RePhOKUs

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Global Food Security
Programme Activity: Resilience of the UK's Food System
E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL
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NERC SCIENCE OF THE ENVIRONMENT
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Riaghaltas na h-Alba

The Role of Phosphorus in the Resilience and Sustainability of the UK Food System

- RePhoKUs aims to refocus phosphorus use in the UK food system in order to improve efficiency and sustainability, and deliver valued ecosystem services such as clean water and biodiversity.

- The project brings together experts in catchment science, adaptive capacity, agricultural economics and food system vulnerability.

Developing Sustainable Food Systems

Security = All food system stakeholders have access to phosphorus to ensure soils are fertile, agriculture is productive, people have sufficient nutritious food, and rivers, lakes and oceans are clean.

Vulnerability = The degree to which a given food system is susceptible to harm due to the dimensions of global phosphorus scarcity (stresses and shocks).

Resilience to stresses and shocks =
Robustness – resist a disturbance
Recovery – recover naturally from a disturbance back to the same state
Reorientation – recovery to a different state – a transformation

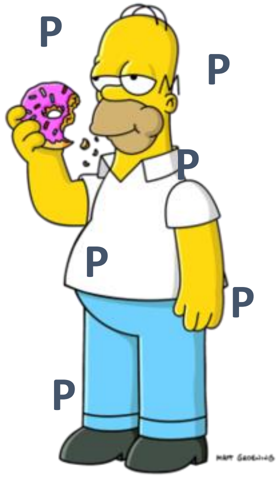
Why do we need to refocus P use?

The UK has no domestic source of P making it vulnerable to global P market shifts- **no one has previously evaluated this vulnerability nor have strategies to overcome this vulnerability been identified**

Do we have a secure source of P, will it become too expensive, or will reserves dwindle?

How efficient is our P use?

How sustainable is our P use?



Excess P in the diet is unnecessary and may cause health issues?

Compromising UK freshwaters (£37 billion), are there environmental constraints on P use?

Project Overview

Rationale

Improved P stewardship will reduce vulnerability to P shocks and increase the resilience and sustainability of the UK food system.

Overall objective

To enhance the resilience and sustainability of the UK food system by developing and prioritising adaptive strategies that reduce the vulnerability of UK farming to future P scarcity at multiple scales, and that enhance the balanced delivery of multiple ecosystem services for future food and water security.

Research Questions

- What are the key indicators of **P vulnerability** in the UK food system? What are the **risk pathways**?
- Which technical, agronomic and behavioural measures are most **appropriate** to increase food system resilience and at which scales?
- What is the **adaptive capacity** of UK food system stakeholders to transform to a sustainable phosphorus system?
- How can a transformed system be achieved?
  (what are the **transition pathways**?)
- What are the **barriers** and **opportunities**?
  (e.g. identify policy drivers to trigger action)
- Which measures are best implemented at **local/catchment scales**, and which at **national**?

Work Programme

Catchment scale

WP1 Geophysical Constraints

- Understanding catchment P buffering capacity
- Inventory of secondary P resources
- 5R P stewardship optimisation

WP2 Socioeconomic Constraints

- Adaptive capacity assessment
- Economic analysis of P stewardship
- Co-design 5R management options

National scale

WP3 UK Vulnerability Assessment

- Establish multi-actor platform
- Risk pathway analysis
- National adaptation strategy
- Knowledge transfer

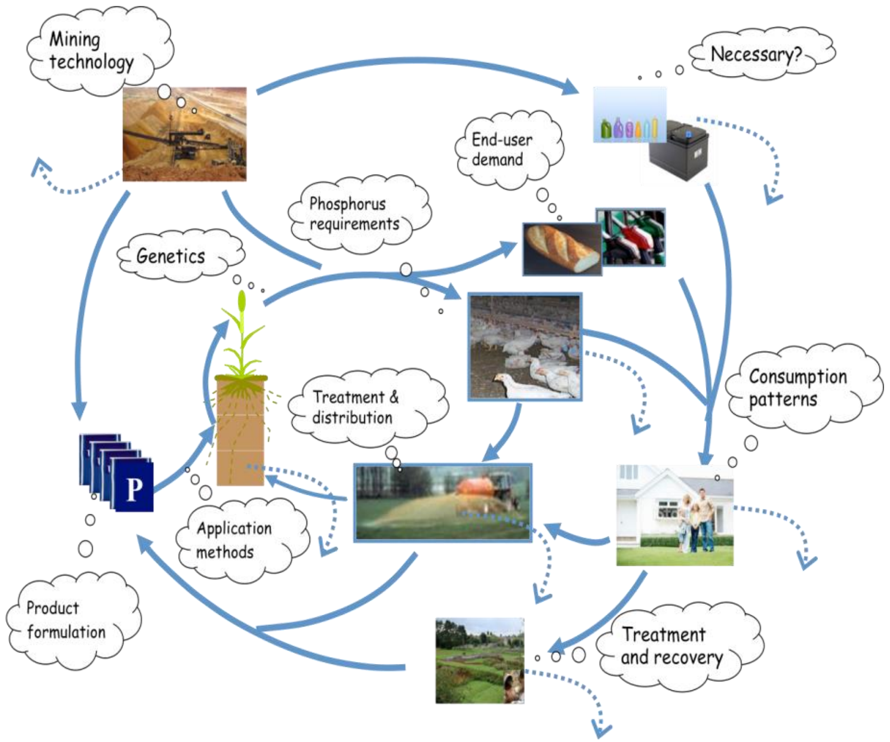
Multi scale

OUTPUT:

suite of strategies that are technically feasible, environmentally beneficial, socially acceptable, cost-effective and institutionally supported

Phosphorus Stewardship

P Circular Economy



Building on the principles of green chemistry:

- Developing benign systems
- Use of renewable materials
- Zero waste
- Use only what is necessary (output driven)

5R P Stewardship

Realign P inputs
- *remove non-essential P inputs (e.g.additives and detergents)*
- *match P inputs to P requirements more closely*
- *utilise legacy P stores*

Reduce P losses to water
- *optimise P input management*
- *minimise P loss in runoff and erosion*
- *deploy strategic P retention zones*

