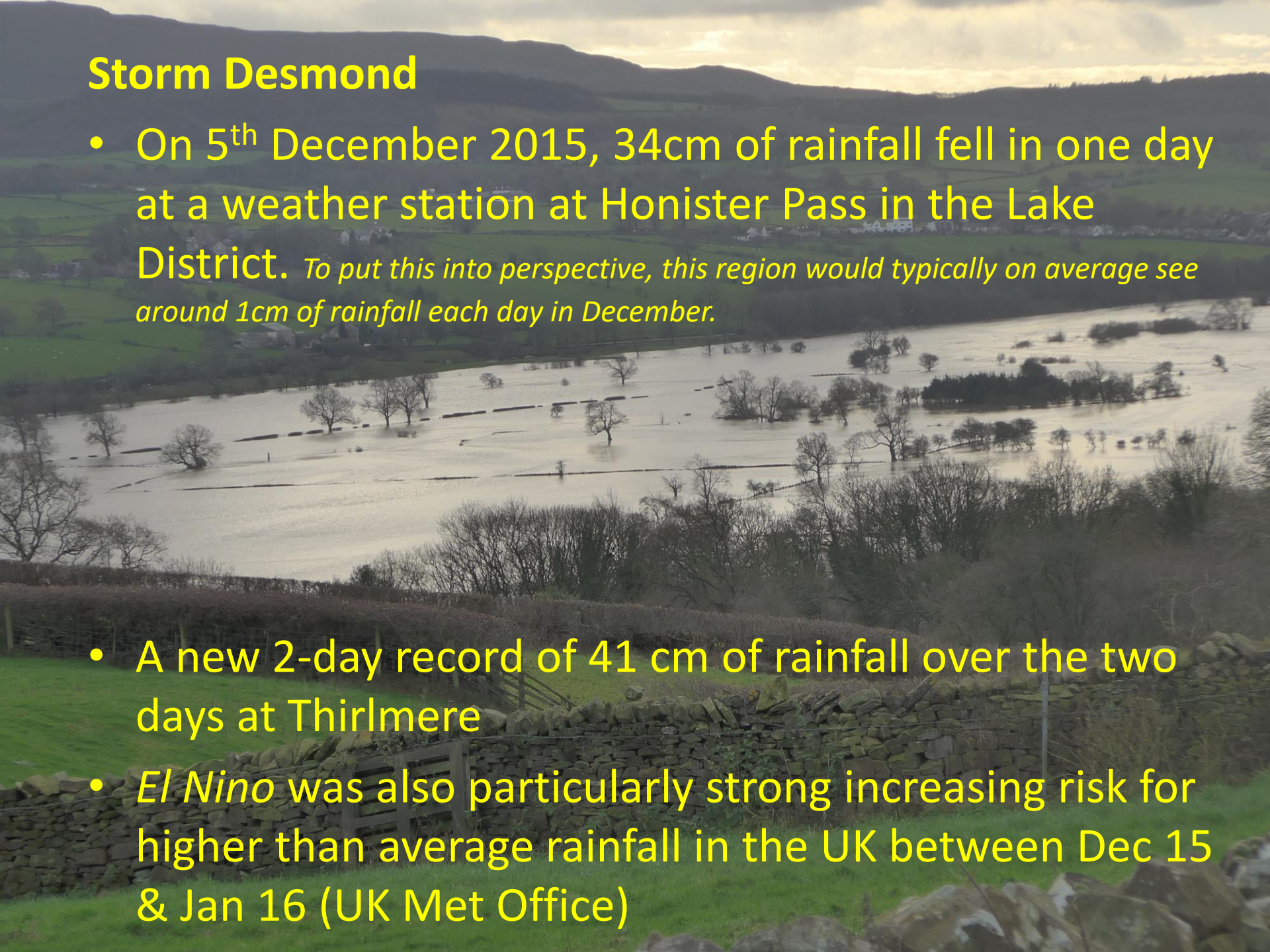
@ProfPHaygarth
#stormdesmond

Prof Phil Haygarth @ProfPHaygarth · 5 Dec 2015



Storm Desmond

- On 5th December 2015, 34cm of rainfall fell in one day at a weather station at Honister Pass in the Lake District. *To put this into perspective, this region would typically on average see around 1cm of rainfall each day in December.*

- A new 2-day record of 41 cm of rainfall over the two days at Thirlmere
- *El Nino* was also particularly strong increasing risk for higher than average rainfall in the UK between Dec 15 & Jan 16 (UK Met Office)

