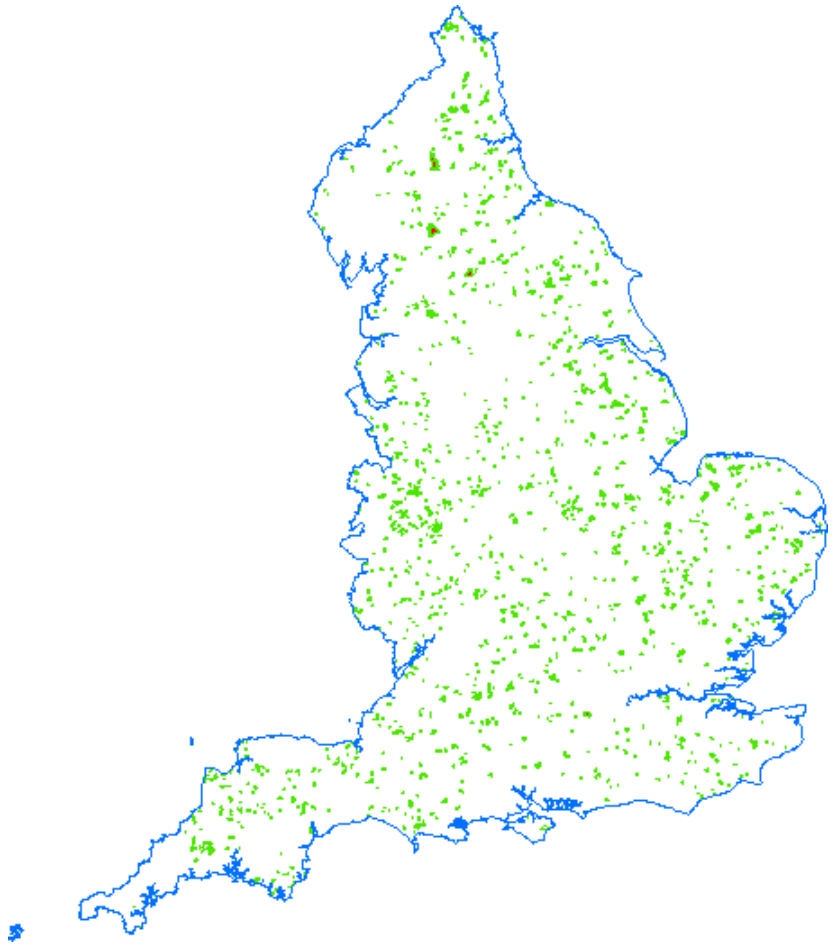
Modelling agricultural impacts: challenges

- Incorporation of progress in the understanding of pollutant delivery and associated model development
- Characterisation of baseline environmental conditions and farming activities with updated and/or high resolution spatial data
- Representation of existing regulatory efforts and impacts of agri-environment schemes
- Selection of more mechanistic-based measures
- Accounting for climate change impacts