Recycle P in bio-resources
- *avoid wastage of P in the whole food chain*
- *improve P utilization efficiency*
- *integrate crop and livestock systems*

Recover P in wastes
- *recover P in societies' wastes*
- *produce P fertilizer substitutes*
- *improve manure transportability*

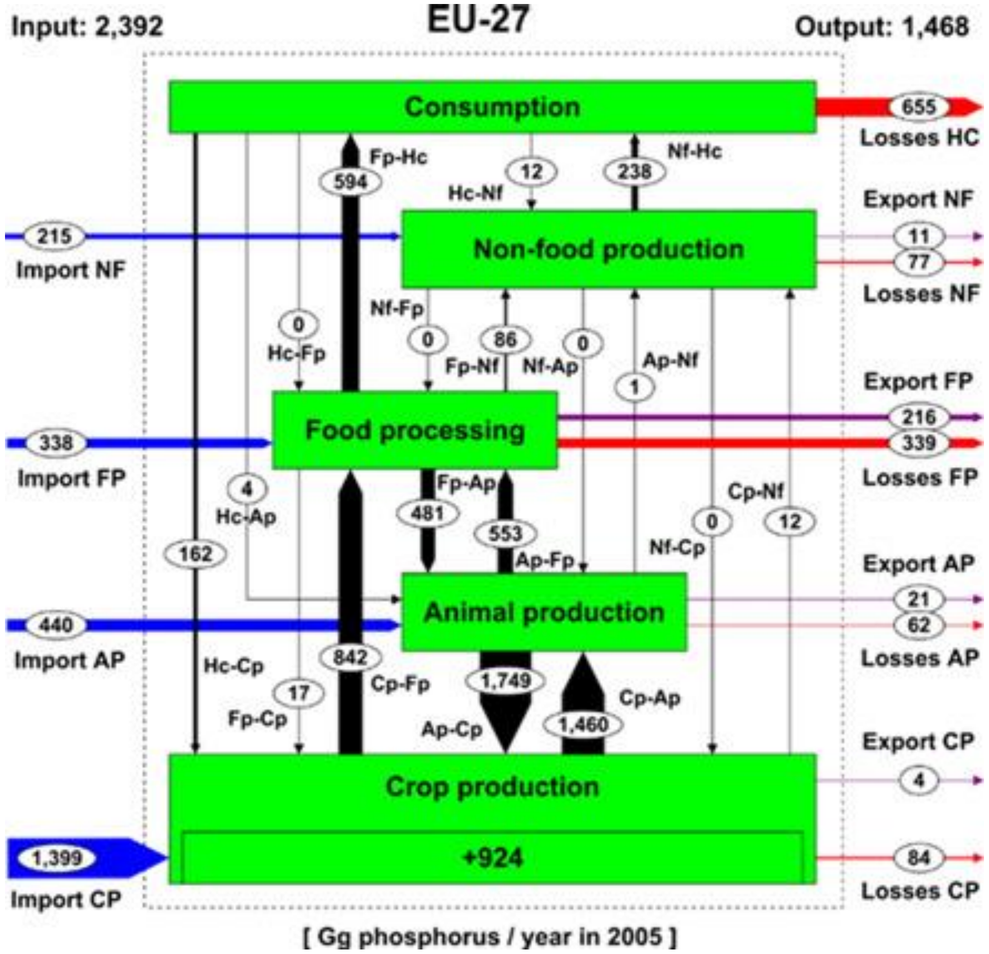
Redefine P in the food chain
- *influence dietary choice*
- *define end-user P requirements*
- *reduce P requirements by genetic engineering*

Withers et al. (2015)

Managing the Resilience of the Food System

Farm to Fork (P supply)

Landscape (food and water security)