Environment Centre | Lancaster University

Building Soil and Watershed Resilience in a Changing Climate

@ProfPHaygarth

@EdenDTC

landwaterblog.blogspot.com

Prof Phil Haygarth @ProfPHaygarth · 5 Dec 2015
Wading home through the Keer

FOOD

FOOD depends on the PHOSPHORUS cycle

source: wikimedia commons

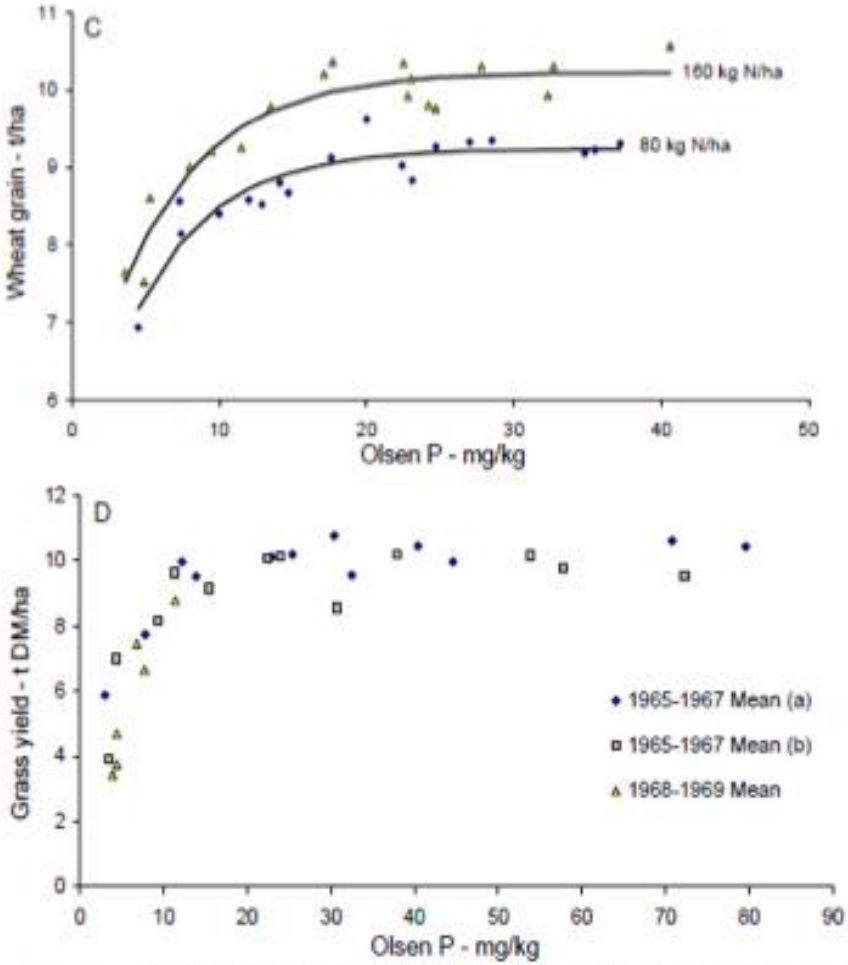


Figure 5: *Relationship between Olsen P and the yield of three arable crops and of grass. (Johnston, 2001; Johnston et al., 2001a).*

Environment Centre | Lancaster University

A Turning Point in the Phosphorus Cycle?

@ProfPHaygarth

@EdenDTC

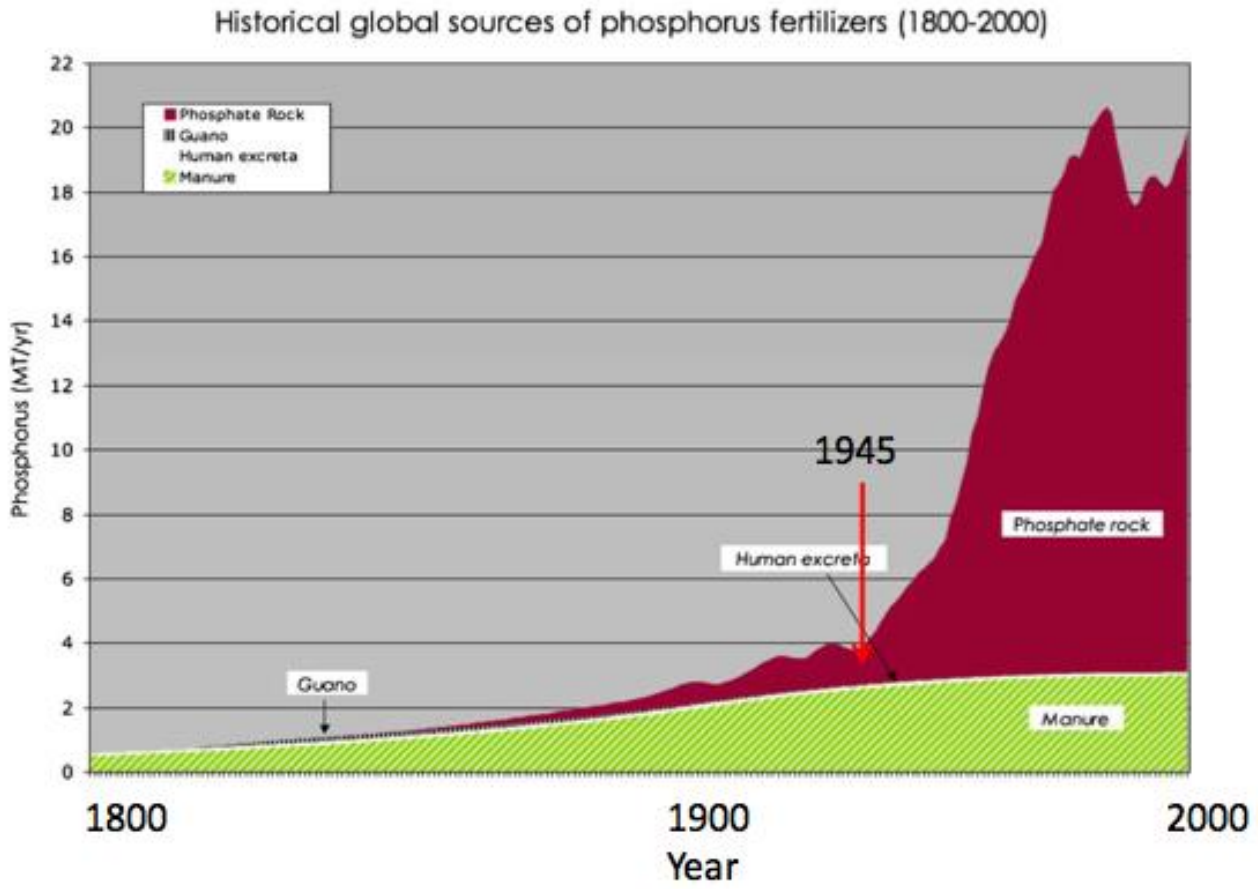
landwaterblog.blogspot.com


Yunnan Province, China, August 2016


磷矿粉
phate ore powder
股份|云南磷化集团有限公司
酸法矿
Ore used for wet-process phosphoric acid
云天化股份|云南磷化集团有限公司
黄磷矿
Ore used for yellow phosphorus
云天化股份|云南磷化集团有限公司
浮选
Flotation pho

The Green (P) Revolution!