CS area in 2016

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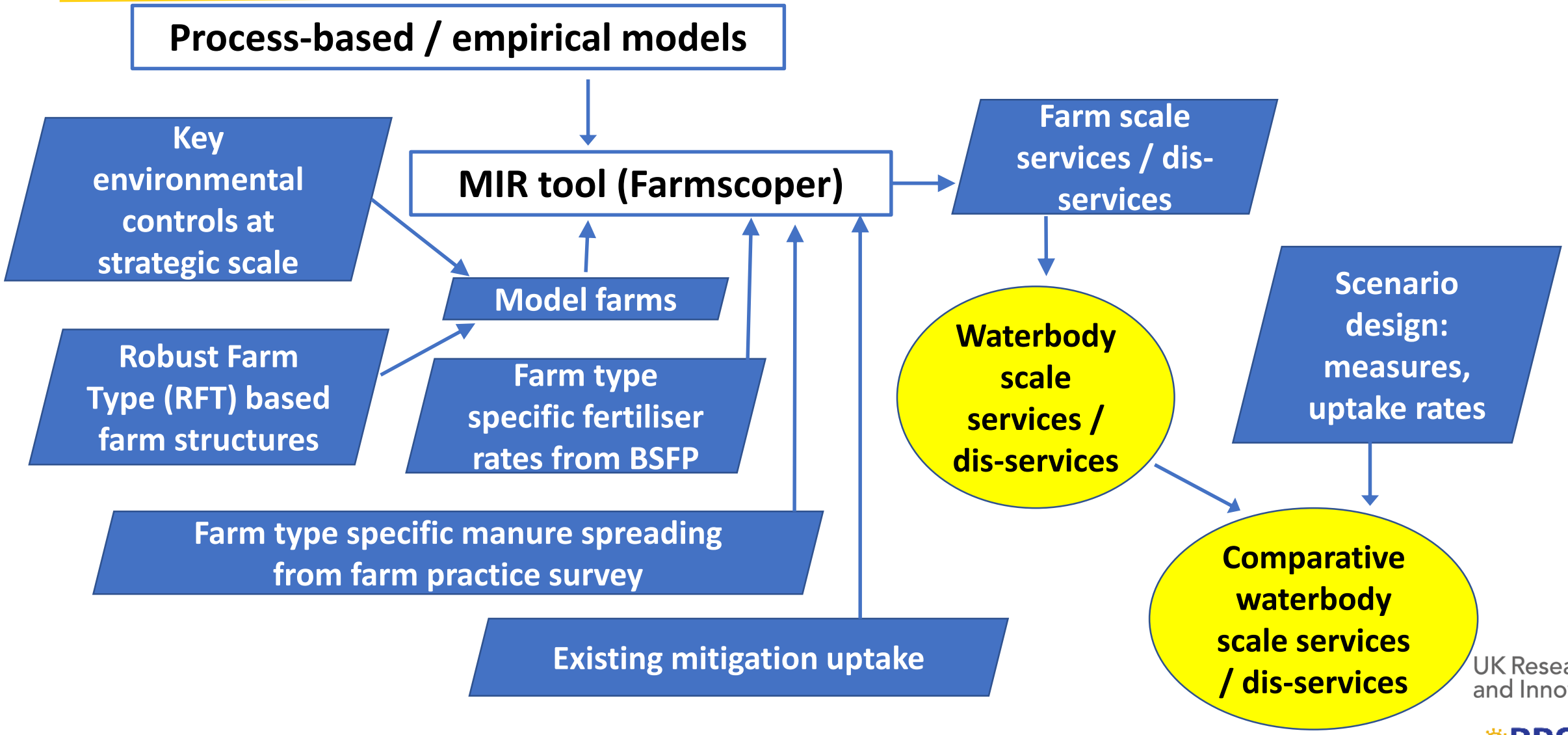
Modelling agricultural impacts: approach



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Using UKCP18 baseline data to characterise rainfall

- Improved spatial resolution: 5km x 5km to 1km x 1km
- Updated baseline from 1961-1990 to 1981-2010

Implications of using improved baseline data (1981 to 2010): AAR based rainfall band

Difference (new – old)	Area (km2)	%
1	21733	14.5
0	127047	85.0
-1	610	0.4

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Revision of model farms using 2016 JAS data

Average cereal farm at national scale

Livestock	2016	2010	Crops	2016	2010
Beef Cows and Heifers	2.3	1.8	Permanent Pasture	15.8	16.7
Other Cattle (2 years +)	0.5	0.0	Rotational Grassland	4.6	4.5
Other Cattle (1 - 2 years)	2.2	2.0	Rough Grazing	0.6	1.1
Other Cattle (< 1 year) & Calves	2.7	2.2	**Winter Wheat**	**46.8**	**54.2**
Sheep	17.9	17.6	Winter Barley	9.5	8.0
Lambs (< 1 year)	19.7	18.2	**Spring Barley**	**11.5**	**7.9**
Other Pigs (20 - 50kg)	0.1	0.5	**Winter OSR**	**16.7**	**20.7**
Other Pigs (< 20kg)	0.2	0.6	**Maize**	**2.5**	**1.2**
Broilers	0.6	0.2	Beans	5.8	5.9
Turkeys	0.1	0.2	Other Crops	7.1	7.3
Breeding Birds	0.5	0.4	Bare Fallow	5.5	7.4
Other Poultry	0.1	0.6	Woodland	7.3	6.4

Revision of model farms using 2016 JAS data

Average dairy farm at national scale

Livestock	2016	2010	Crops	2016	2010
Dairy Cows and Heifers	**152.4**	**134.1**	Permanent Pasture	**65.6**	**61.1**
Dairy Heifers in Calf (2 years +)	17.2	22.7	Rotational Grassland	**28.8**	**23.4**
Dairy Heifers in Calf (< 2 years)	15.4	14.3	Rough Grazing	2.1	2.5
Bulls (2 years +)	0.7	0.0	Winter Wheat	15.3	15.0
Beef Cows and Heifers	2.3	0.0	Winter Barley	3.5	3.7
Beef Heifers in Calf (2 years +)	0.5	0.0	Spring Barley	3.6	3.2
Beef Heifers in Calf (< 2 years)	0.3	0.0	Winter OSR	1.7	2.8
Other Cattle (2 years +)	8.3	6.8	Maize	11.9	11.6
Other Cattle (1 - 2 years)	**37.7**	**23.3**	Potatoes	0.1	0.1
Other Cattle (< 1 year) & Calves	**75.5**	**67.0**	Sugar Beet	0.4	0.3
Sheep	25.7	31.0	Peas	0.1	0.1
Lambs (< 1 year)	29.6	32.6	Beans	0.9	0.8