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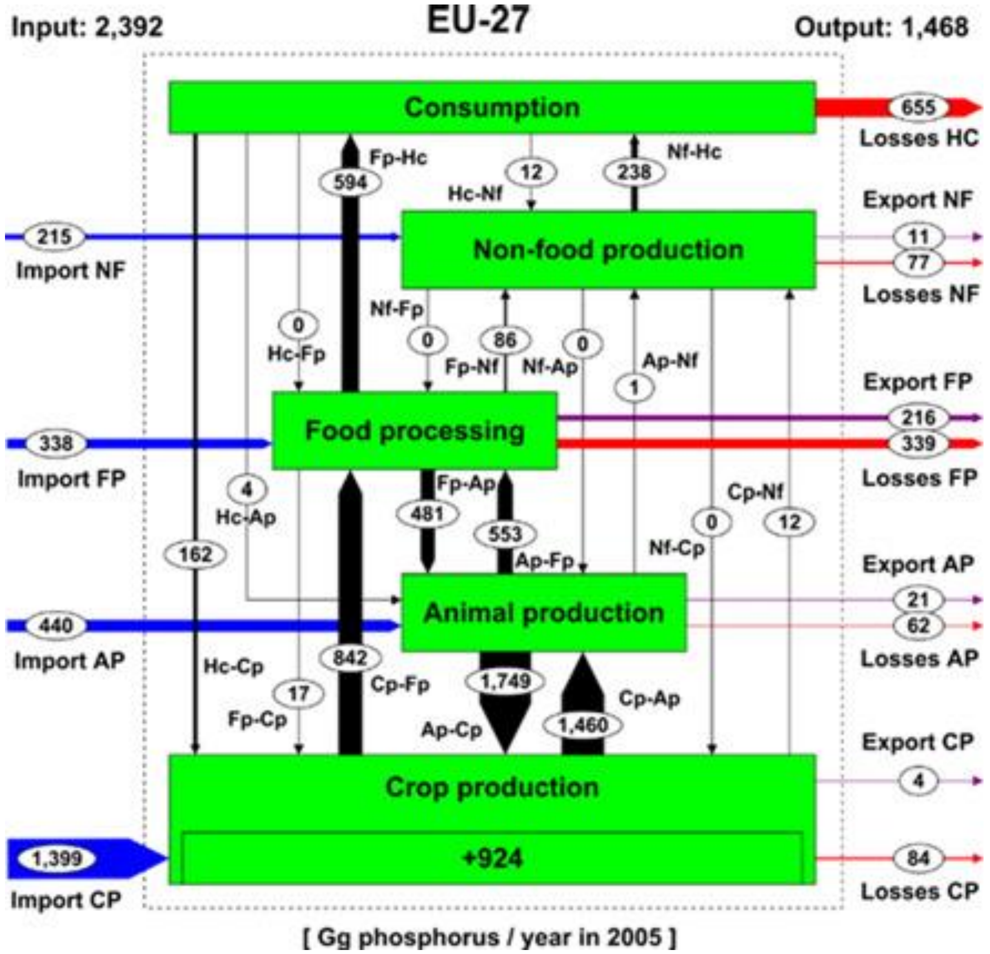
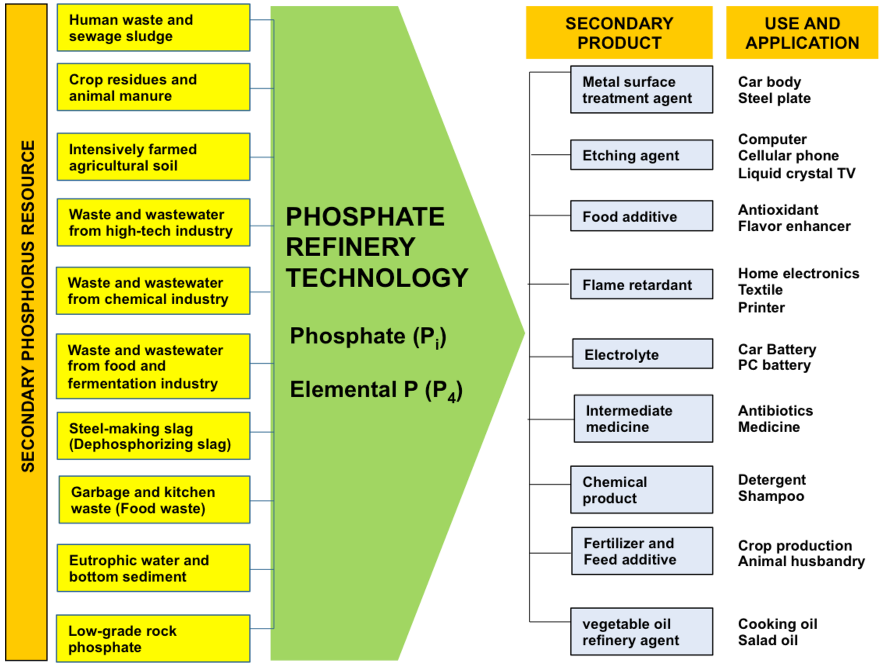
Van Dijk et al. (2016)

Secondary P Resources



The P Refinery

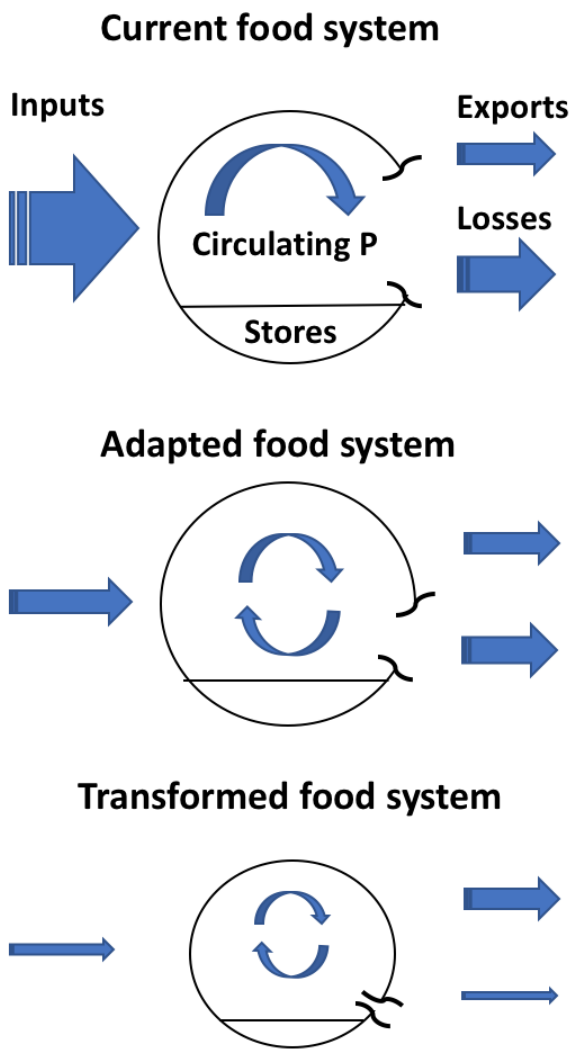
(Hisao and Ohtake, 2014)



Key aspects:

- P availability
- Other elements
- Consistency
- Affordability
- Contaminants
- Legislative constraints

Managing Food System Phosphorus



Assessing reactive P input requirement (PI):

$$PI = PD - (PS + PR)/PE$$

System momentum governs P demand (PD) – circulating P

requires co-optimisation of all resources (not just P)

System stores govern the soil P supply (PS))