Showing the global expansion of phosphorus fertilizer production



Cordell et al, "The Story of Phosphorus: Global Food Security and Food for Thought," *Global Environmental Change* (2009): 293. Web. 1 May 2011

Peak phosphorus supplies?

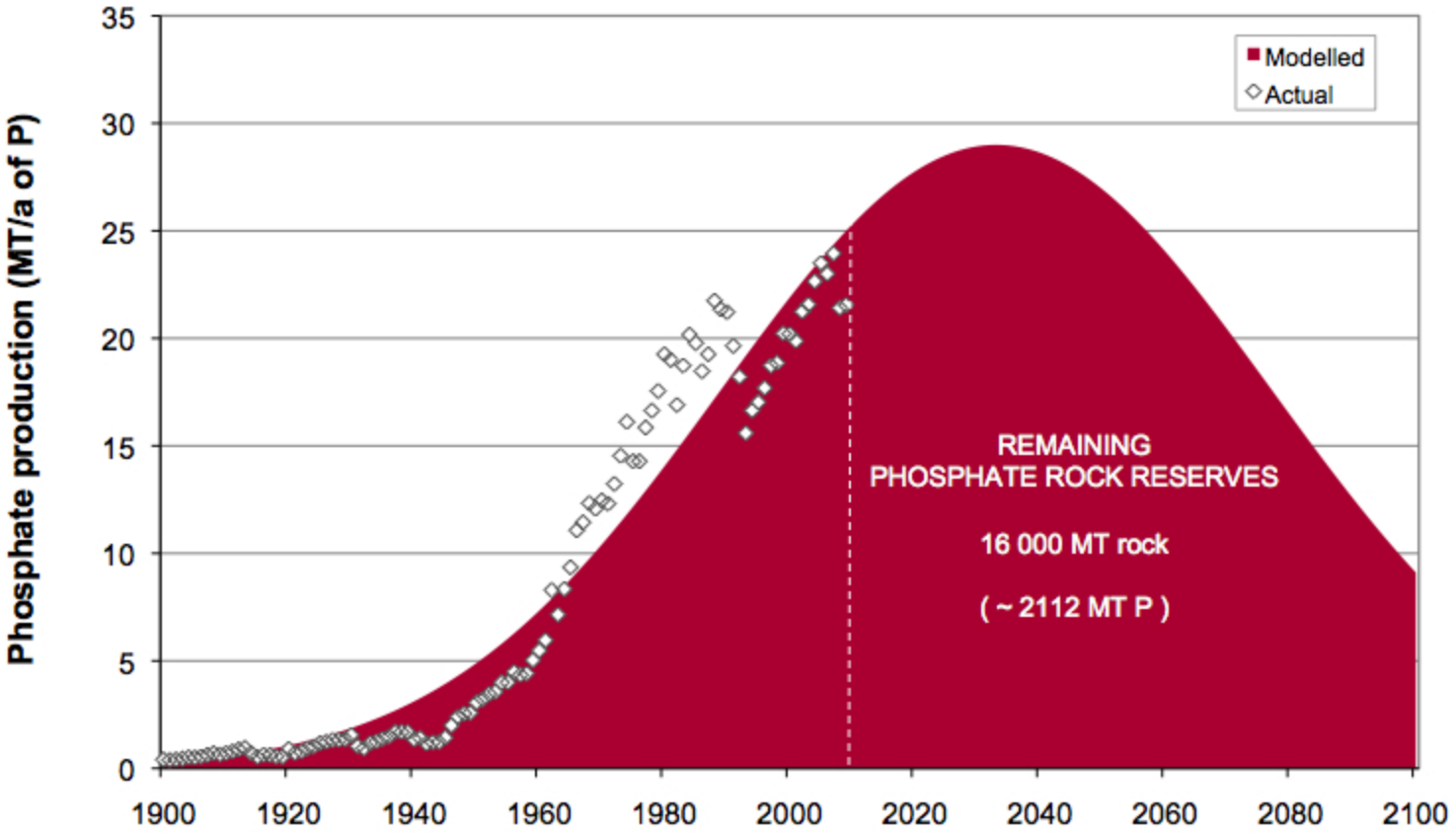
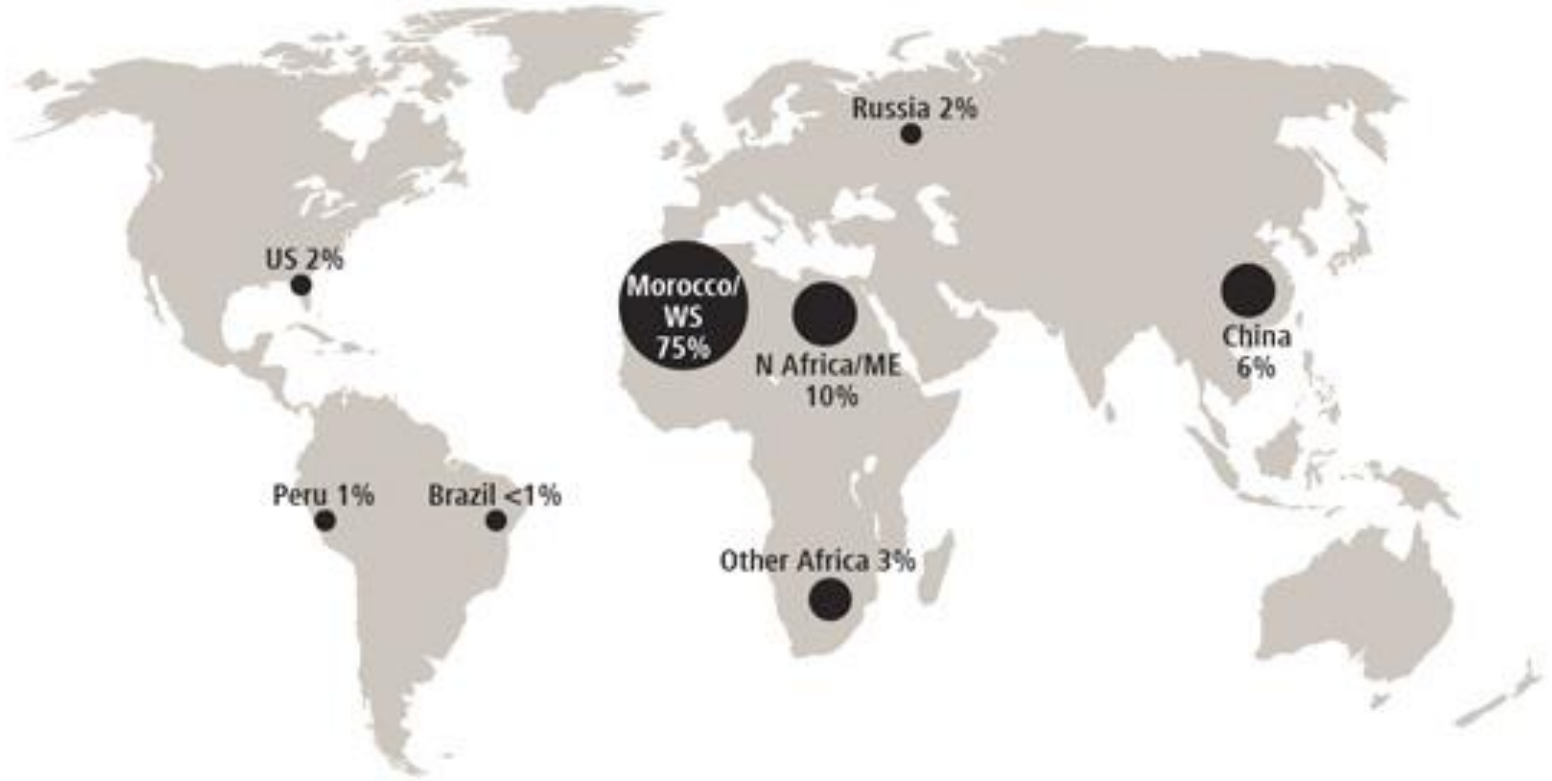