Revision of fertiliser application rates

	N rate (kg/ha)			P_2O_5 rate (kg/ha)		
	Arable existing	Cereal revised	General croping revised	Arable existing	Cereal revised	General cropping revised
Permanent pasture	28	36	35	4	5	5
Rotational grassland	82	86	80	13	11	15
Winter wheat	194	192	189	28	30	25
Winter barley	144	150	142	32	35	27
Spring barley	111	113	106	27	32	29
Winter OSR	196	186	192	30	31	26
Maize	82	80	64	24	43	24
Potatoes	161	148	148	109	140	103
Sugar beet	98	93	97	20	23	20
Peas	0	2	1	14	18	12
Beans	0	1	2	19	16	17
Fodder crops	80	73	100	30	22	32
Vegetables (Brassica)	136	117	131	61	54	72
Vegetables (Other)	75	23	103	43	23	61
Orchards	68	65	73	8	16	14
Soft fruit	31	55	67	24	30	46

2010 to multi-year average (2013 to 2017)

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Potential efficacy with doubling existing uptake rates

	Average farm-based reductions at national scale (%)					
	Nitrate	Phosphorus	Sediment	Ammonia	Methane	Nitrous oxide
Cereal	9.1	8.7	9.1	14.4	1.9	8.8
General cropping	9.9	9.2	10.4	13.4	2.4	7.0
Dairy	7.4	14.4	10.5	1.1	3.4	8.2
LFA grazing	4.6	8.1	7.6	-0.7	1.3	5.0
Lowland Grazing	5.6	11.3	9.3	-1.1	1.8	5.5
Mixed	7.9	9.4	6.7	6.4	1.9	7.3

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Soil to Nutrition (S2N): Institute Strategic Programme

Mechanistic understanding

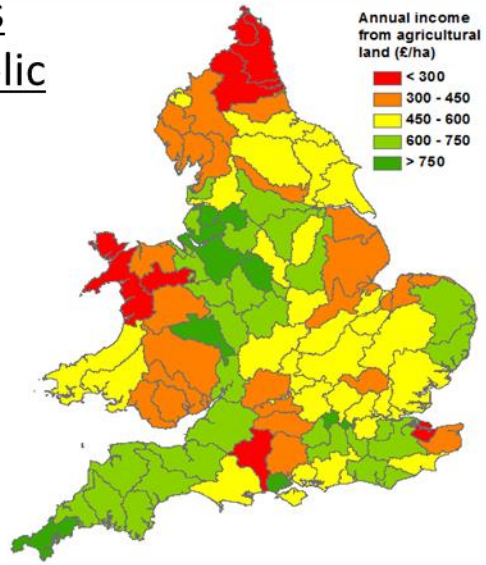
Micro-scale processes which drive nutrient use

Targeted interventions

Management impacts on nutrient use

Food Systems Private and public good

Delivering 'fit-for-purpose' rics to mark and improve nutrient use



https://www.rothamsted.ac.uk/projects/soil-nutrition-s2n

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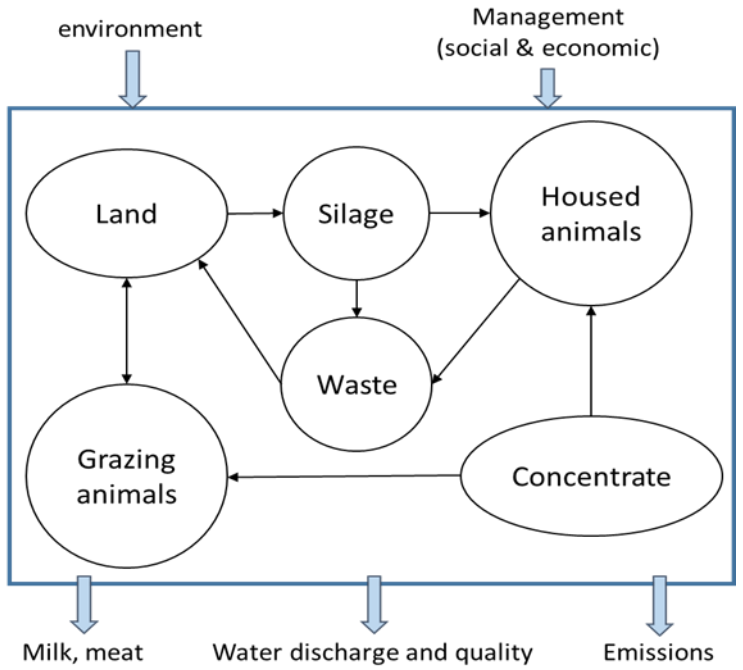
New and improved models / indicator datasets

