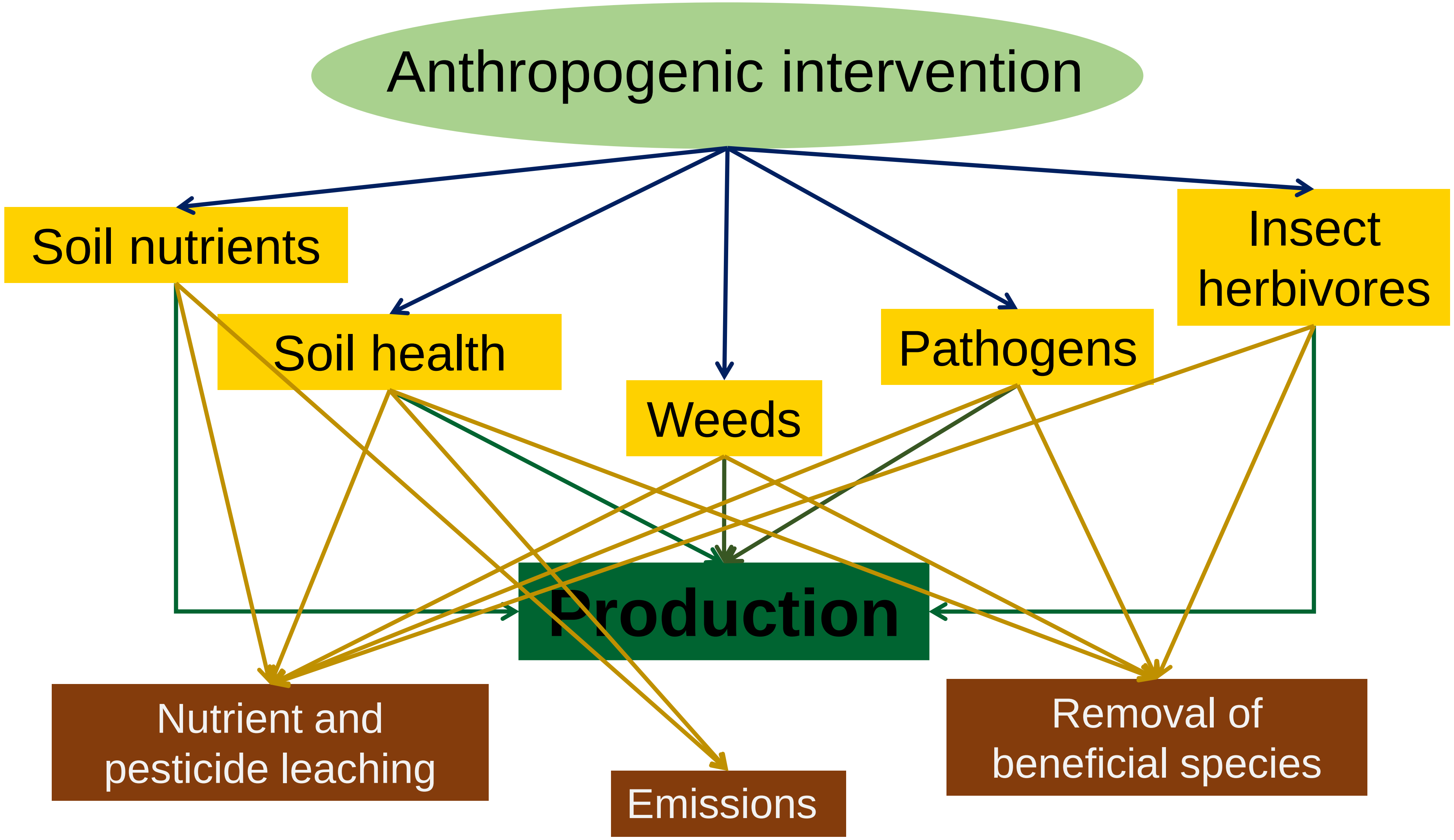
The Rothamsted Landscape Model: Current capabilities and planned developments

Alice Milne, Ryan Sharp, Kevin Coleman, Helen Metcalfe, Andy Whitmore

ROTHAMSTED RESEARCH

Background



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Aim

- Monitoring trade-offs between production and environment can be expensive.
- Understanding the impacts of various scenarios is impractical through field experiment
- Computer simulation models can fill gaps between what we need to know and what is available from measurements.

Produce a tool that can be used to explore scenarios and associated trade-offs between production and environment factors.

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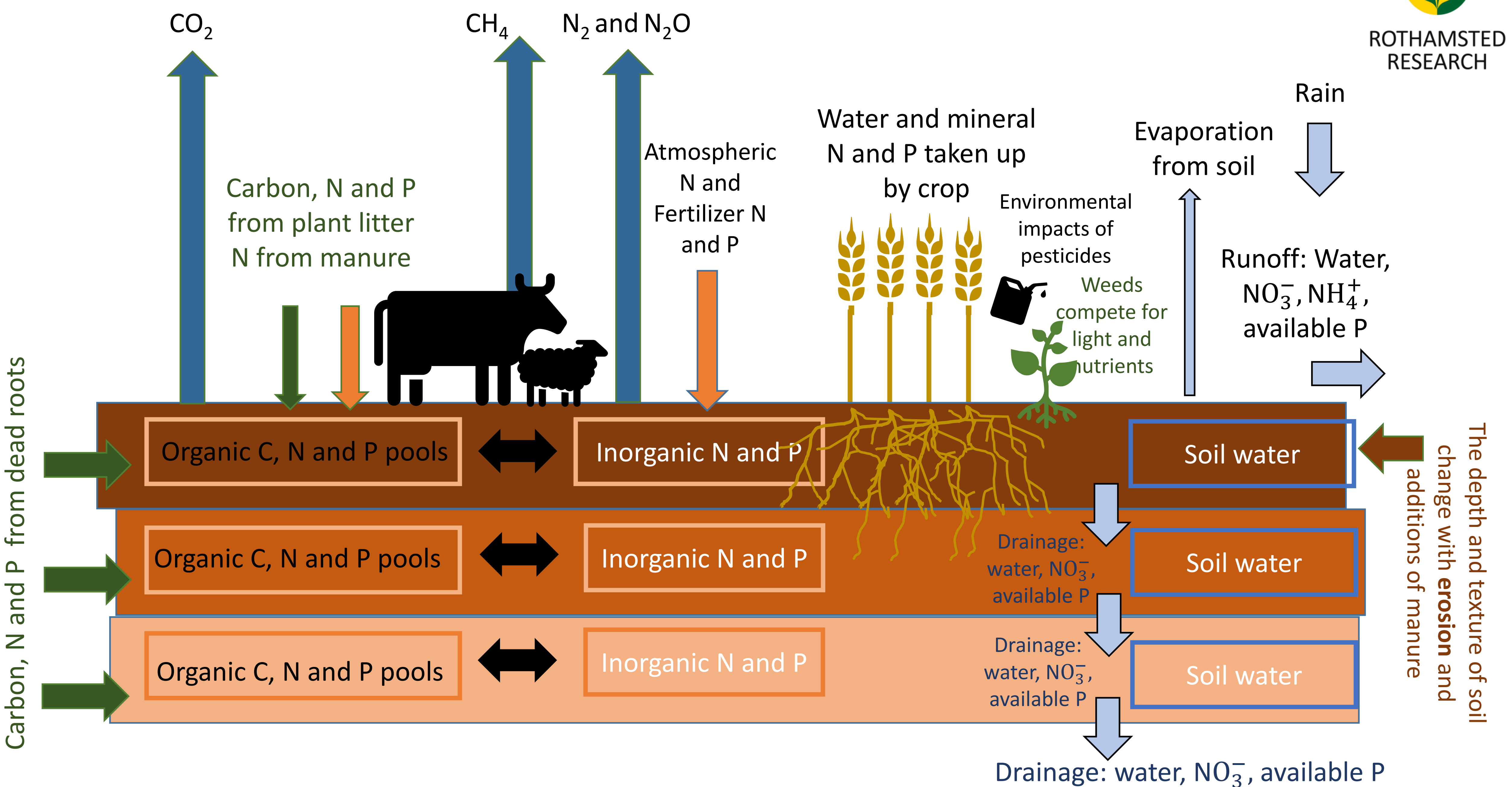
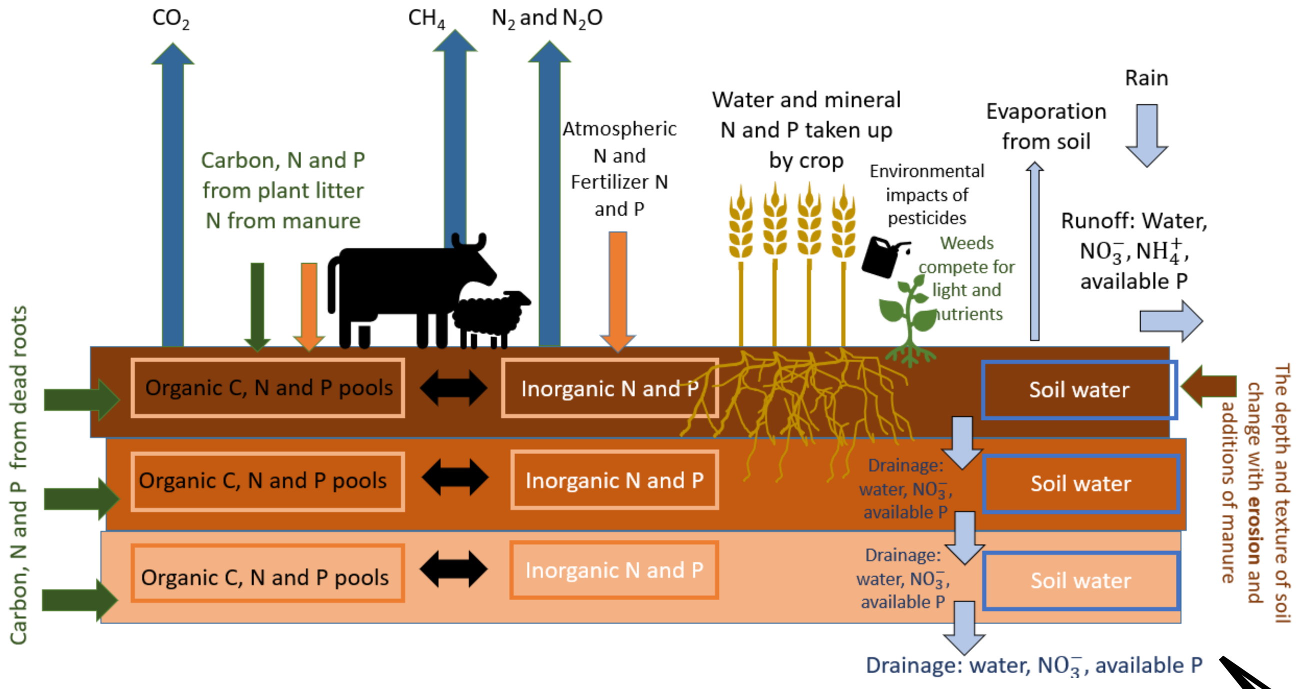
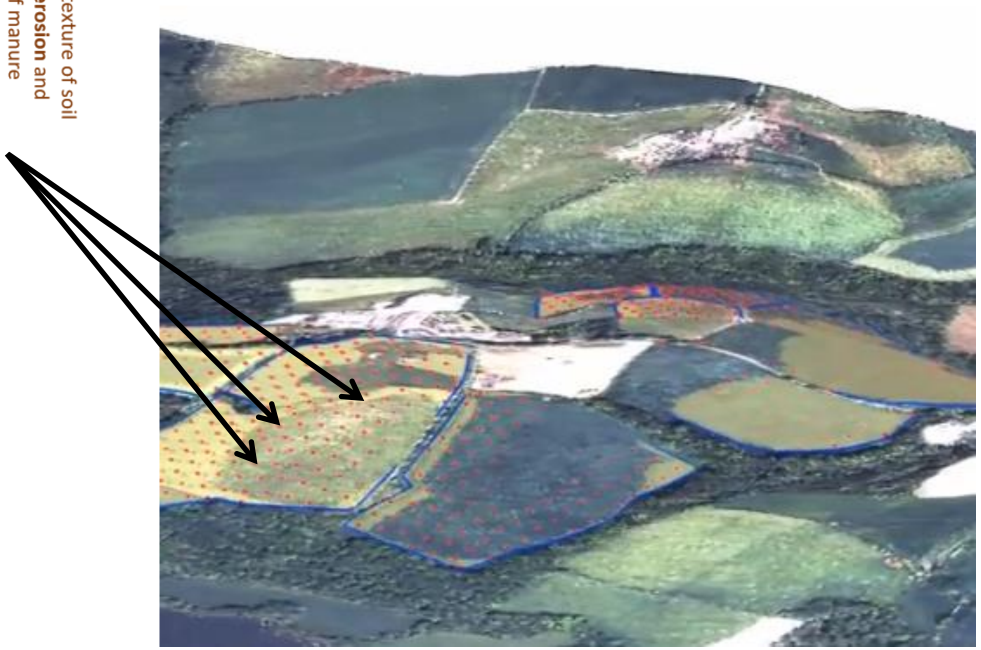
The Rothamsted Landscape Model functionality