Figure Peak phosphorus curve indicating a peak in production by 2033, derived from US Geological Survey and industry data. Cordell and White (2011) Sustainability, 3, 2027-2049.

Geo-political uncertainties with phosphorus supply

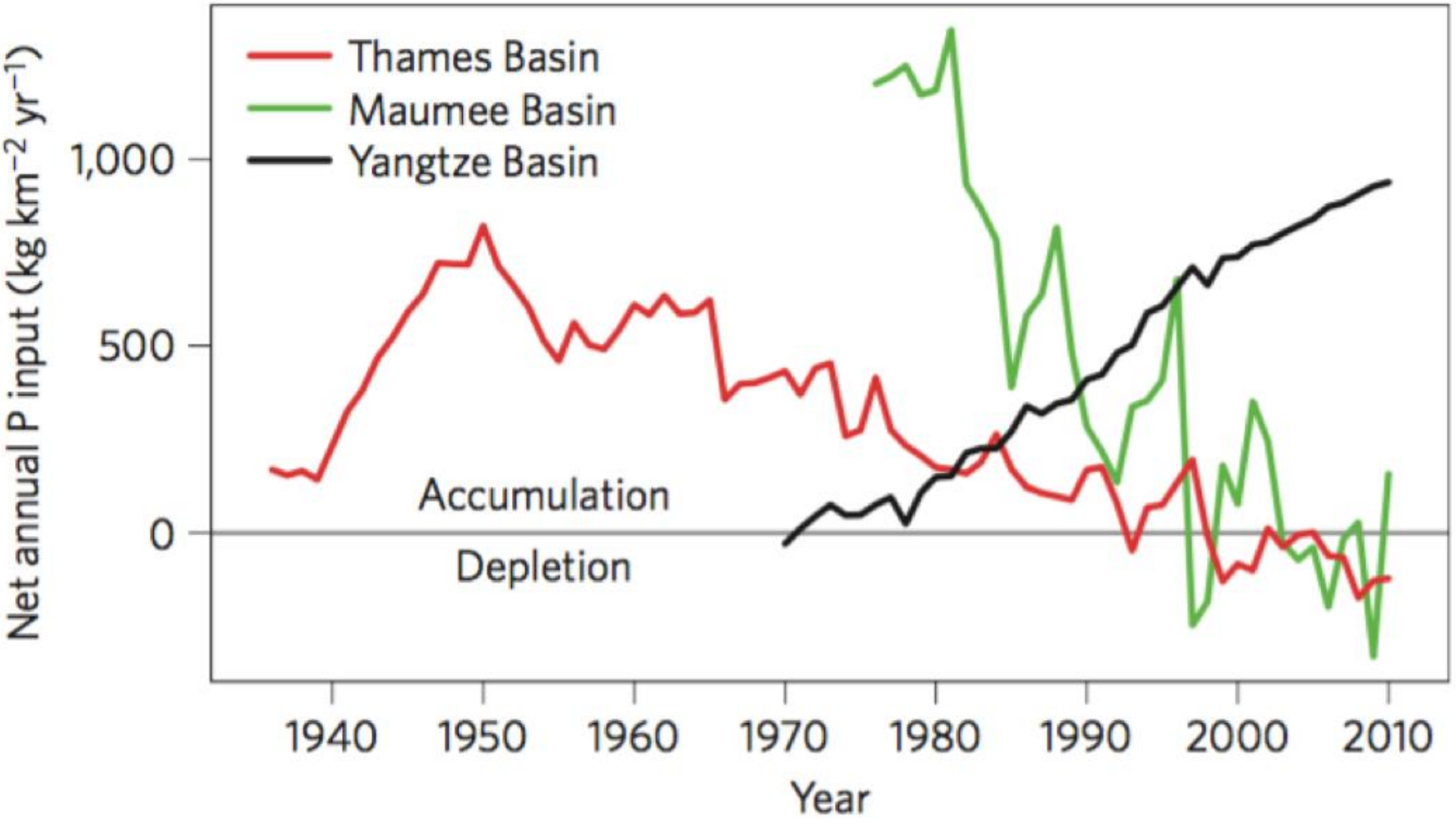


World P reserves

http://www.potashcorp.com/overview/upload/nutrients/phosphate/02-N_Pov_World-Phosphate-Rock-Production-and-Demand.jpg

Long-term accumulation and transport of anthropogenic phosphorus in three river basins