- SPACSYS
- Landscape Model
- Catchment Systems Model
- ROTH-C

- Updated SEPARATE
- Updated risk matrix for diffuse water pollution at catchment scale – to take account of spatial and temporal mismatches between on-farm activities and downstream effects



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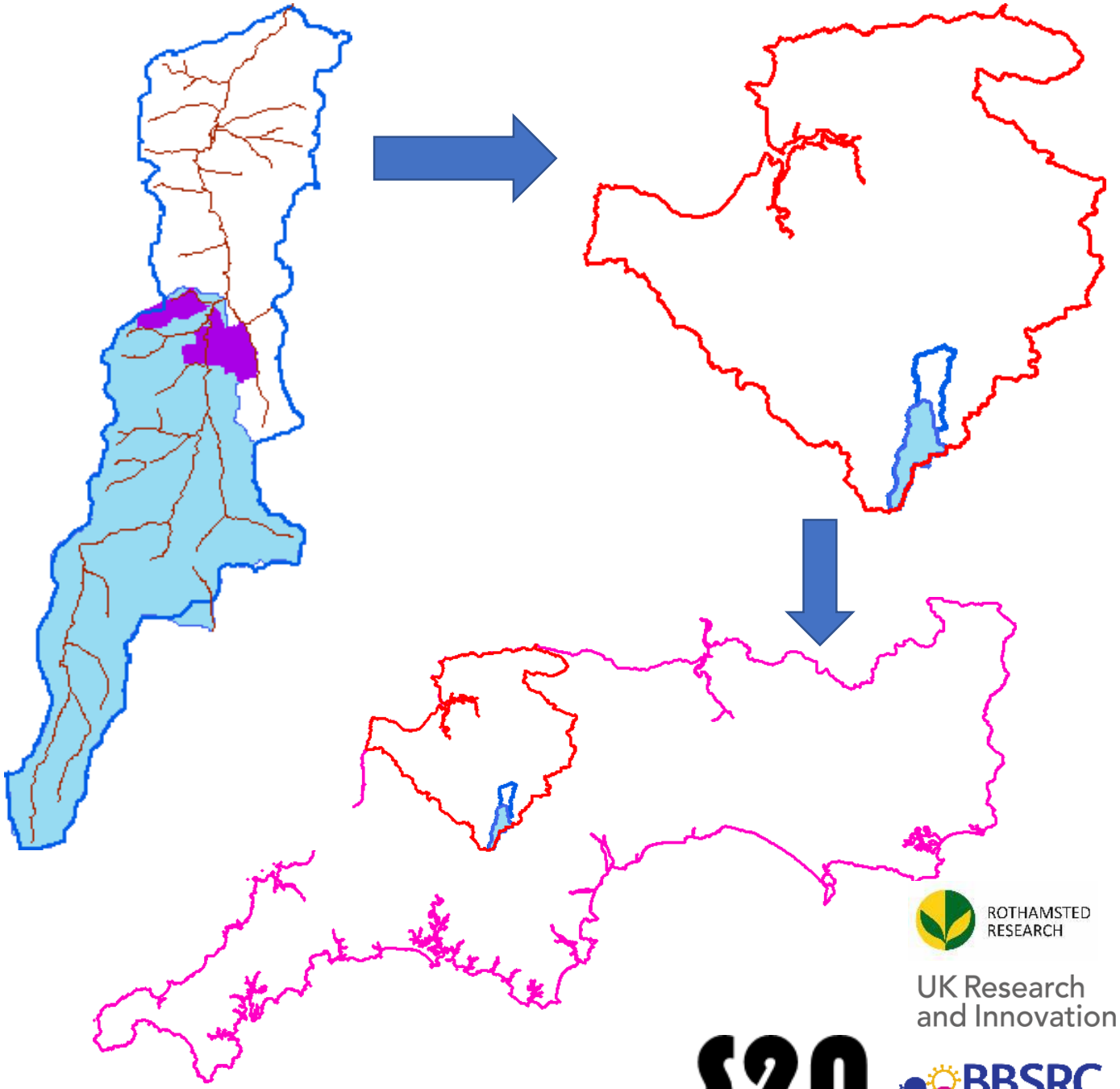
Hierarchical research platform