requires legacy soil P management and prediction

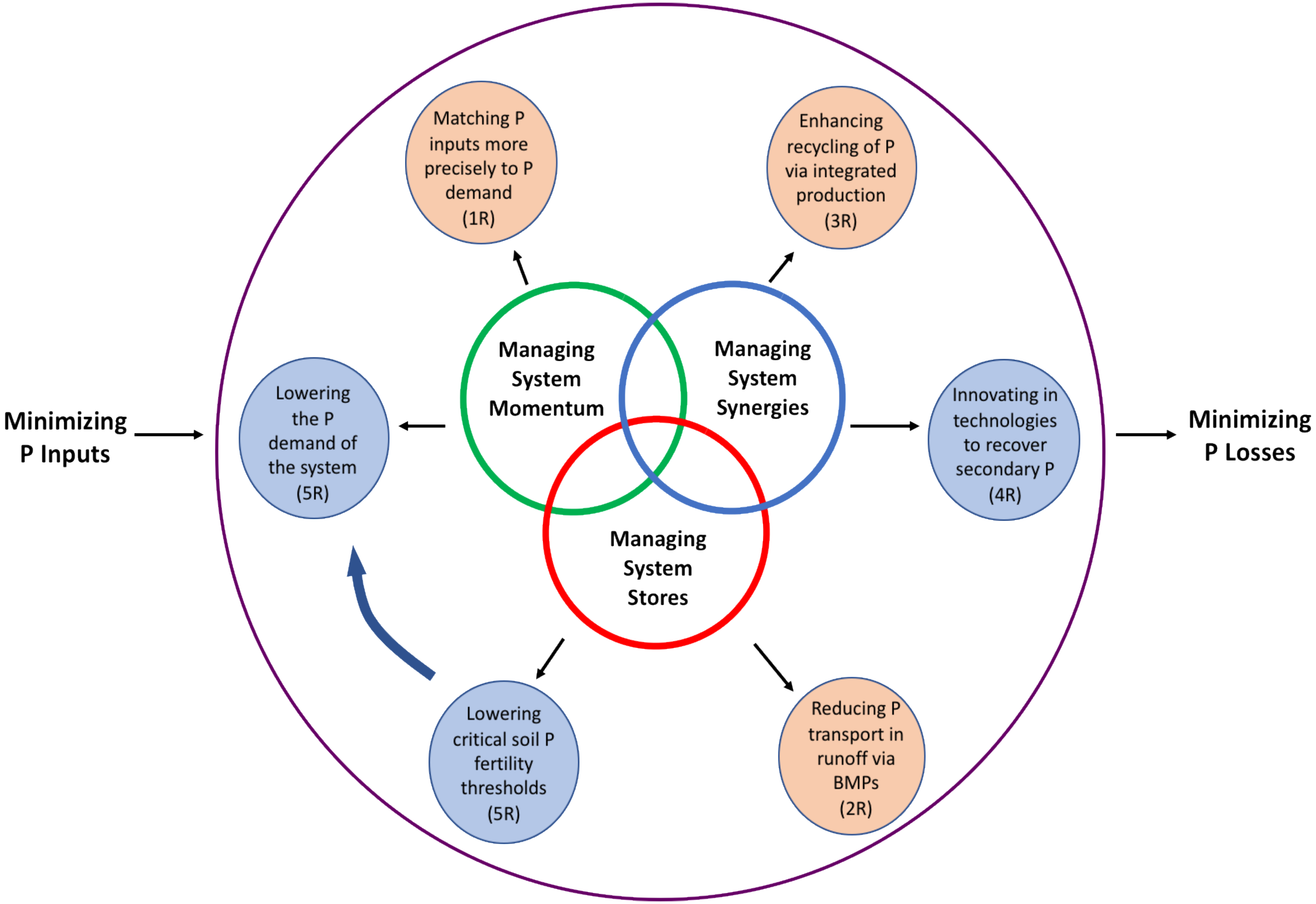
System synergies govern access to recyclable P (PR)

requires recovery technologies and integrated farming practices

Withers et al. (2018)

PE – efficiency of applied P

Managing Food System Phosphorus



The principle of minimisation is key to successful implementation of the P circular economy

Withers et al. (2018)

Assessing P Adaptations and Transformations

BAU – Business as usual

Option 1 – Recover 50% of point P

Option 2 – Reduce P demand by 25%

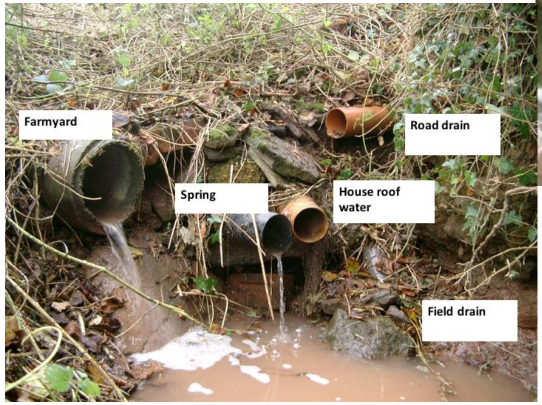
Option 3 – Reduce soil STP by 50%

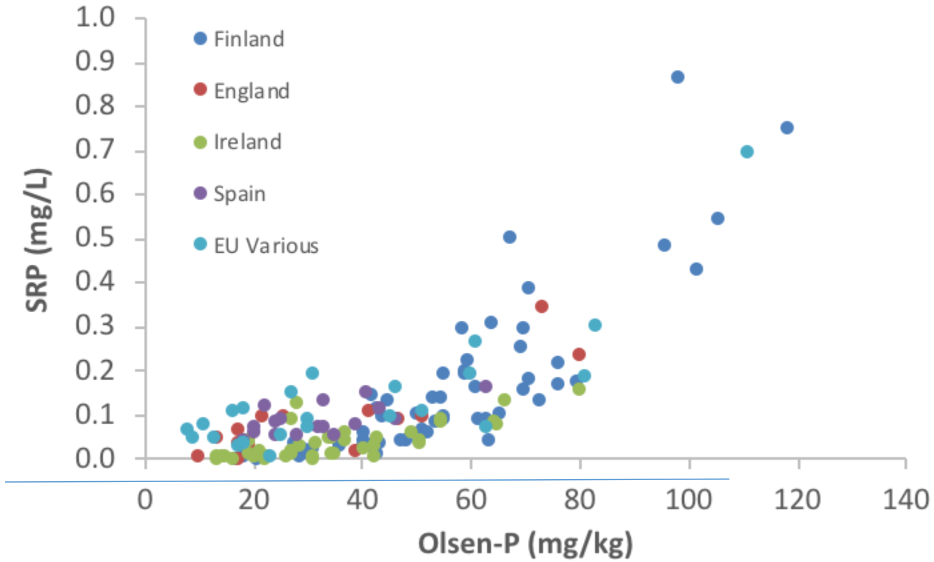
Option 4 - Options 1, 2 and 3

P flow (Gg)	BAU	Option 1	Option 2	Option 3	Option 4
Total P inputs	2392	1895	2063	1832	1141
Circulating P	5961	6458	4710	5961	5133
New stored P	924	924	810	420	360
Recycled P	1928	2425	1573	1928	1996
Total P losses	1217	720	1030	1160	573
Inputs as % of circulating P	40	29	44	31	22
Losses as % of circulating P	20	11	22	20	11