nature geoscience
LETTERS
PUBLISHED ONLINE: 11 APRIL 2016 | DOI: 10.1038/NGEO2693



Stephen M. Powers[1]*, Thomas W. Bruulsema[2], Tim P. Burt[3], Neng Iong Chan[4], James J. Elser[4], Philip M. Haygarth[5], Nicholas J. K. Howden[6], Helen P. Jarvie[7], Yang Lyu[8], Heidi M. Peterson[9], Andrew N. Sharpley[10], Jianbo Shen[8], Fred Worrall[11] and Fusuo Zhang[8]

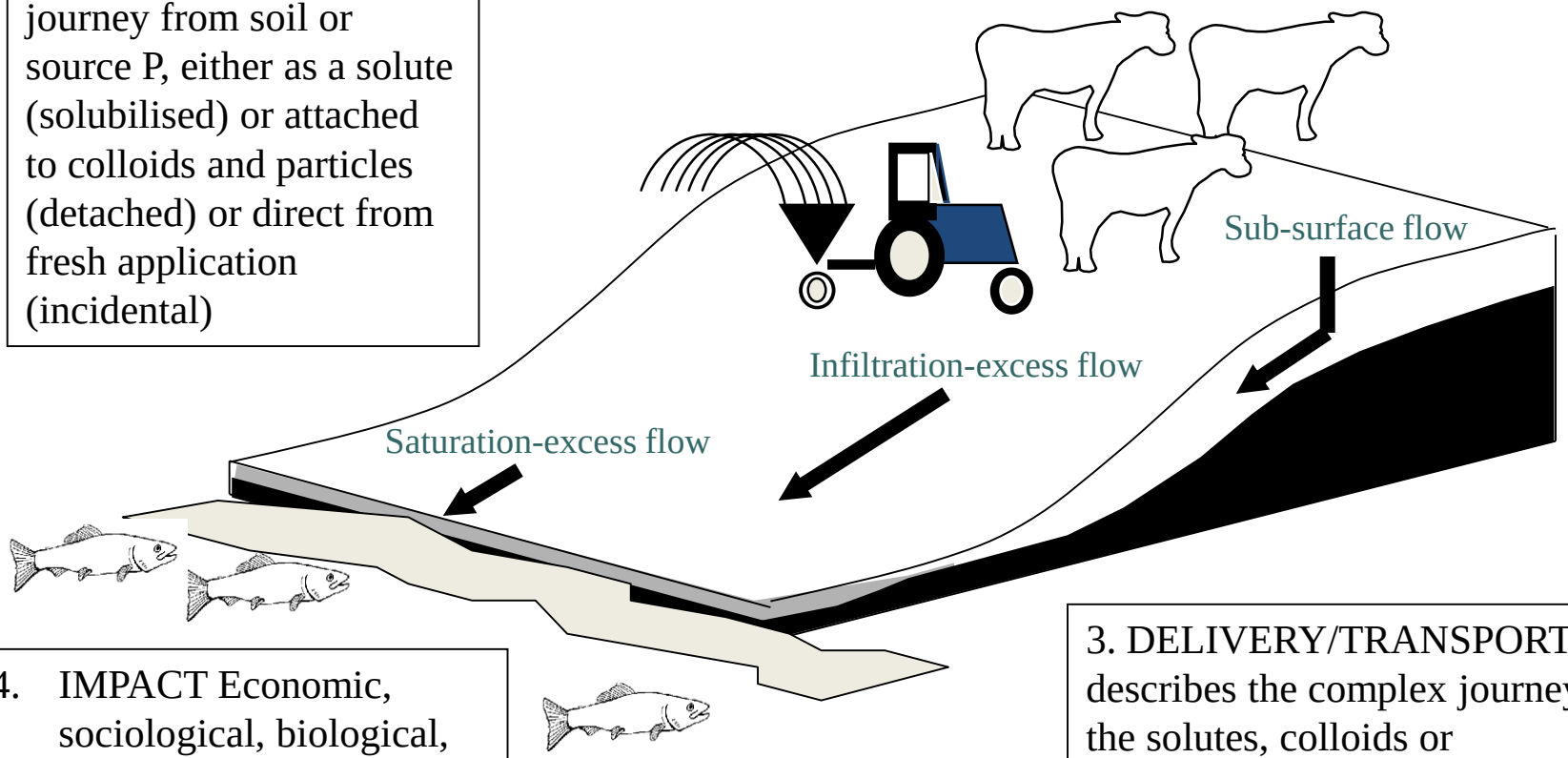
Aquatic plants *also like*

PHOSPHORUS....