North Wyke Farm platform	15 sub-catchments (2 – 12 ha)
Study catchment	Upper Taw (46 km^2)
Surface water body	Taw (Source to Bullow Brook, 71km^2)
Management catchment	North Devon (2364 km^2)
River Basin District	South West (17622 km^2)



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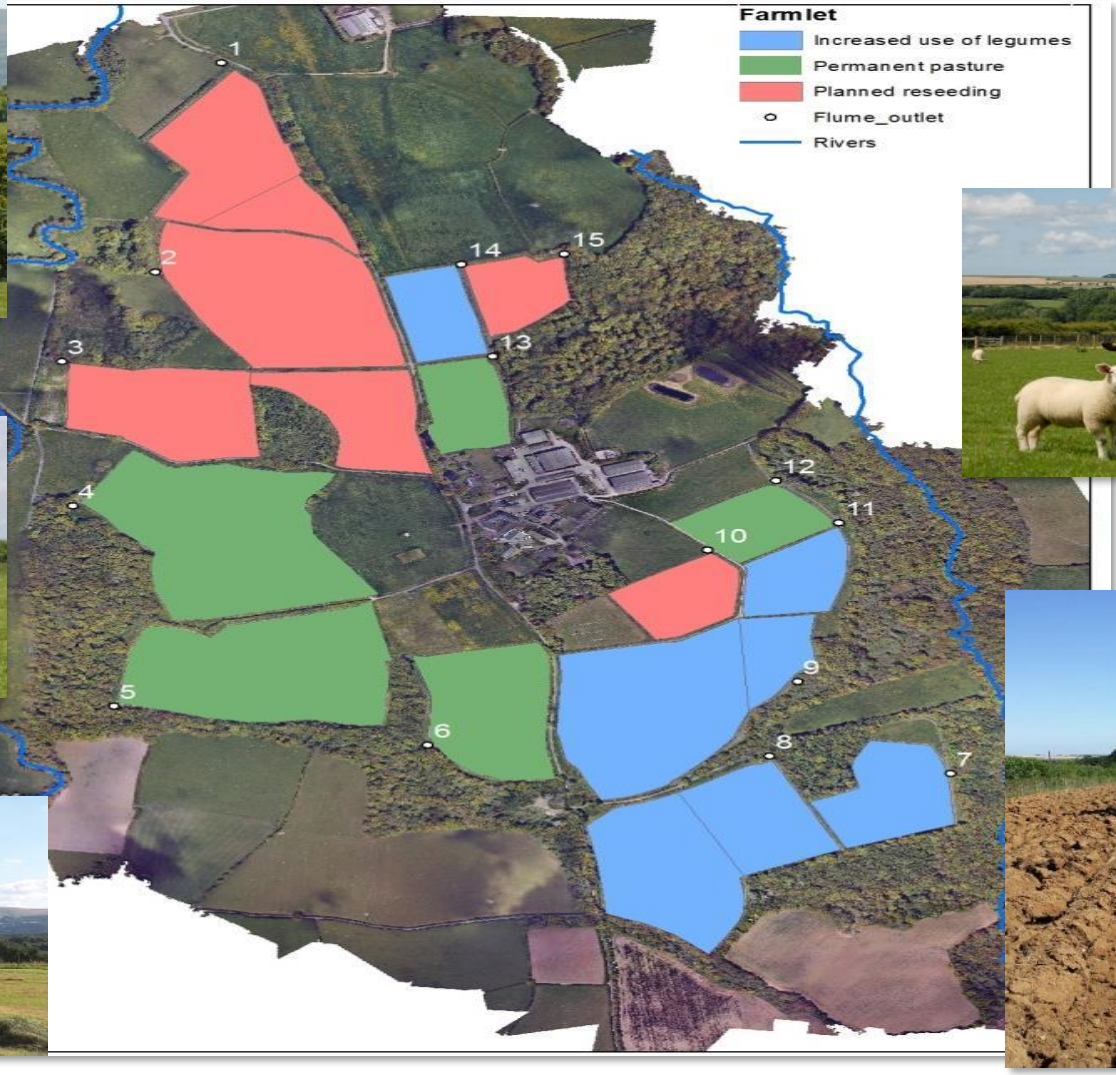
The North Wyke Farm Platform