The Rothamsted Landscape model





- Water and nutrients may flow laterally
- Slope across the landscape affects erosion

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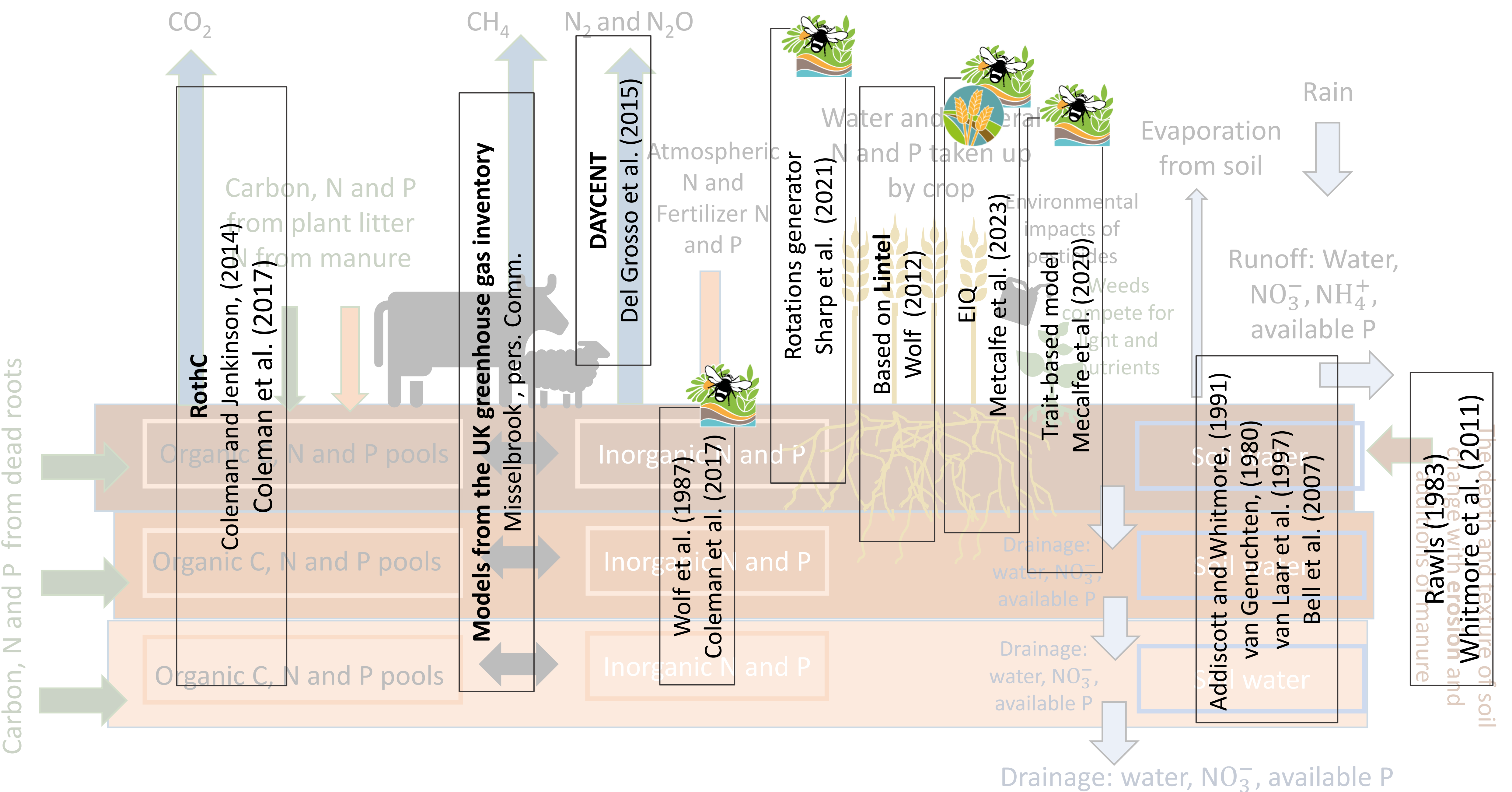
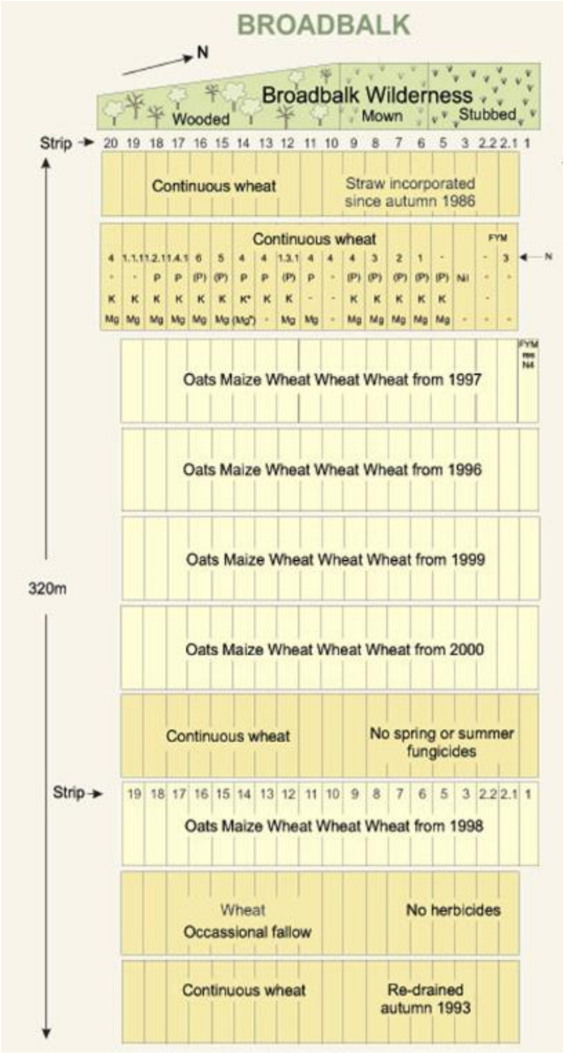
A summary of the current Rothamsted Landscape Model functionality



Model validation using data from Broadbalk



Broadbalk is the longest running experiment in the world. Set up in 1843 to study the effect of organic and inorganic fertilizers on wheat.