The Phosphorus 'transfer continuum' (Haygarth et al., STOTEN, 344, 2005)

1. SOURCES include fertilizer applications, feed input to animals

2. MOBILISATION describes the start of the journey from soil or source P, either as a solute (solubilised) or attached to colloids and particles (detached) or direct from fresh application (incidental)



3. DELIVERY/TRANSPORT describes the complex journey the solutes, colloids or particles take after mobilisation to connect to the stream

4. IMPACT Economic, sociological, biological, ecological

Framework for understanding substance transfer to water from agriculture - the 'transfer continuum' (Haygarth et al., STOTEN, 344, 2005)

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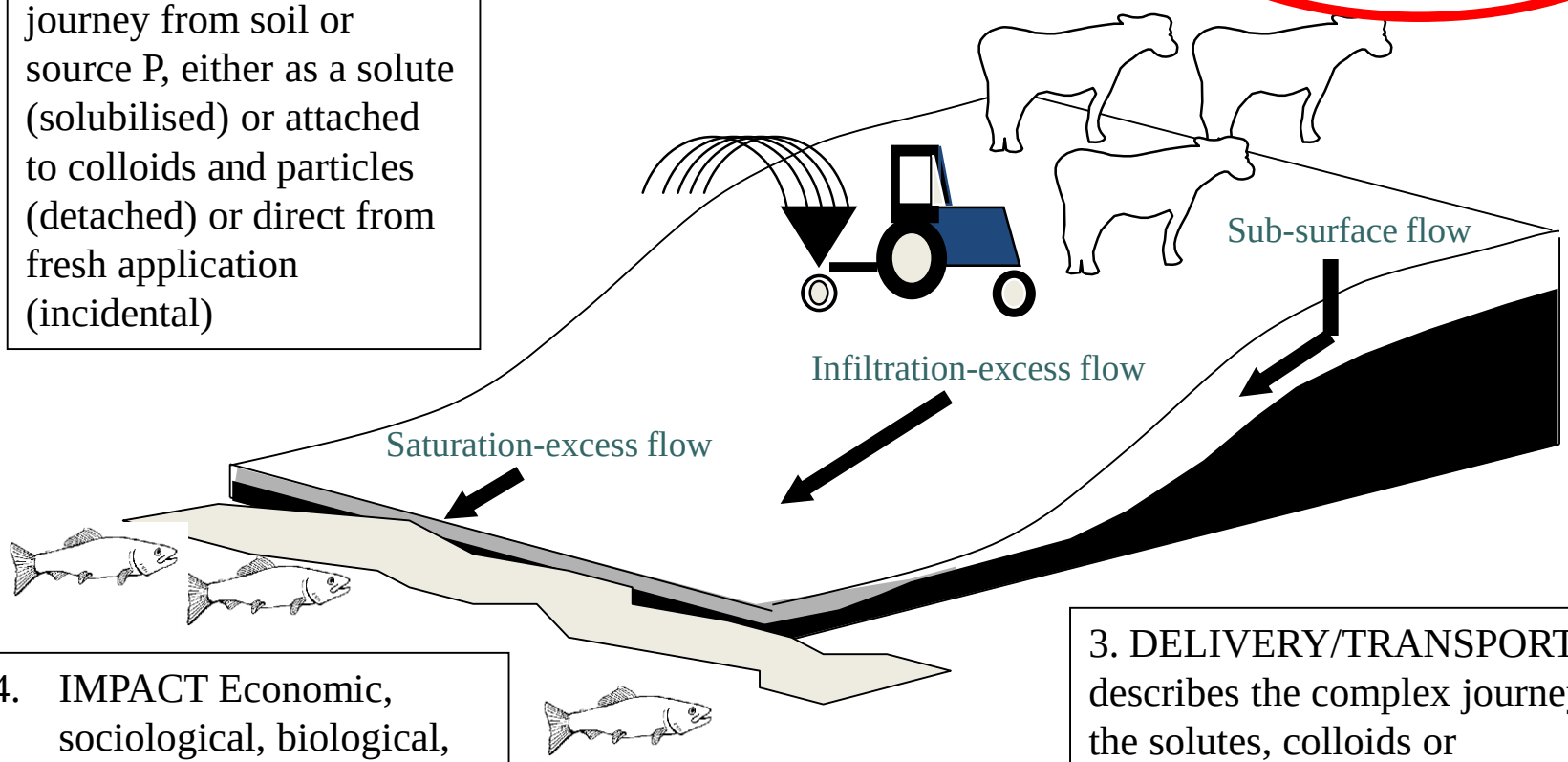