Recovery and recycling does not reduce surplus P in the system and increases the amounts of P circulating! Need to consider ***minimisation*** of P inputs

Legacy Stores of Phosphorus



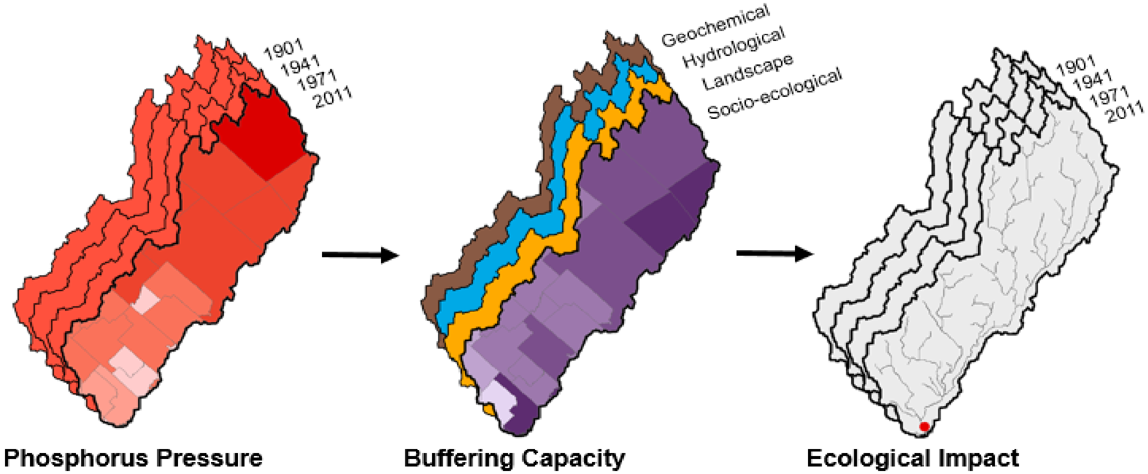


System P stores and circulating P are important sources of P loss to water

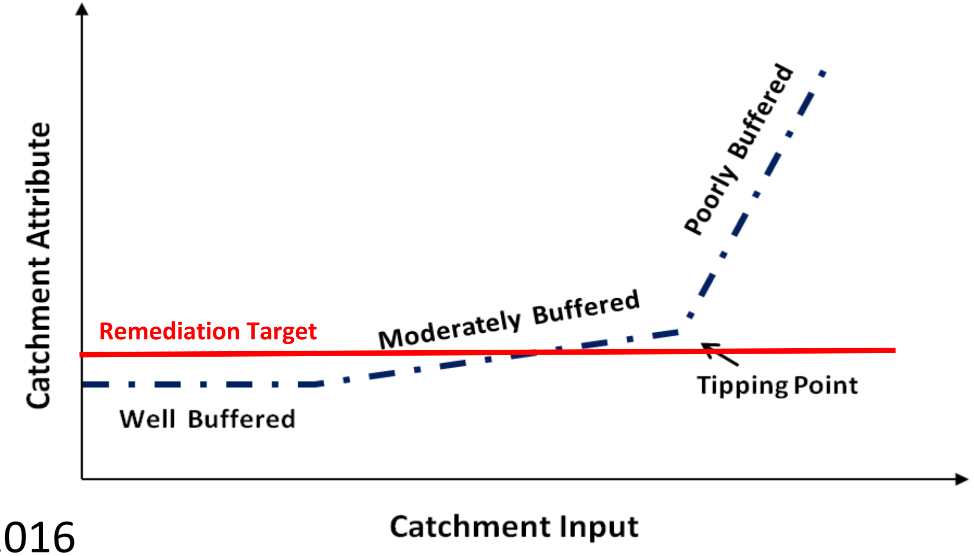
These stores take a long time to draw down

Environmental Vulnerability

Eutrophication Impact

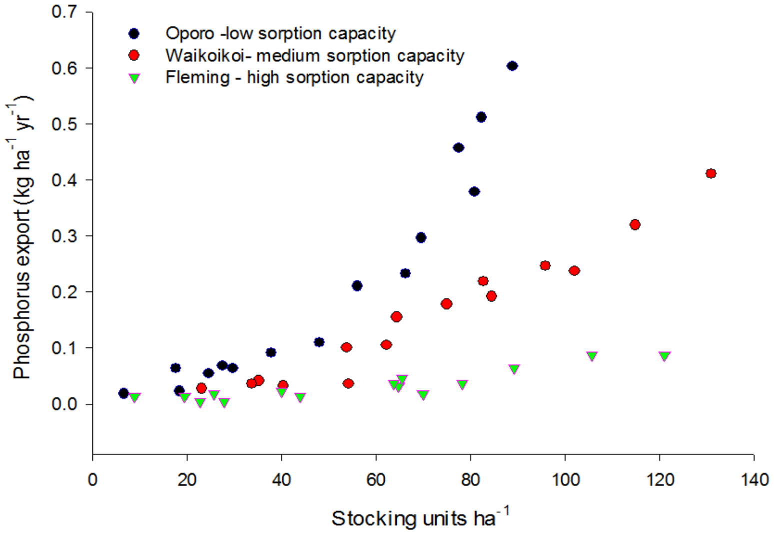


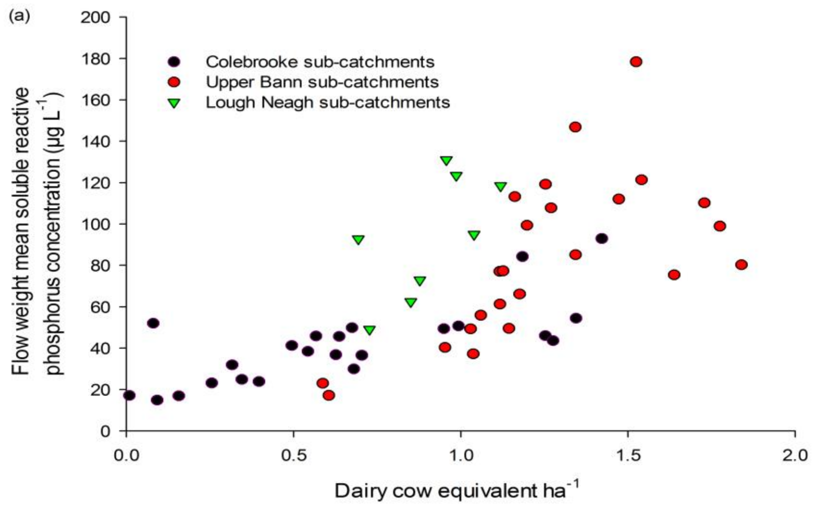
Kusmer et al. (2018)