Data available:

- Wheat grain and straw yield
- Yields of other crops grown in rotation
- Soil data
- Weed surveys
- Disease data
- Crop nutrient data
- Grain quality data
- N leached

http://www.era.rothamsted.ac.uk/

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Model validation using data from Broadbalk

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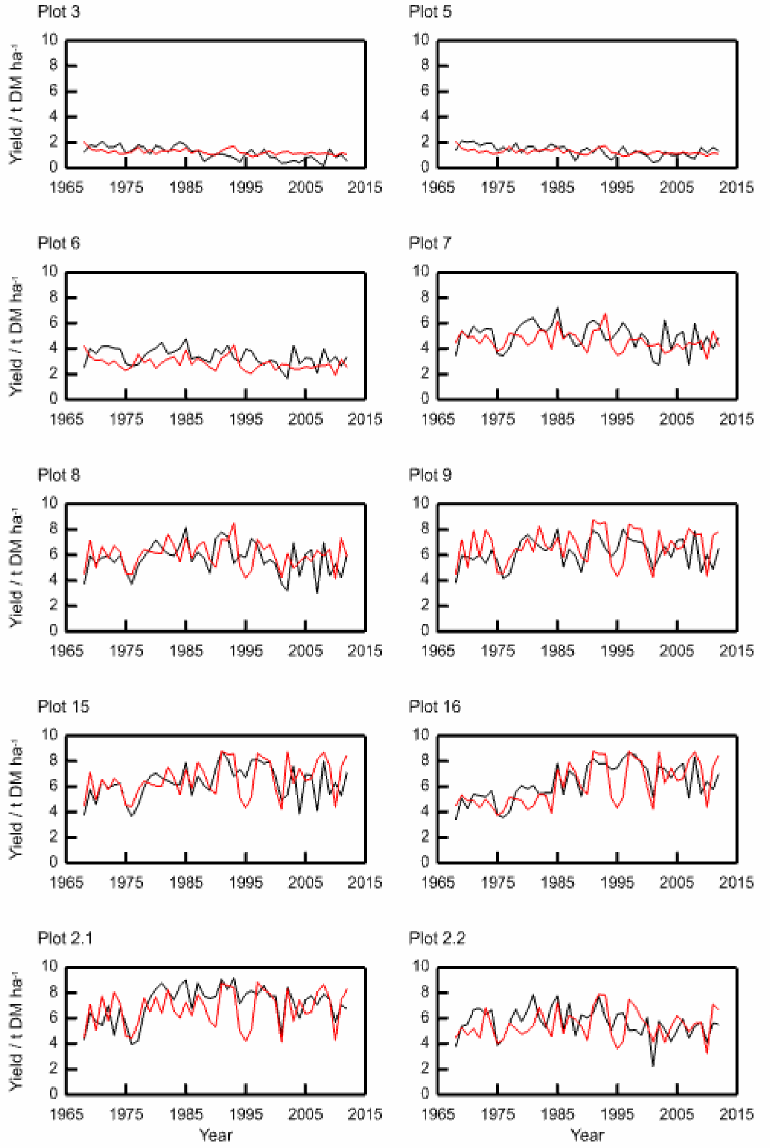
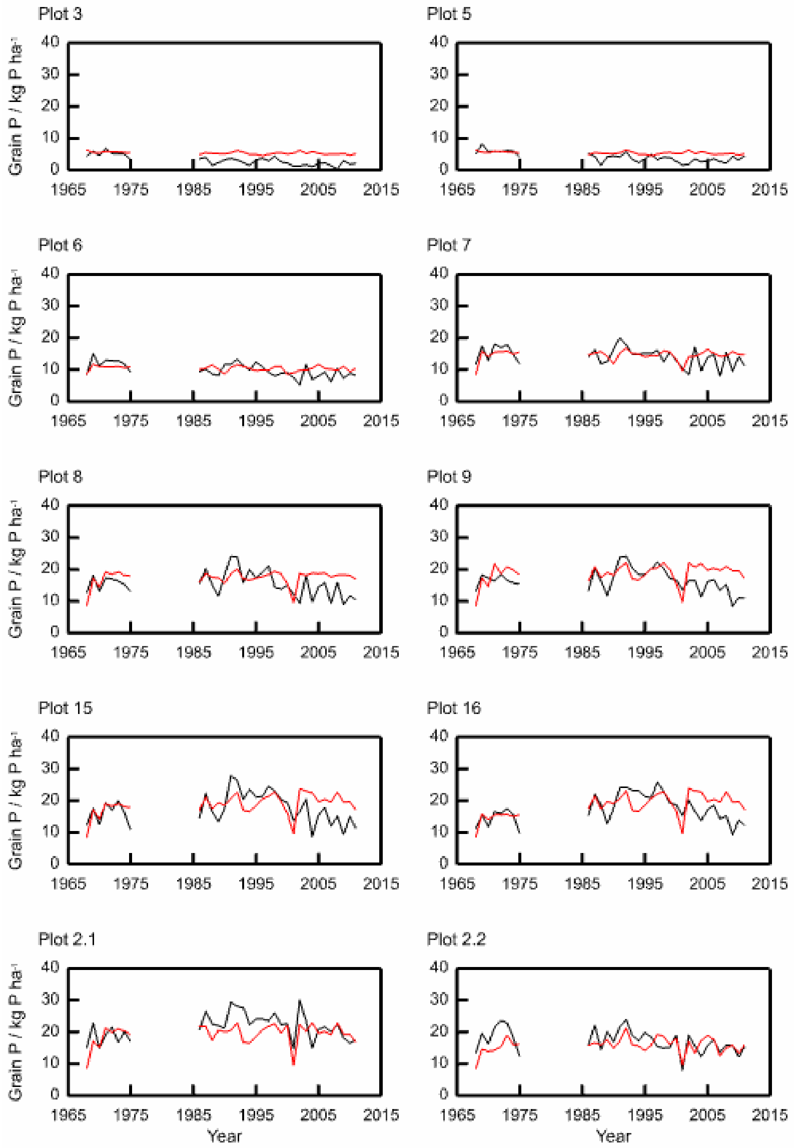
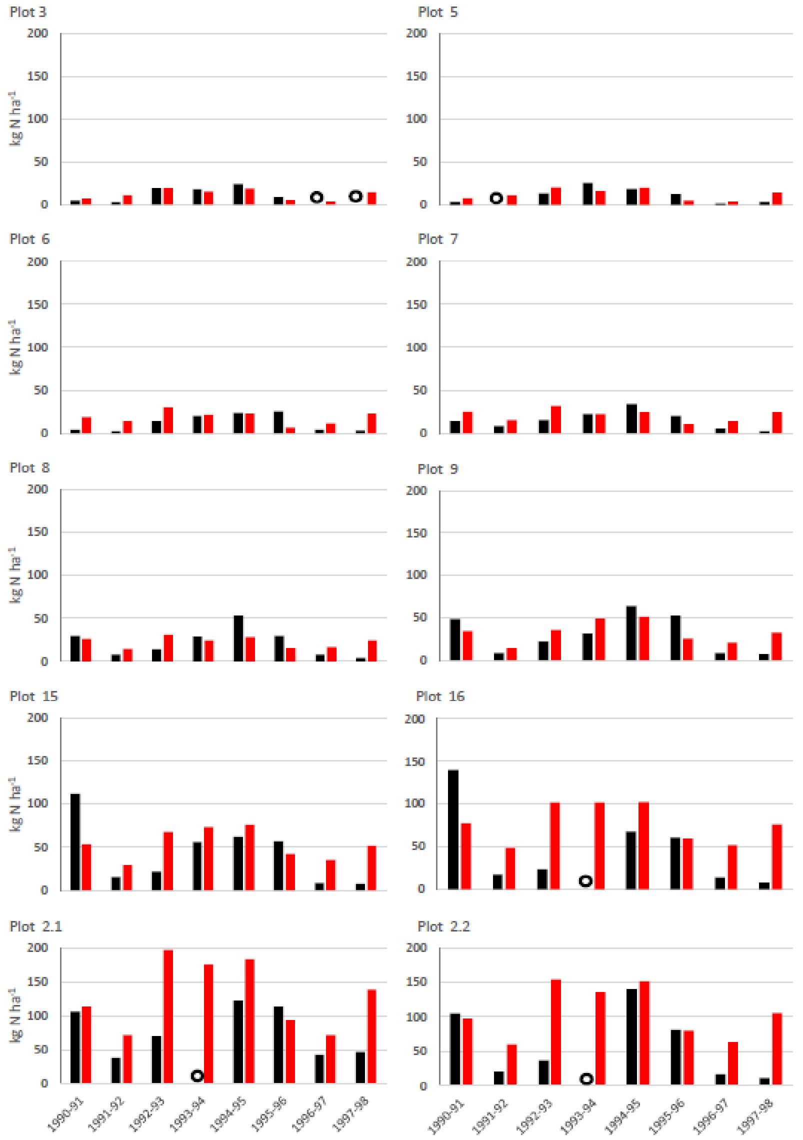
Wheat Yield