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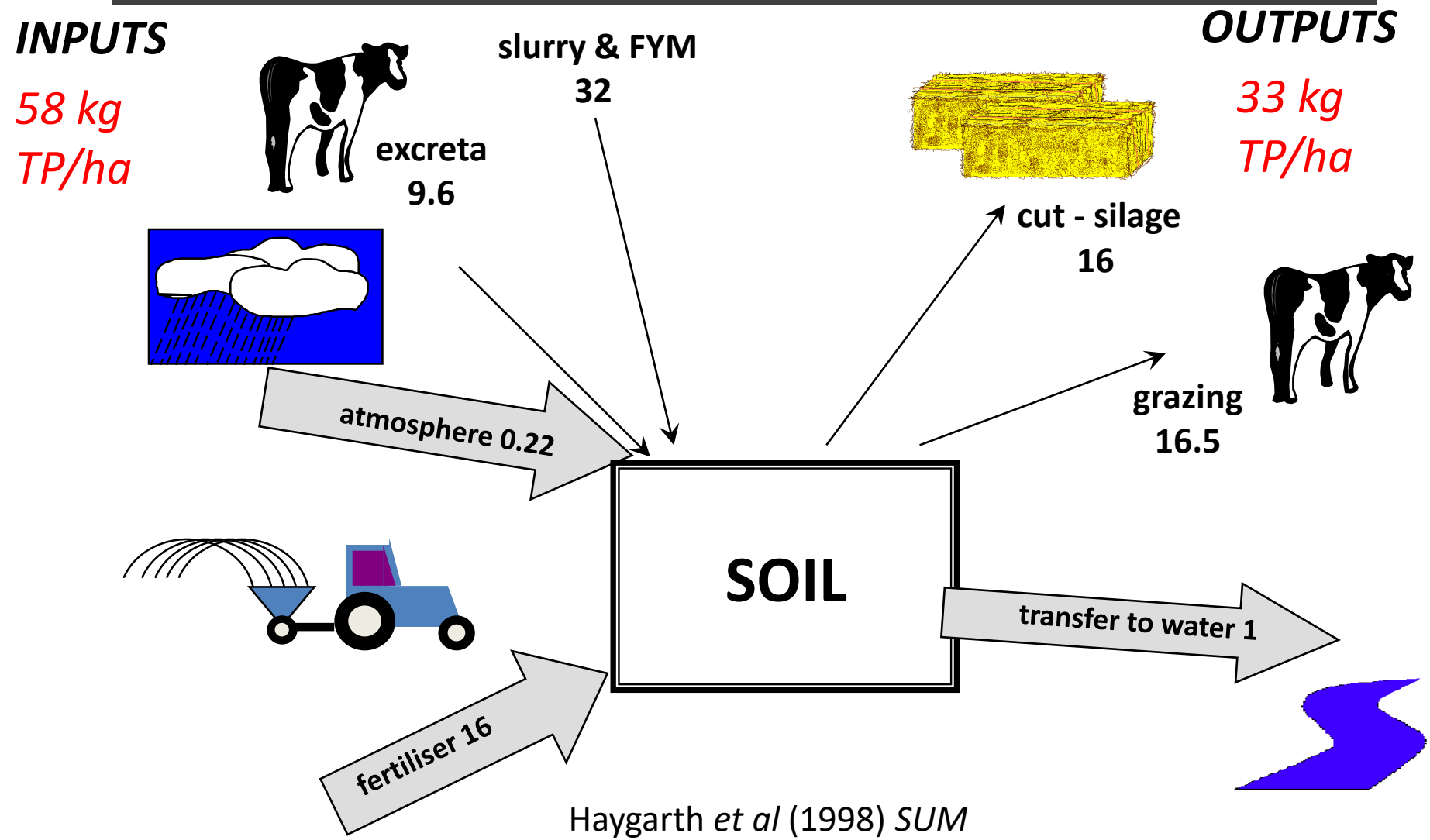
饲料添加剂
饲料级磷酸二氢钙
云天化
净含量：50KG
云南磷化集团有限公司
3

Phosphorus balance in a UK dairy farm *ca.* 2000



Haygarth *et al* (1998) *SUM*

Framework for understanding substance transfer to water from agriculture - the 'transfer continuum' (Haygarth et al., STOTEN, 344, 2005)