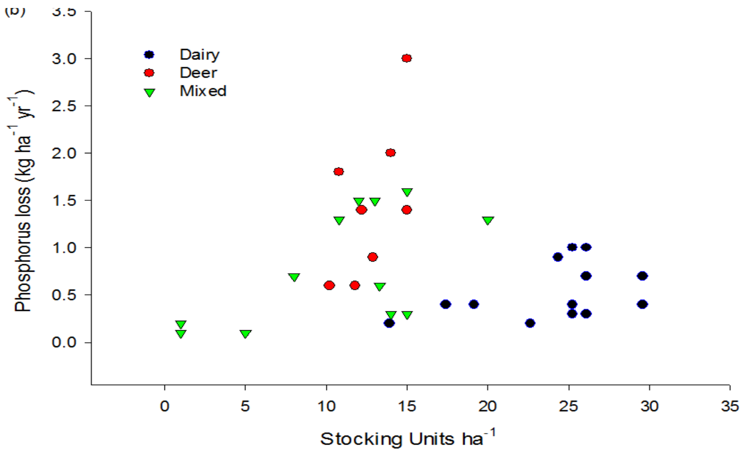


Doody et al. 2016

Catchment Heterogeneity

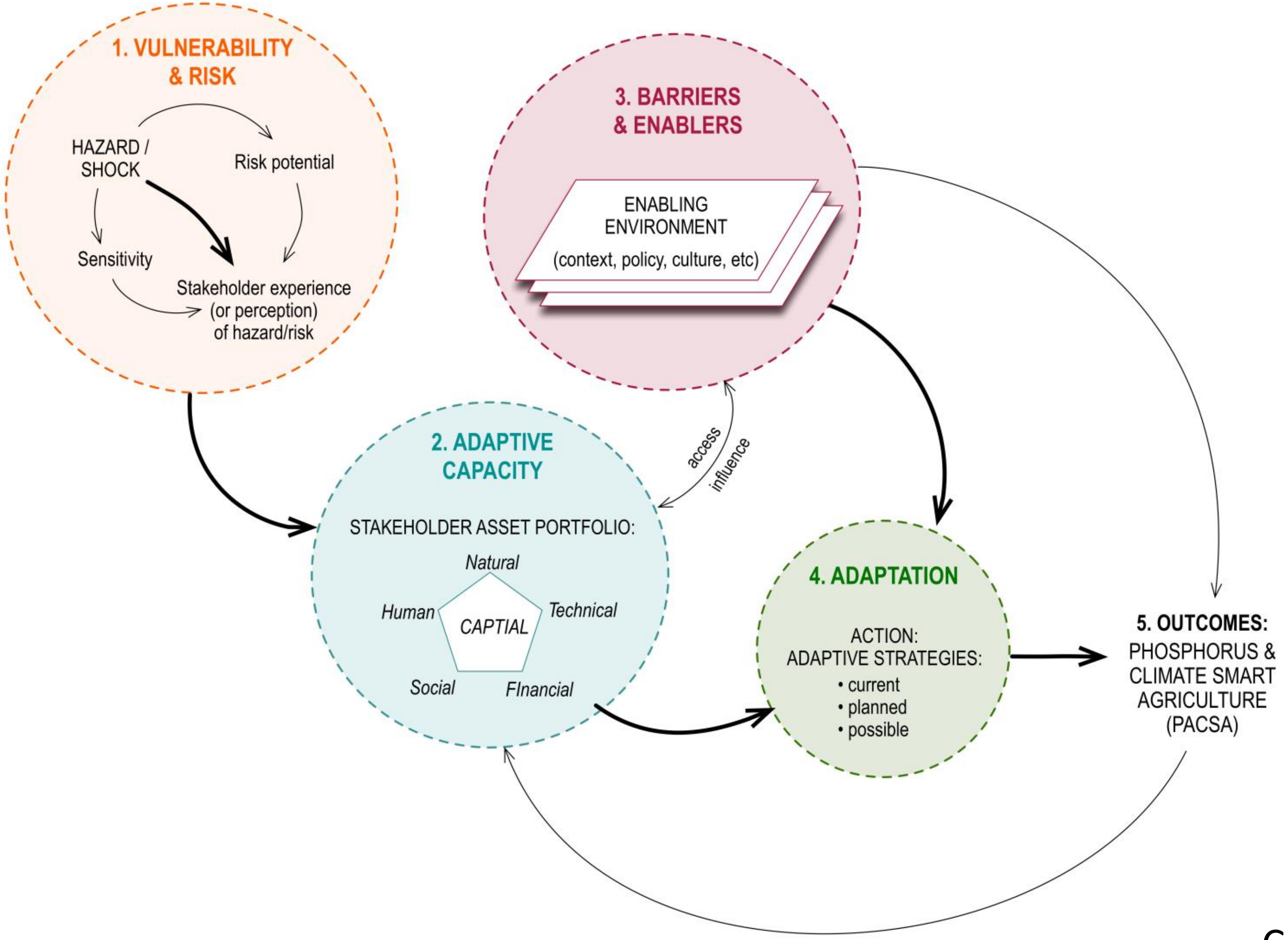






Sustainable intensification may not be compatible with acceptable water quality in all areas, but should be more feasible in well-buffered catchments!