P in the grain



Nitrate in drains



Modelled, Measured

Model validation using data from Park grass

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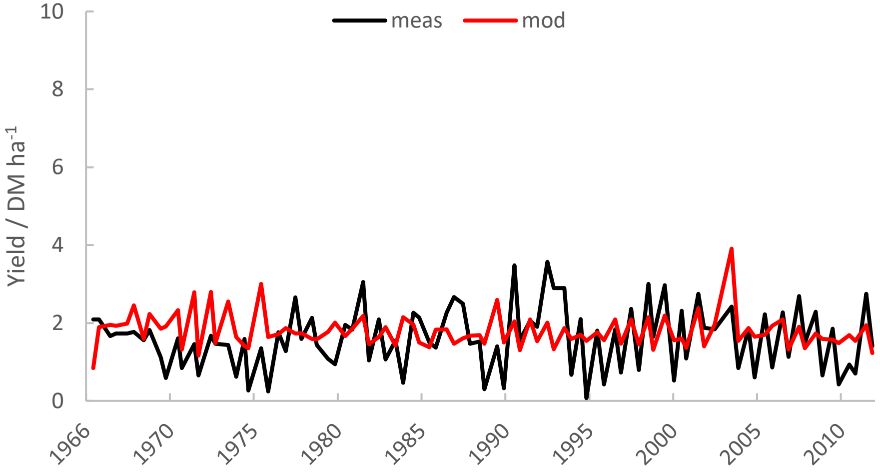
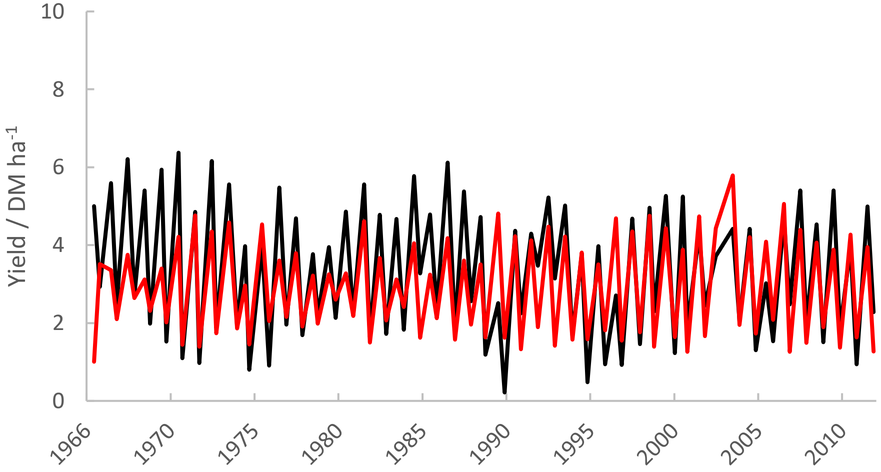
Plot 3a



Plot 14a

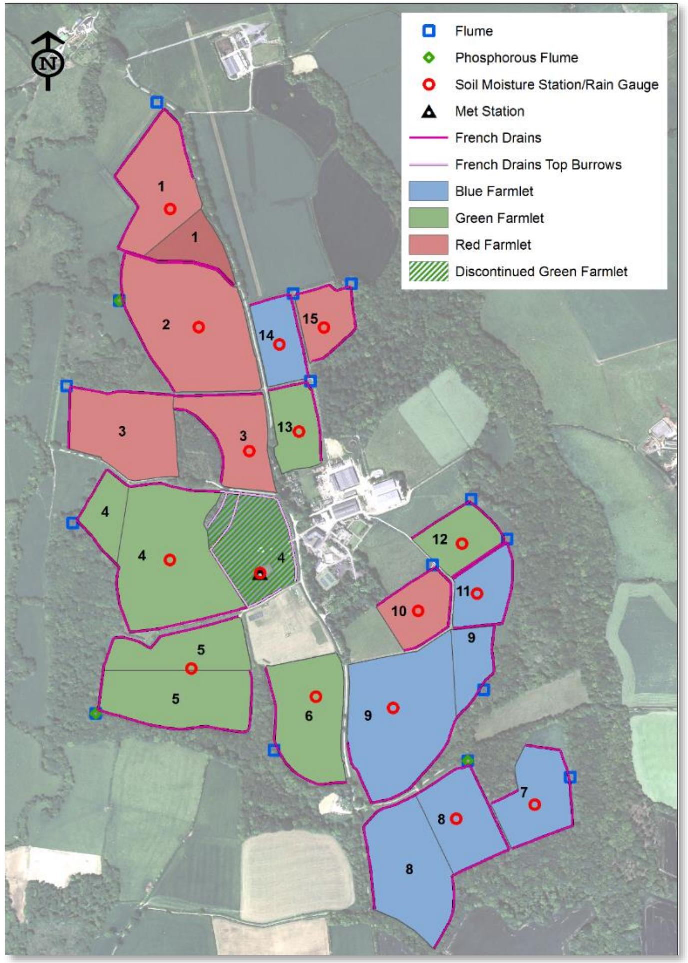


The Park Grass experiment is the oldest experiment on permanent grassland in the world. Started in 1856, to investigate the effect of fertilizer on yield of hay

Data available:

- Grass yield
- Soil data
- Botanical composition
- herbage nutrient content

Model validation using the North Wyke Catchment



3 farmlets; 15 sub-catchments; 21 fields

UK NBRI, North Wyke, SW England

The North Wyke farm platform was set up in 2011 to assess livestock productivity and ecosystem responses to 3 different managements:

Currently (2013/5 – 2018/9)

- Permanent pasture
- Improvement through the use of legumes
- Improvement via planned reseeding and innovation

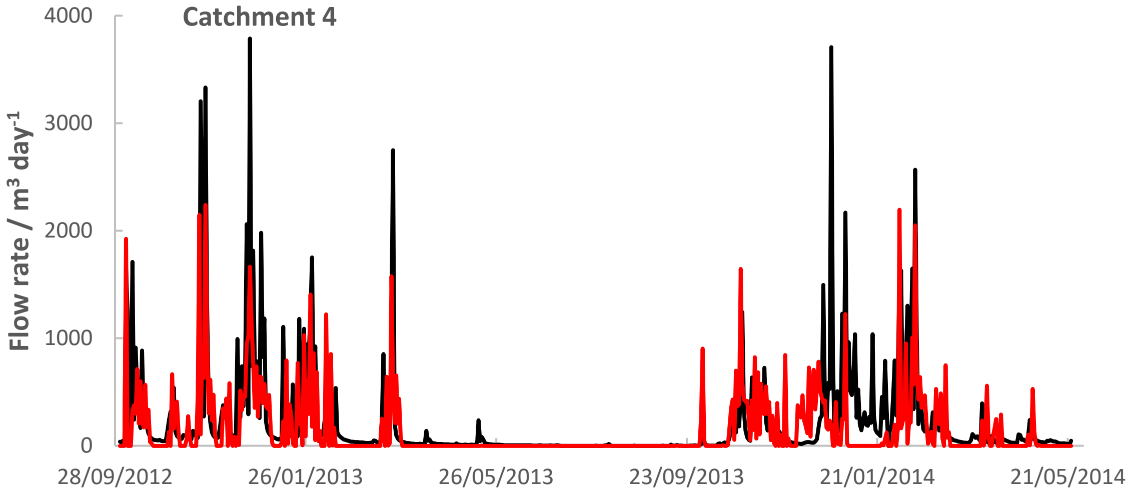
Data available:

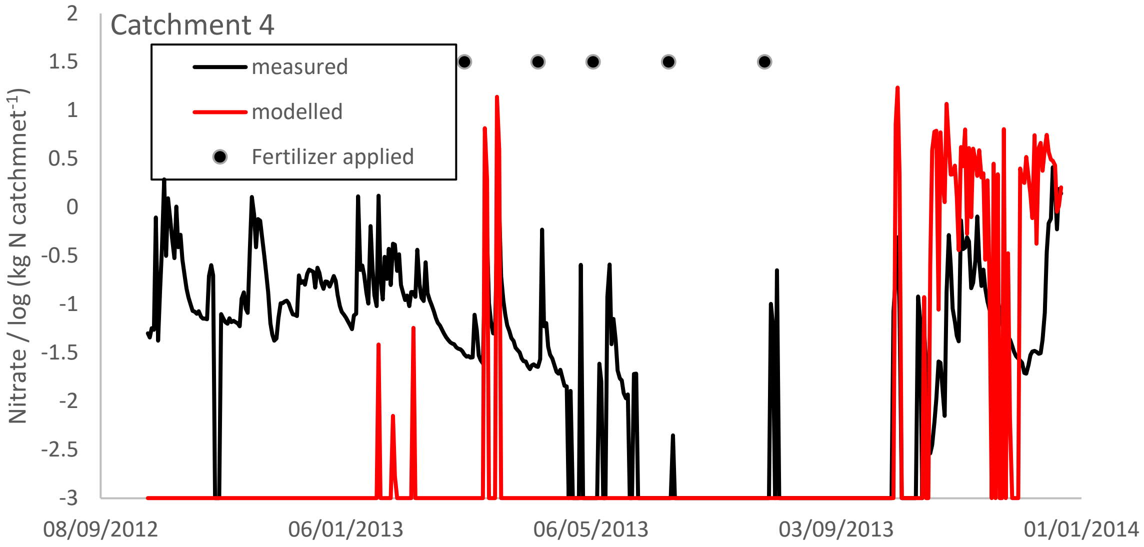
- Water flow
- Water chemistry
- Soil data
- Herbage survey
- Botanical survey