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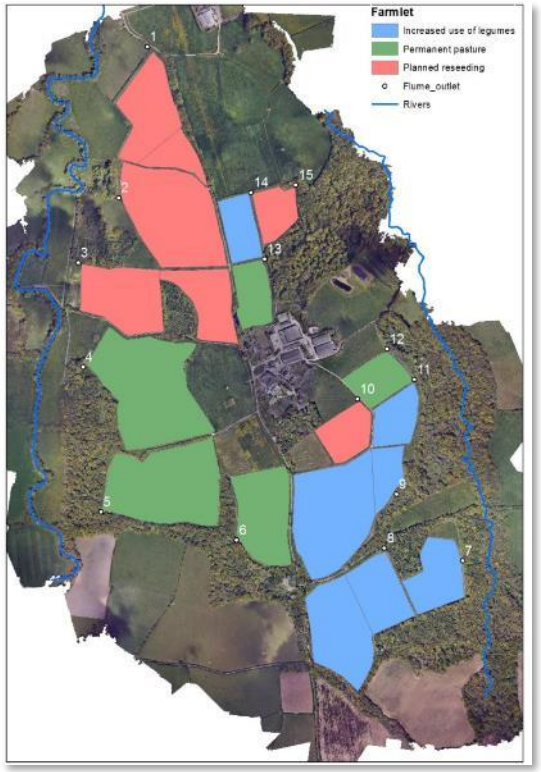
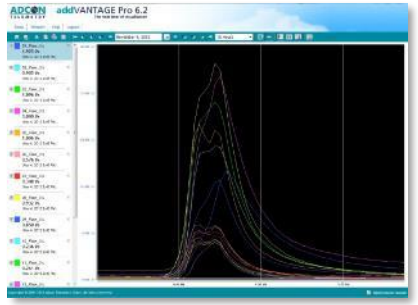
The North Wyke Farm Platform

Soil	Atmosphere	Farm Management
% Moisture	Rainfall	Field inputs/outputs
Temperature	CO_2 and N_2O	Liveweight gain
pH		Farm activities
Bulk density		Labour hours
N, P & C status		Machine hours



15 flume laboratories



Total-P
Ortho-P

Water
Temperature
Conductivity
Turbidity
pH
Dissolved O_2
Ammonium
Nitrate
Dissolved organic C

Sequential/composite sampler

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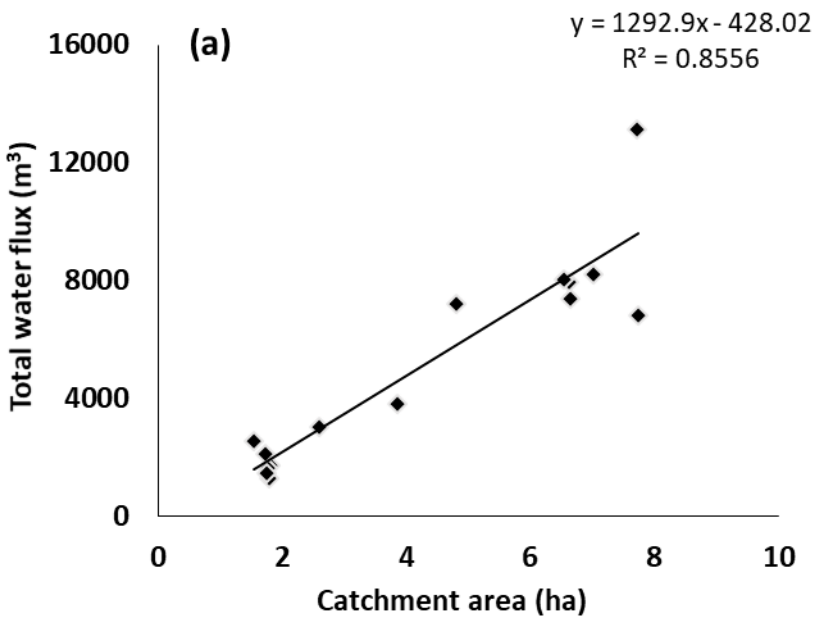
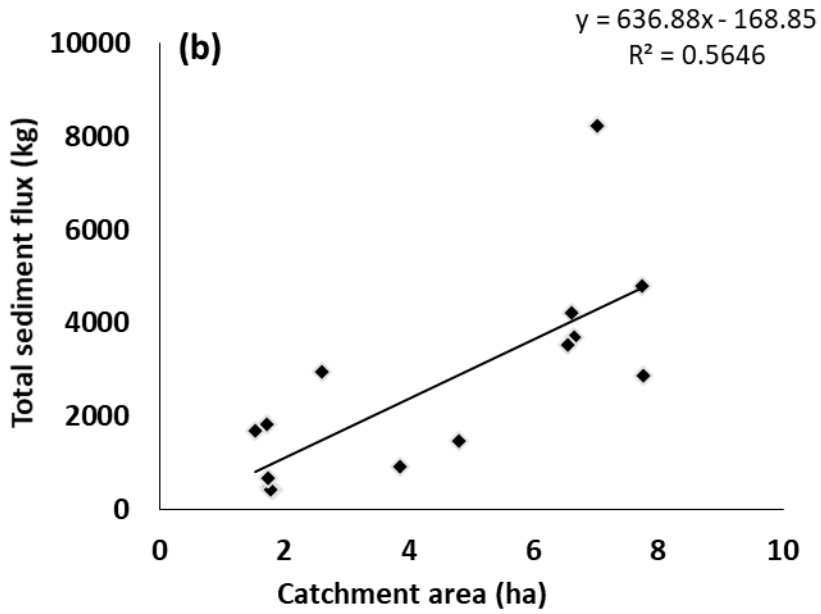
Farm platform data – based mechanistic learning