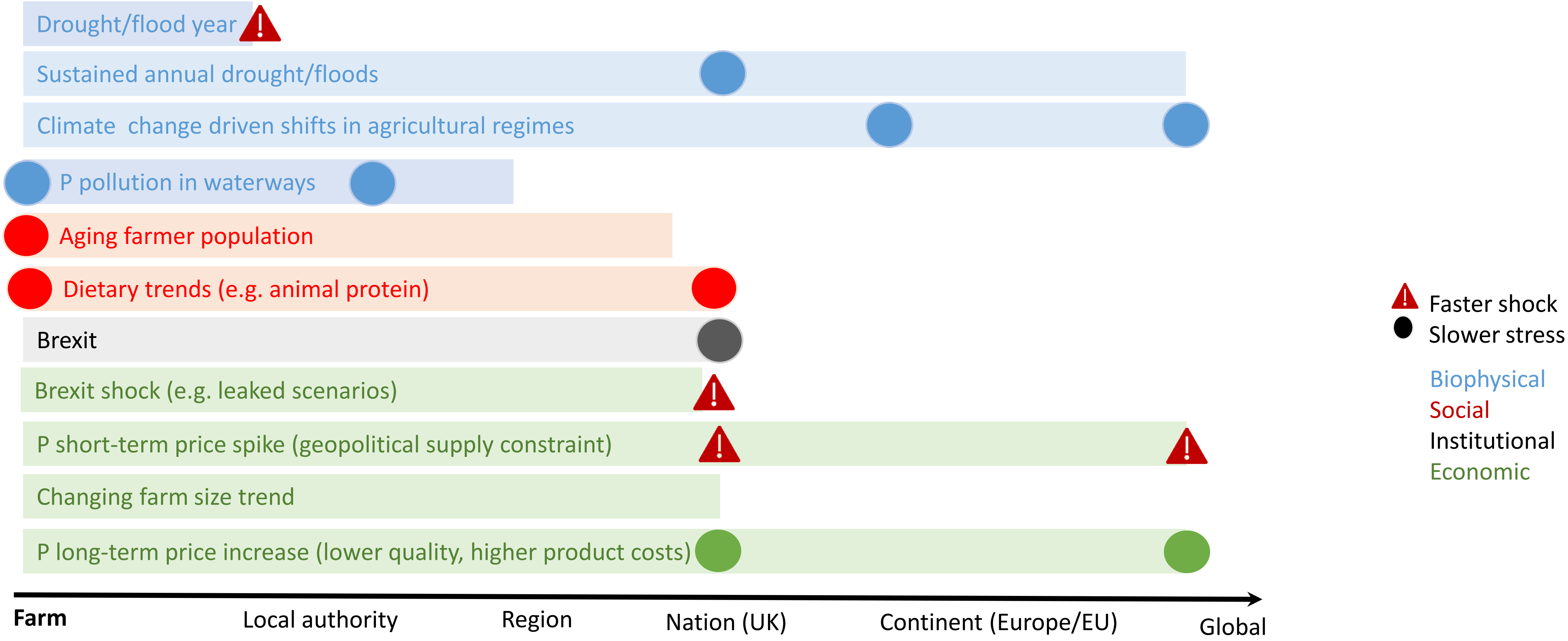
Vulnerability Assessment



Cordell et al. 2017 – Sri Lanka

Phosphorus shocks and stresses

- The UK food system is exposed to phosphorus **shocks** (fast changes) & **stressors** (slow changes)
- Where the shock occurs (⚠ or ●), is not necessarily where **impact** will be felt (transmission of impacts across other scales & sectors in the phosphorus value chain)

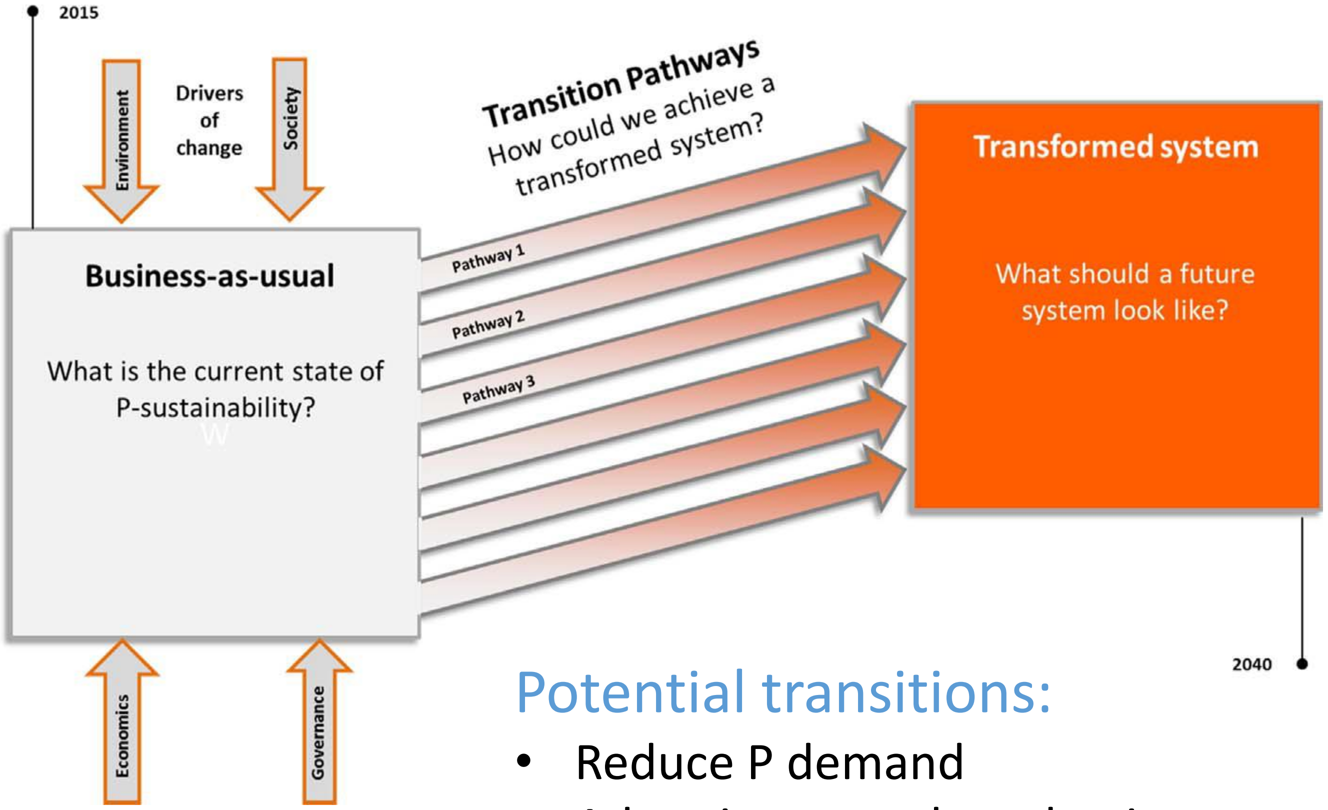


Adapted from Cordell et al (2015)