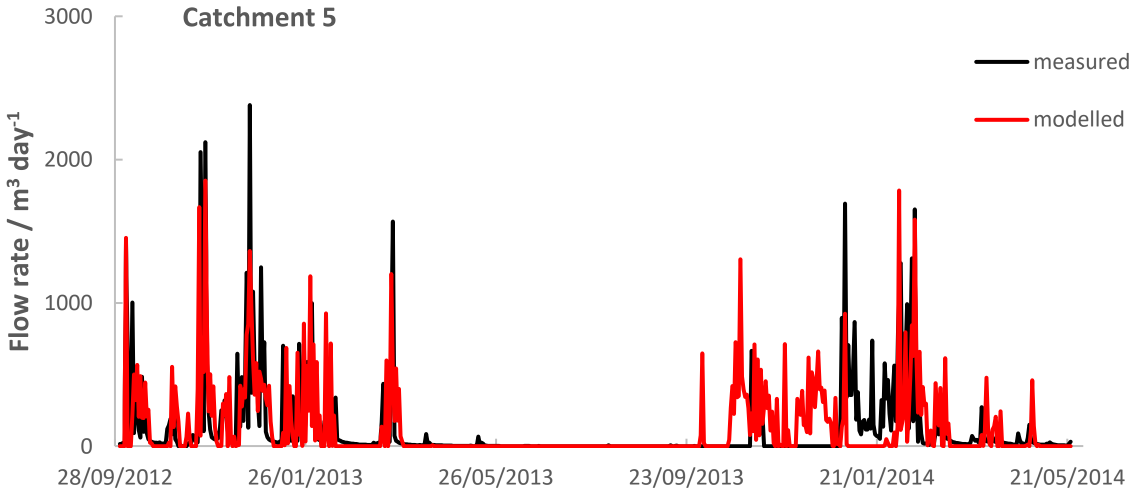
Open data: https://nwfp.rothamsted.ac.uk/

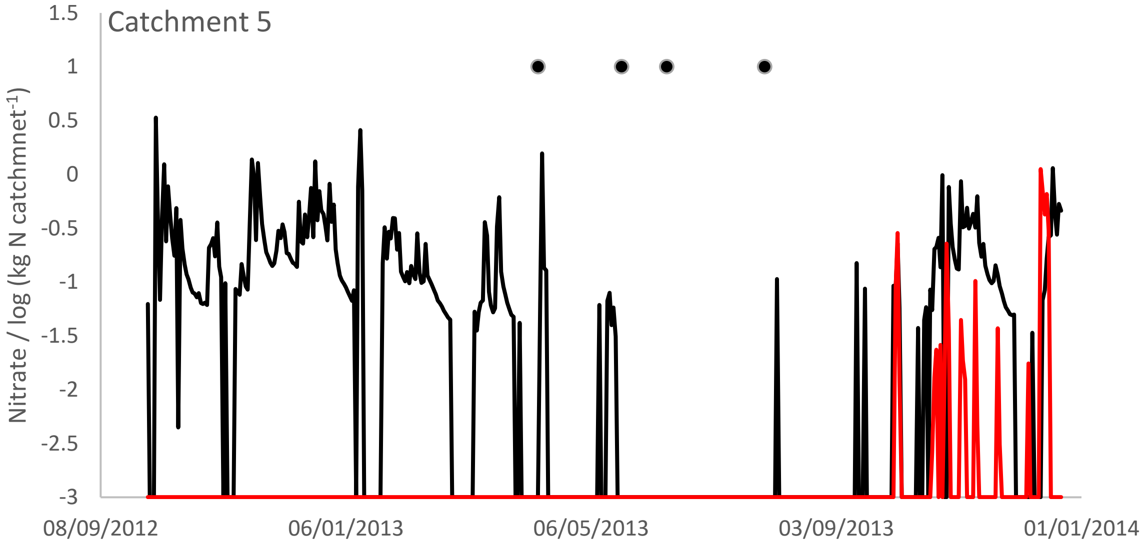
ROTHAMSTED RESEARCH

Model validation using the North Wyke Catchment



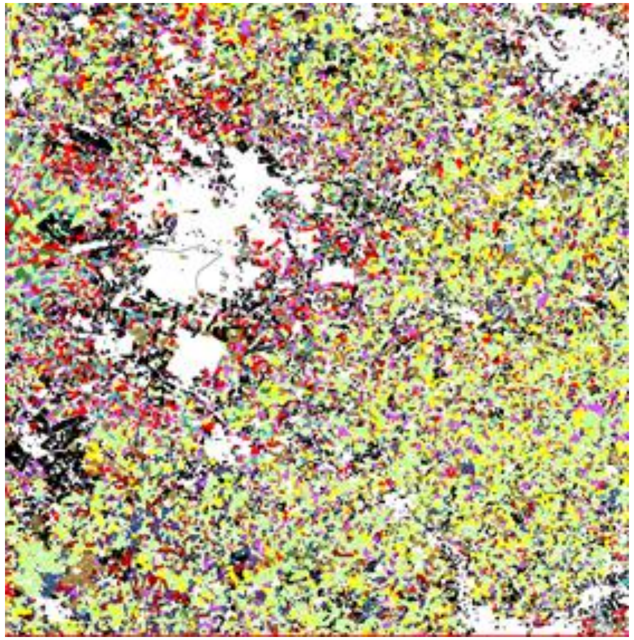






Model development: Crop Sequence Generator

- **Method:**
  - Uses CEH Land Cover® plus: Crops 2016-2018.
  - Probability calculated of one crop following another (e.g. wheat → maize).
  - Add additional agronomic rules programmatically (e.g. max 1 potato crop every 4 years).
- **Result:** Realistic crop sequences.
- **Intended use:** BAU scenario models in GB.



BAU

Previous Crop	Next Crop: be	fb	gr	ma	or	ot	po	sb	sw	wb	ww	sum
be	0.01	0.01	0.01	0.05	0	0.07	0.02	0.11	0.18	0.04	0.51	1
fb	0.01	0.01	0.03	0.01	0.01	0.05	0.01	0.02	0.03	0.07	0.76	1
gr	0.03	0.02	0.56	0.04	0.02	0.09	0.02	0.03	0.04	0.04	0.11	1
ma	0.07	0.01	0.12	0.17	0	0.13	0.04	0.04	0.05	0.06	0.32	1
or	0.01	0	0.01	0	0	0.02	0	0.01	0.01	0.06	0.88	1
ot	0.05	0.03	0.13	0.04	0.05	0.18	0.03	0.04	0.06	0.08	0.31	1
po	0.04	0	0.02	0.03	0	0.07	0.01	0.03	0.04	0.06	0.71	1
sb	0.07	0.08	0.04	0.02	0.17	0.09	0.03	0.09	0.08	0.13	0.2	1
sw	0.08	0.08	0.05	0.02	0.1	0.09	0.04	0.05	0.1	0.14	0.25	1
wb	0.12	0.06	0.05	0.02	0.35	0.09	0.04	0.03	0.04	0.12	0.1	1
ww	0.12	0.08	0.03	0.02	0.12	0.08	0.05	0.05	0.05	0.14	0.26	1

ELSEVIER
Computers and Electronics in Agriculture
Volume 188, September 2021, 106330

Original papers

Simulating cropping sequences using earth observation data

Ryan T. Sharp [a], Peter A. Henrys [b], Susan G. Jarvis [b], Andrew P. Whitmore [a], Alice E. Milne [a], Kevin Coleman [a], Sajeev Erangu Purath Mohankumar [a], Helen Metcalfe [a]

zenodo

Search

June 20, 2021

CropSequenceGenerator

Helen Metcalfe; Ryan T. Sharp

Science of the Total Environment 767 (2021) 144903

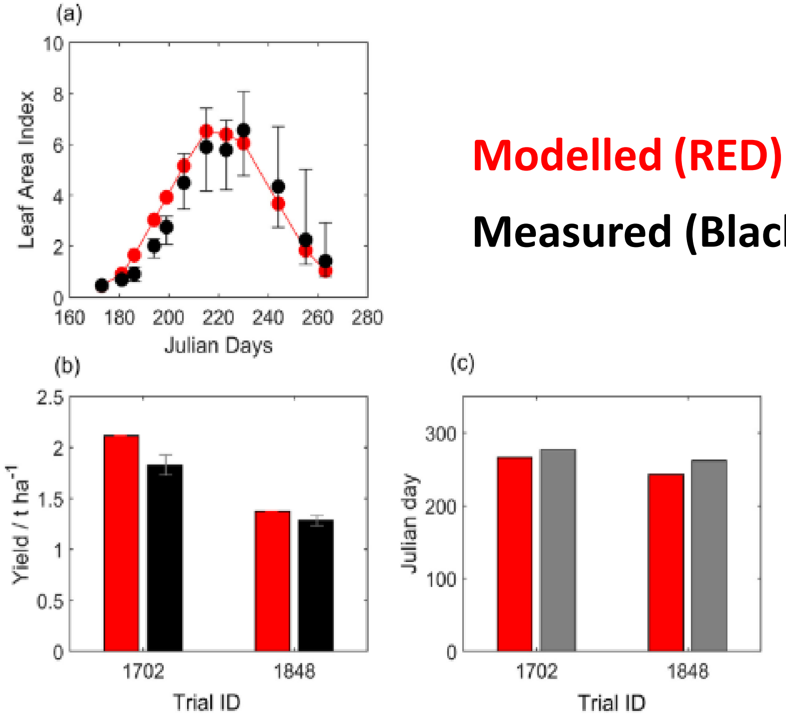
Contents lists available at ScienceDirect