Flow discharge and sediment loadings are a function of catchment area - no relationships between the distribution of compacted areas, e.g. poached and feeder locations or gateways, and sediment loadings

Pulley and Collins (2019), Journal of Environmental Management

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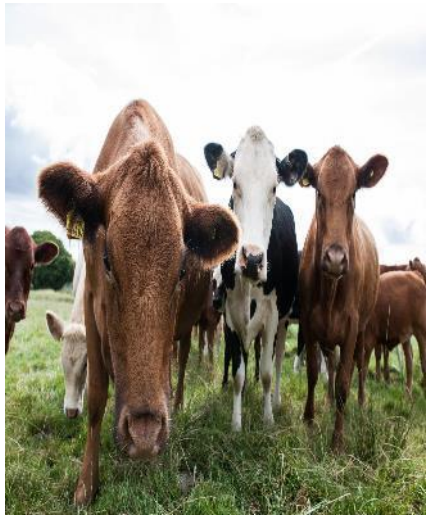
Implications for best management

Farm visit visually-based current interventions
Move feeder rings are regular intervals
Construct troughs with a concrete base
Re-site gateways away from high risk areas
Farm track management
Establish riparian buffer strips

Business-as-usual

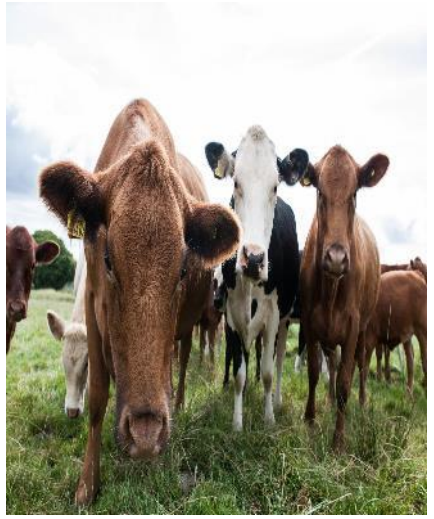


Revised management

Mechanistically-based best management interventions
Reduce the length of the grazing season
Reduce field stocking rates when soils are wet
Locate out-wintered stock away from watercourses
Loosen compacted soil layers in grass fields
Use correctly-inflated low ground pressure tyres

Impacts and trade-offs

Trade-offs	Visually-based Interventions	Mechanistically-based interventions
Capital cost (£)	114	70
Operational cost (£)	576	1533
Total cost (£)	690	1603
Nitrate (%)	**1.2**	**2.1**
Phosphorus (%)	**1.0**	**2.6**
Sediment (%)	**2.1**	**5.0**
Ammonia (%)	0.0	-21.6
Nitrous oxide (%)	**1.9**	**12.4**
Pesticides (%)	0.0	**1.3**
FIOs (%)	**0.4**	**0.6**
Energy use (%)	-0.3	-7.6
Soil quality (score)	**1.0**	**12.5**



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Upper Taw catchment: in-situ monitoring / sampling

- River discharge
- Phosphorus (TP & SRP)
- NO_3^- and NH_4^+
- Turbidity/sediment
- pH and temperature