Stakeholder realm of influence & responsibility

- Where the risks occur (inside/outside UK food system), has implications for whether UK stakeholders have agency to **mitigate** risks, or simply facilitate **adaptation** to stressors and shocks, e.g.:
    - UK stakeholders cannot influence **international market price**, but can support market access to local renewable fertilisers
    - UK stakeholders can influence **dietary trends** to reduce UK demand for imported P
- Stakeholders’ power to influence adaptation varies, e.g. **structural** power, **innovative** power, **antagonistic** power, **synergistic** power, **invisible** power (Avelino & Rotmans 2011, Brisbois & de Loë 2016, Gaventa 2006)
- Similarly, stakeholders’ ‘**interest**’ can be aligned with or opposing adaptive strategies (e.g. waste managers may wish to recover energy from food waste, which can be aligned with recovering P from same process, e.g. AD)

Transformative Change



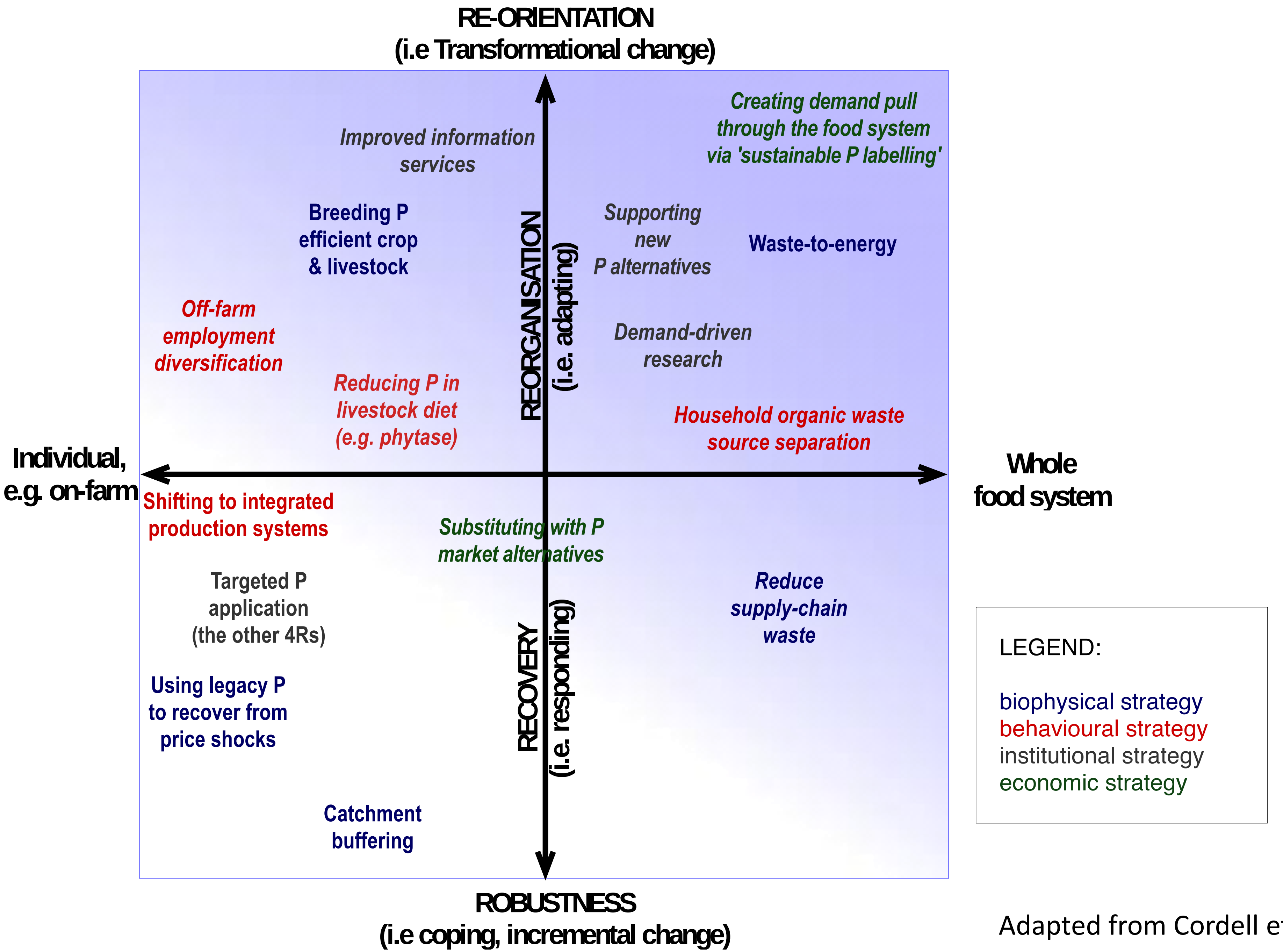
Jacobs et al. (2017)

Potential transitions:

- Reduce P demand
- Adopt integrated production systems
- Use secondary P resources
- Promote dietary change
- Governance beyond the farm gate

Challenges

- Highly dispersed industries operating at variable scales
- Stakeholders have different perceptions of sustainability
- Lack of awareness of the phosphorus nexus and role of food choice
- No regulatory driver for more efficient P use
- Historic practices and behaviours hard to change



Adapted from Cordell et al (2017)

Ignoring the P sustainability challenge may destabilise the resilience of the UK food system, and conversely, addressing it creates significant opportunities to buffer against future risks in the longer-term, and increase agricultural productivity in the short-term.

http://wp.lancs.ac.uk/rephokus/

RePhOKUs

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WHY IS PHOSPHORUS IMPORTANT?