Science of the Total Environment

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

The potential for soybean to diversify the production of plant-based protein in the UK

Kevin Coleman [a,*], Andrew P. Whitmore [a], Kirsty L. Hassall [b], Ian Shield [a], Achim Dobermann [d,1], Yoann Bourhis [a], Aryena Eskandary [a], Alice E. Milr



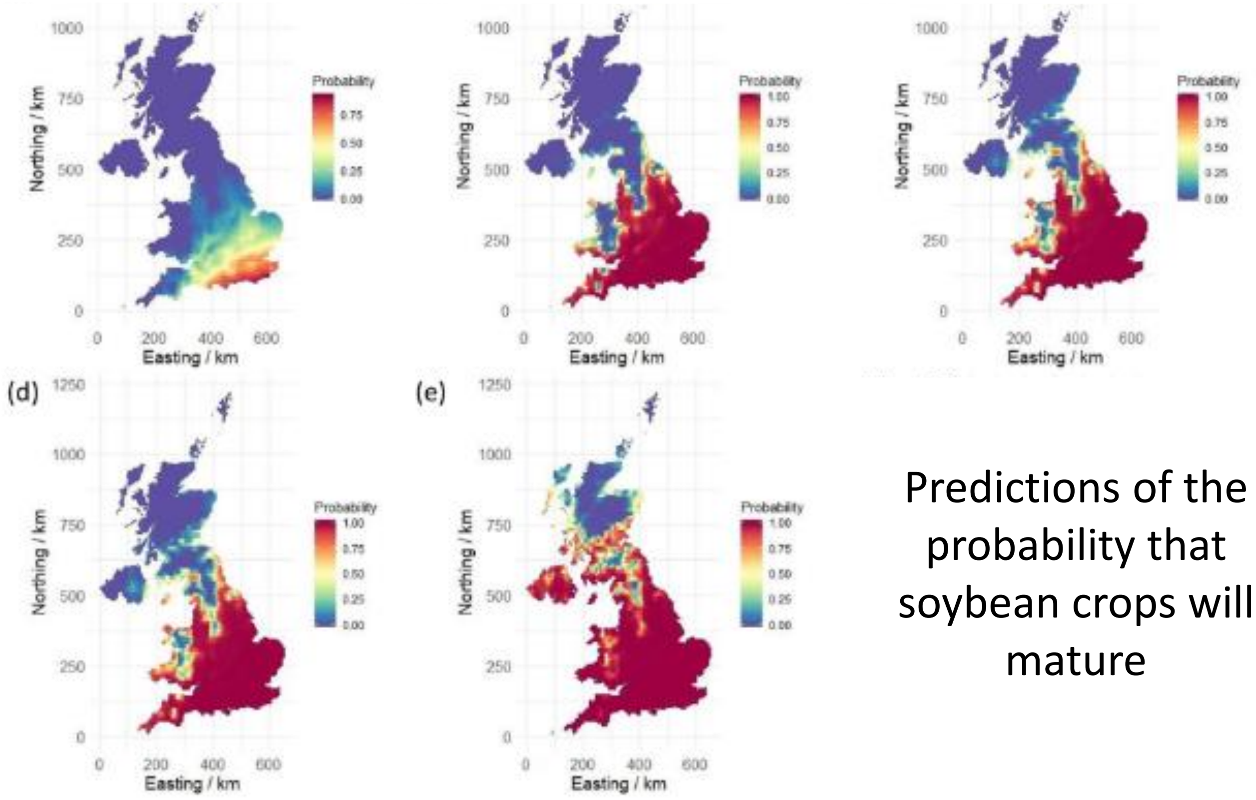
Modelled (RED)

Measured (Black)

Current weather

Near-future (RCP4.5)

Near-future (RCP8.5)



Far-future (RCP4.5)

Far-future (RCP8.5)

Predictions of the probability that soybean crops will mature

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

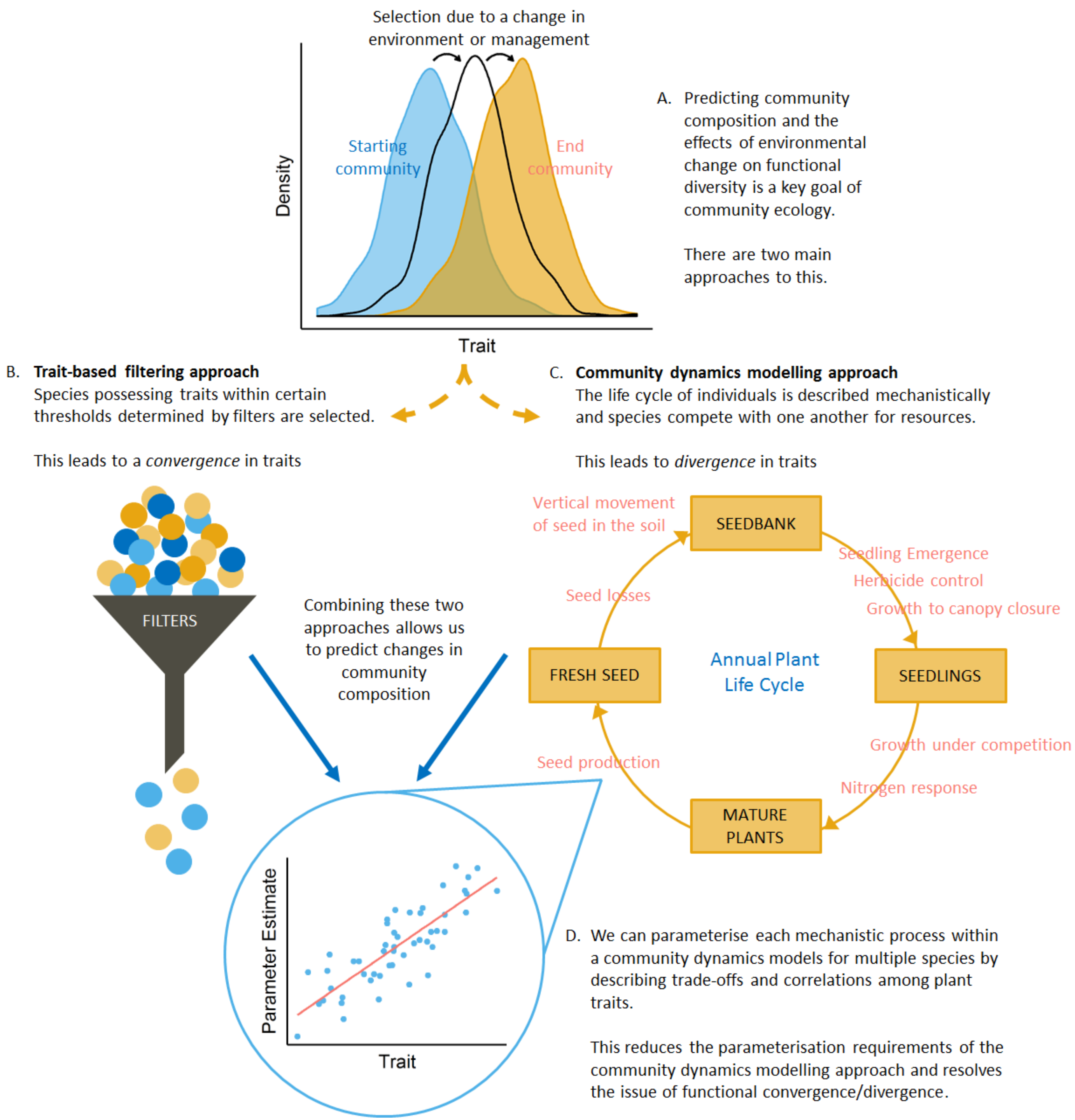
Article | Open Access

Using functional traits to model annual plant community dynamics

Helen Metcalfe, Alice E. Milne, Florent Deledalle, Jonathan Storkey

First published: 26 August 2020 | https://doi.org/10.1002/ecy.3167

Corresponding Editor: Daniel C. Laughlin.