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Upper Taw catchment: source apportionment work

Agricultural vs non-agricultural inputs

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UKCP18 scenarios and projections

Scenario	Ensemble	Climate variable	Spatial resolution
RCP 2.6	1	Maximum air temperature	12 km^2
RCP 4.5 (SRES B1)	4	Minimum air temperature	25 km^2
RCP 6.0 (SRES B2)	5	Precipitation	River Basin District
RCP 8.5 (SRES A1F1)	6	Mean air temperature	Government Region
	7	Sunshine duration	Global
	8	Mean wind speed at 10 m	
	9	Mean sea level pressure	
	10	Mean relative humidity	
	11	Mean vapour pressure	
	12	Days of ground frost	
	13	Days of snow lying	
	15		

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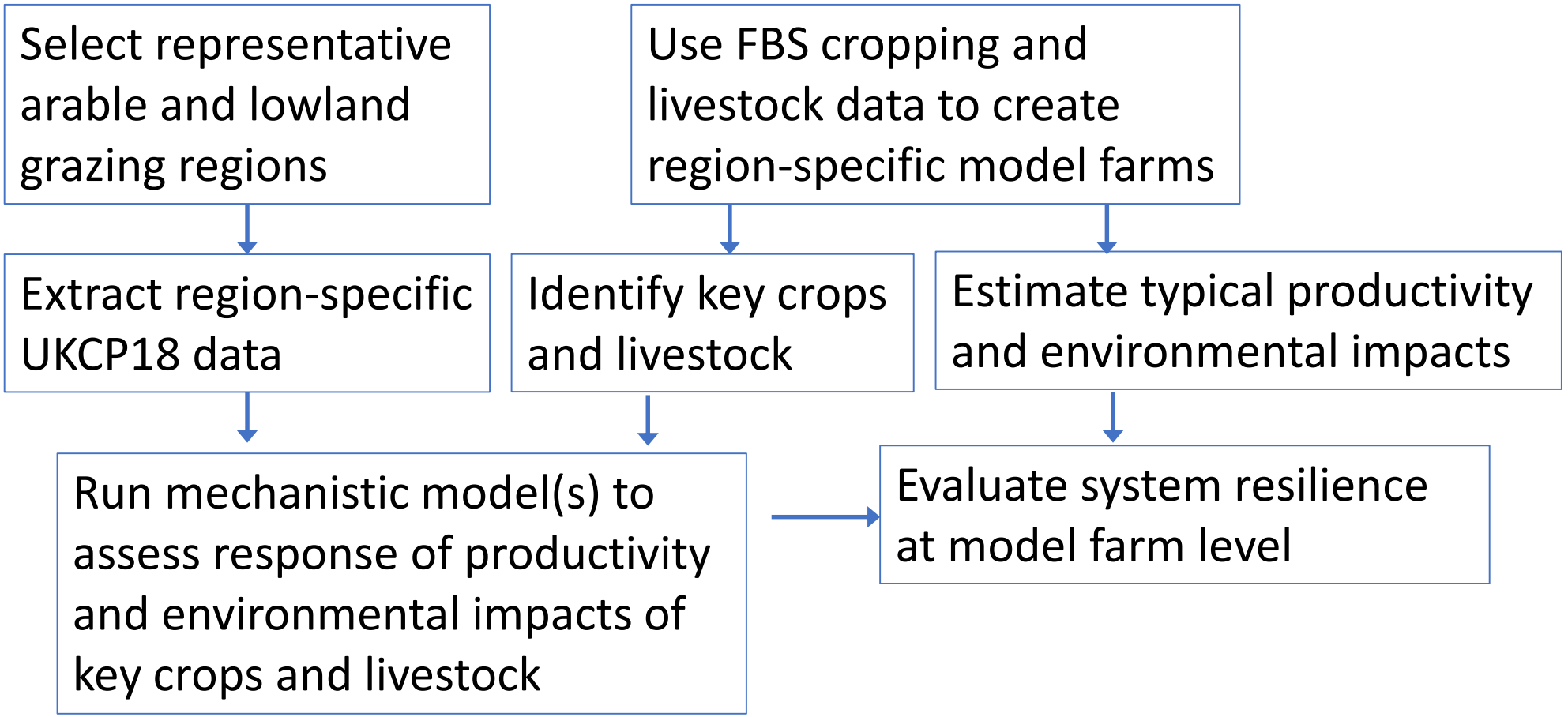
Accounting for climate change impacts on agricultural emissions to water and air



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