Trade offs

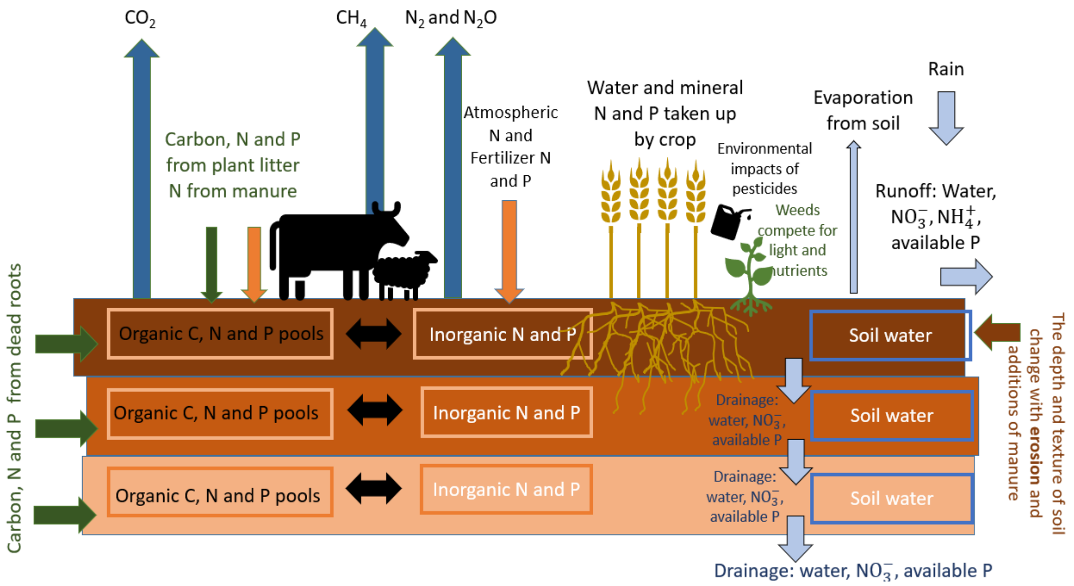
- Landscape model is coupled with an optimisation algorithm to determine Pareto optimal fronts between multiple objectives

Controls:

Fertilizer-N application
Fertilizer-P application
Farm-yard manure
Stocking rate

Objectives:

High Yield (crops only)
High Profit
Low Sediment loss
High NUE
Low N surplus
Low P surplus
Low Emissions
Increase in carbon storage



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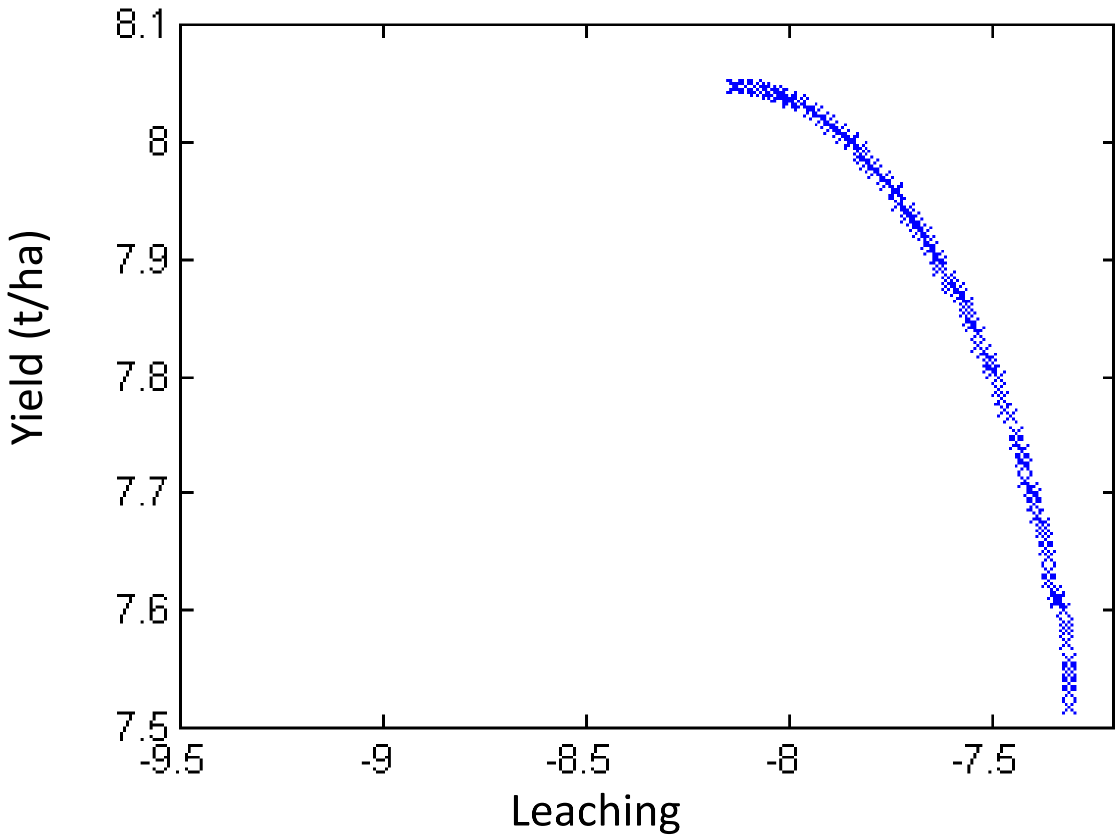
Optimisation

- Algorithm sorts and ranks multiple objectives
- Seeks new management options
- Identifies possible trade-offs



Non-dominated sorting (Deb et al., 2002) combined with differential evolution (Storn and Price, 1997)

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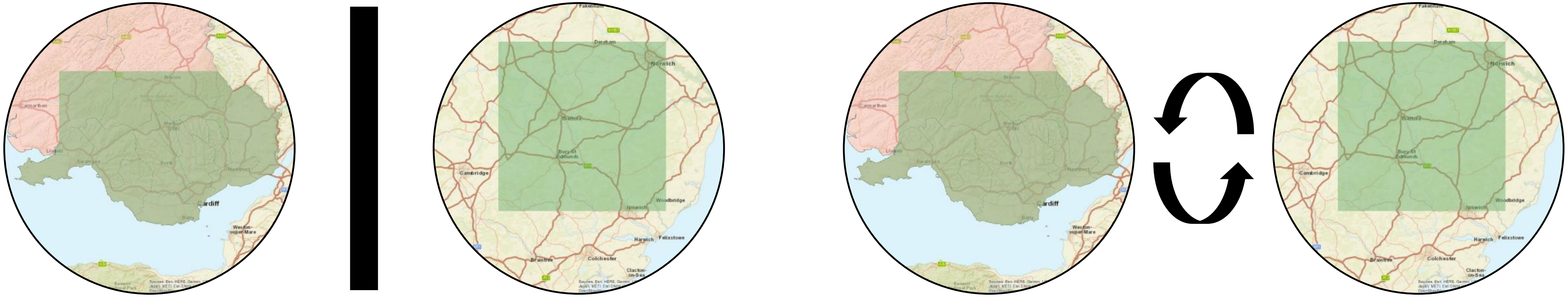
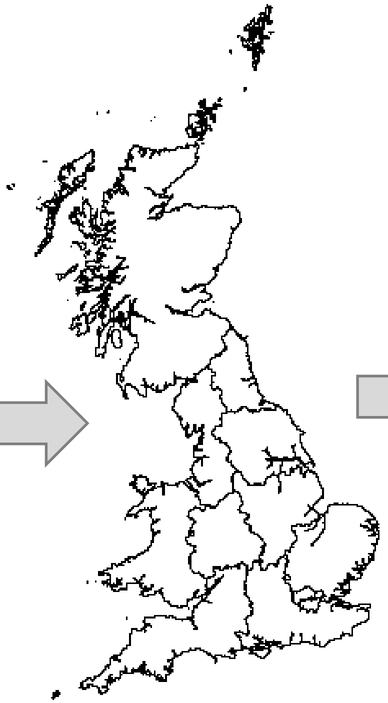
Scenario analysis: TGRAINS

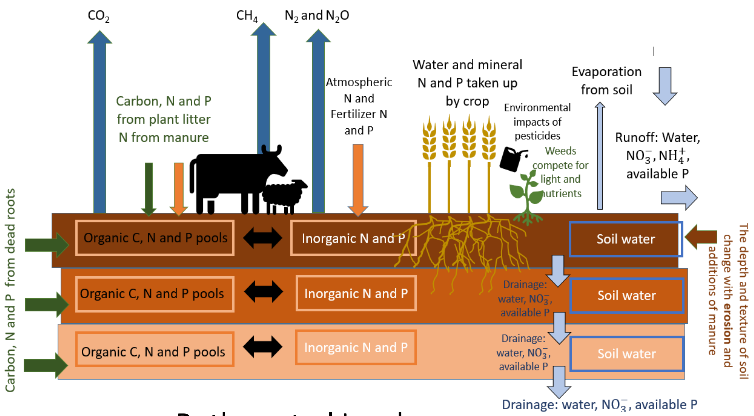
- Scenario food group areas were chosen to align with the EAT-Lancet recommended healthy diet.
- Lowland area kept constant.
- Upland area can only support livestock.
- ‘Regional’ and ‘Trade’ scenarios compared with BAU.



Scenario analysis: LTLS+



5 x 5 km UK grid



Rothamsted Landscape Model (RLM)

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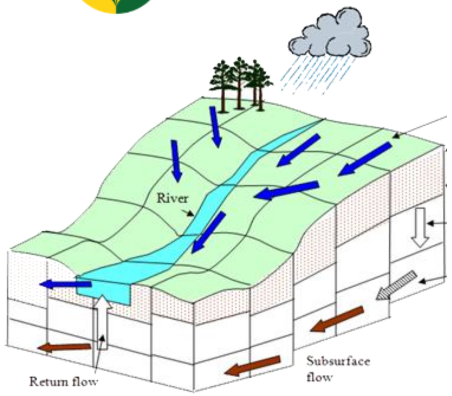
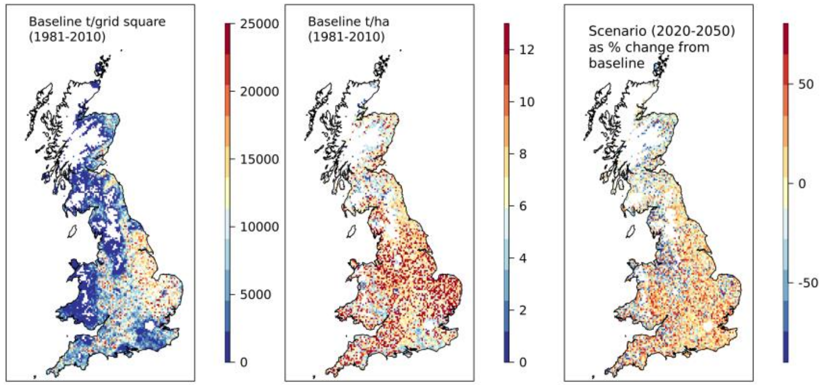


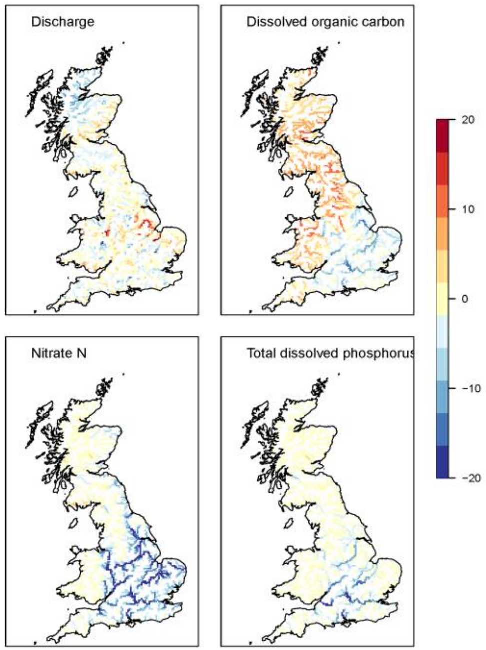
N14CP Model

UK Centre for Ecology & Hydrology

Mean annual yield: Arable (estimated excluding root crops)



Mean annual river load
%change from baseline to scenario



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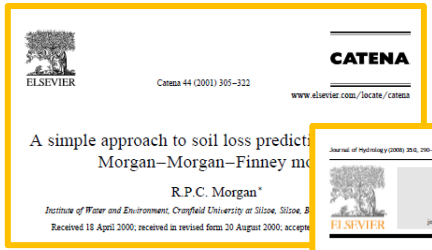
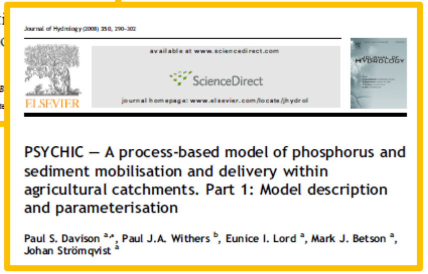
Next steps

- Incorporate soil erosion into the model
- Implement POM/DOM-SPM dynamics
- Fate of pesticides
- Partitioning and fixation to describe metal dynamics
- Relevant transformations for microorganic pollutants


ELSEVIER
Catena 44 (2001) 305–322
CATENA
www.elsevier.com/locate/catena
A simple approach to soil loss predicti…
Morgan–Morgan–Finney m…
R.P.C. Morgan*
Institute of Water and Environment, Cranfield University at Silsoe, Silsoe, B…
Received 18 April 2000; received in revised form 20 August 2000; accepte…


Journal of Hydrology (2008) 350, 290–302
available at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/jhydrol
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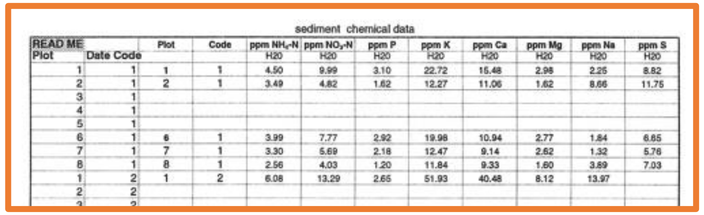
PSYCHIC — A process-based model of phosphorus and sediment mobilisation and delivery within agricultural catchments. Part 1: Model description and parameterisation
Paul S. Davison [a,*], Paul J.A. Withers [b], Eunice I. Lord [a], Mark J. Betson [a], Johan Strömqvist [a]

Erosion Model

Sediment loss

P in drainage, runoff

SOC, SON, SOP loss


sediment chemical data

READ ME Plot	Date Code	Plot	Code	ppm NH_4-N H20	ppm NO_3-N H20	ppm P H20	ppm K H20	ppm Ca H20	ppm Mg H20	ppm Na H20	ppm S H20
1	1	1	1	4.50	9.99	3.10	22.72	15.48	2.98	2.25	8.82
2	1	2	1	3.49	4.82	1.62	12.27	11.06	1.62	8.66	11.75
3	1										
4	1										
5	1										
6	1	6	1	3.99	7.77	2.92	19.98	10.94	2.77	1.84	6.65
7	1	7	1	3.30	5.69	2.18	12.47	9.14	2.62	1.32	5.76
8	1	8	1	2.56	4.03	1.20	11.84	9.33	1.60	3.89	7.03
1	2	1	2	6.08	13.29	2.65	51.93	40.48	8.12	13.97	
2	2										
3	2										

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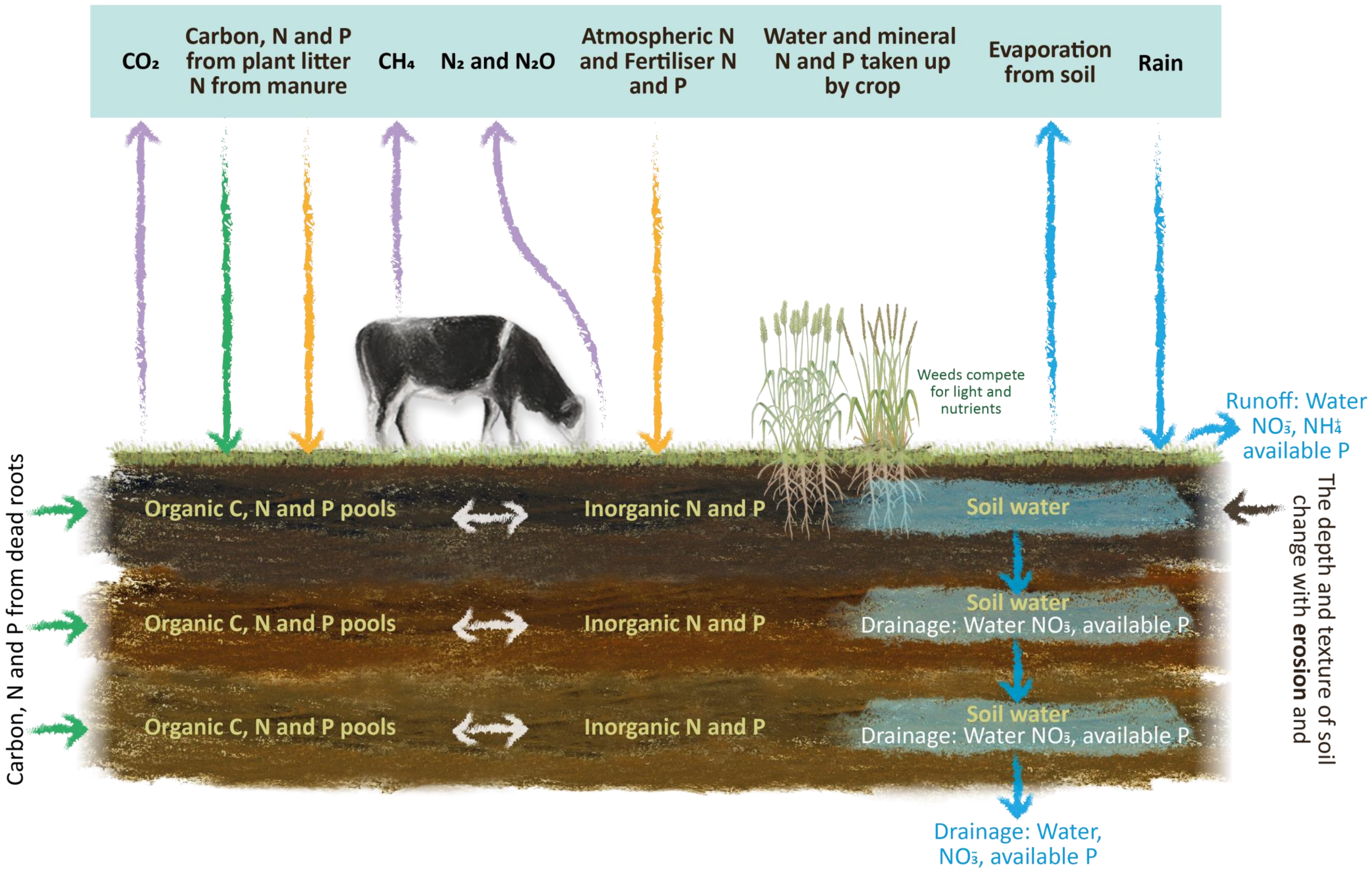

CO_2
Carbon, N and P from plant litter N from manure
CH_4
N_2 and N_2O
Atmospheric N and Fertiliser N and P
Water and mineral N and P taken up by crop
Evaporation from soil
Rain
Weeds compete for light and nutrients
Runoff: Water NO_3^-, NH_4^+ available P
Carbon, N and P from dead roots
Organic C, N and P pools
Inorganic N and P
Soil water
Organic C, N and P pools
Inorganic N and P
Soil water
Drainage: Water NO_3, available P
Organic C, N and P pools
Inorganic N and P
Soil water
Drainage: Water NO_3, available P
The depth and texture of soil change with **erosion** and
Drainage: Water, NO_3, available P

Conclusions

- Models allow us to consider multiple interactions under a large range of management strategies (although must be interpreted carefully)

- Used appropriately, models should allow sound conclusions to be drawn on the relative impact of management strategies and might highlight unintended consequences of certain actions.

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