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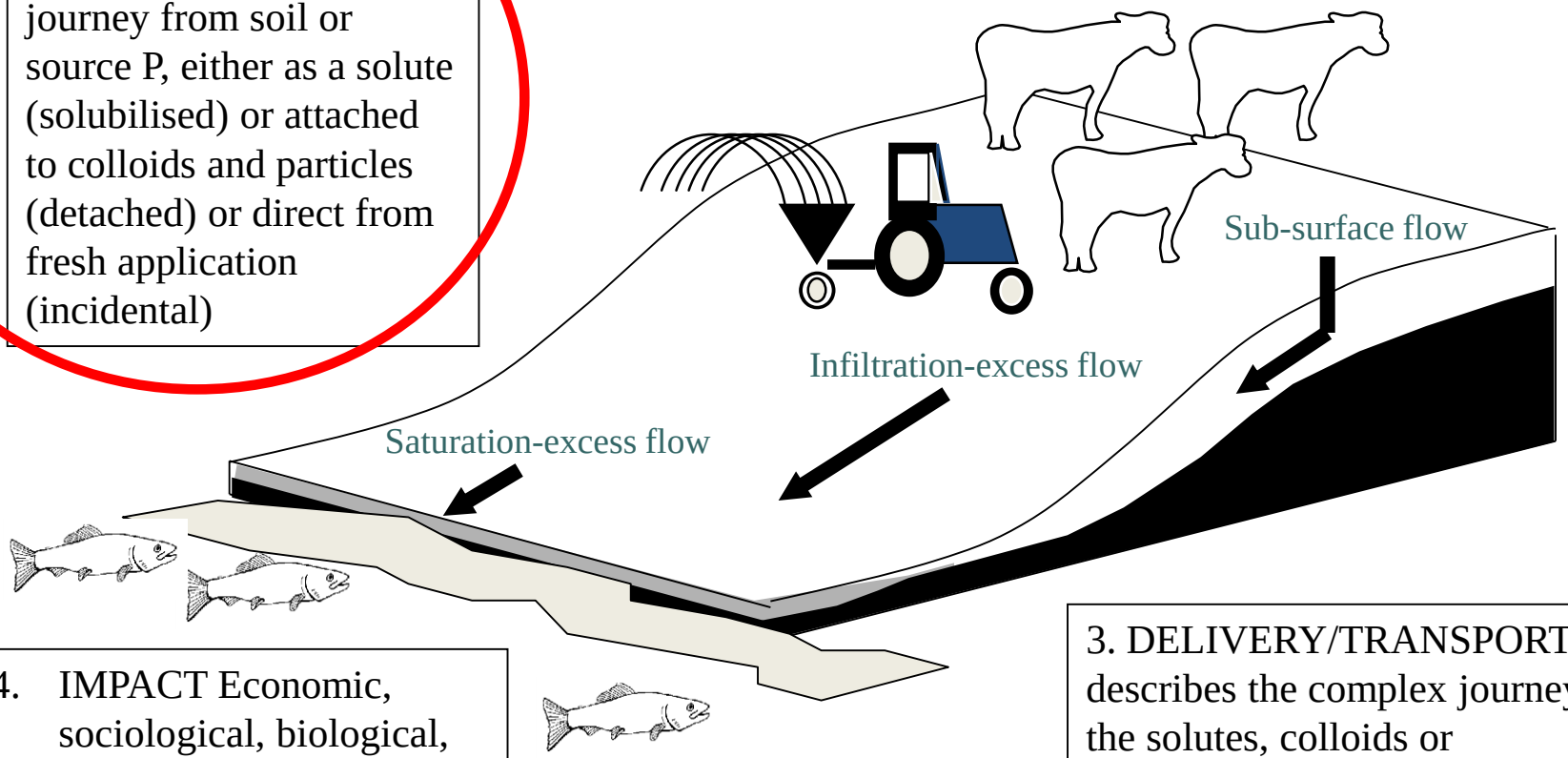

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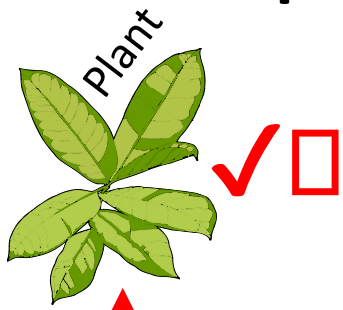
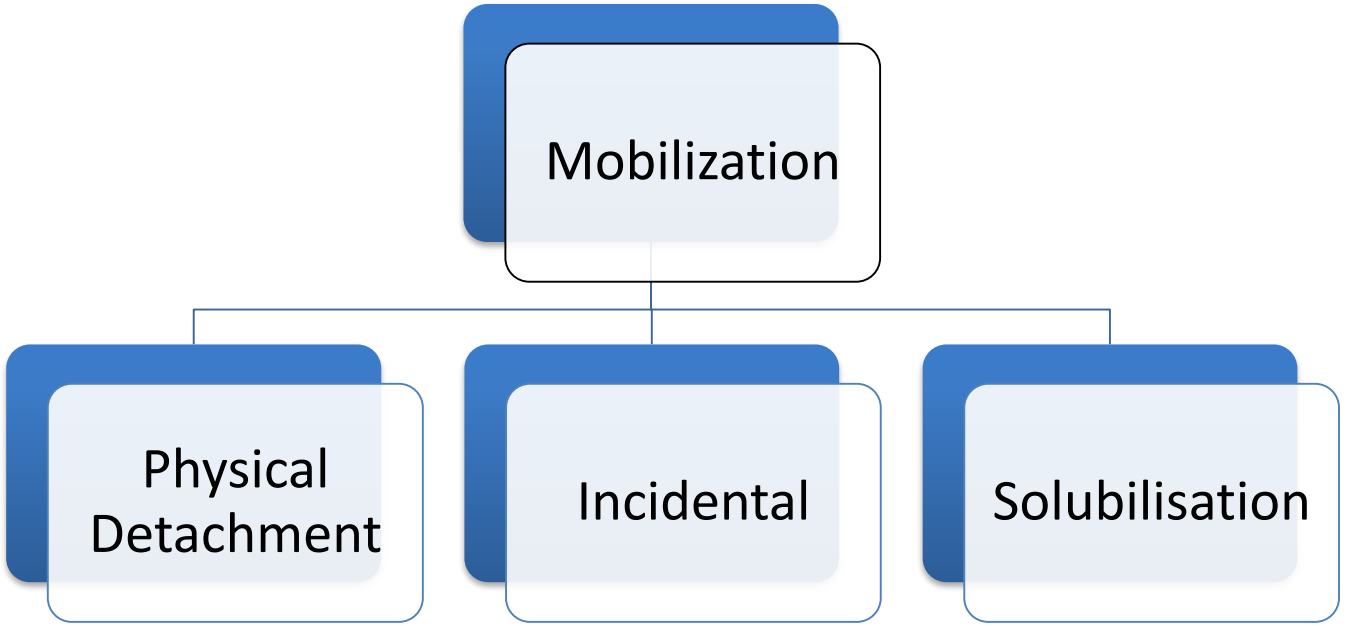
Phosphorus Mobilisation from Soil



✓

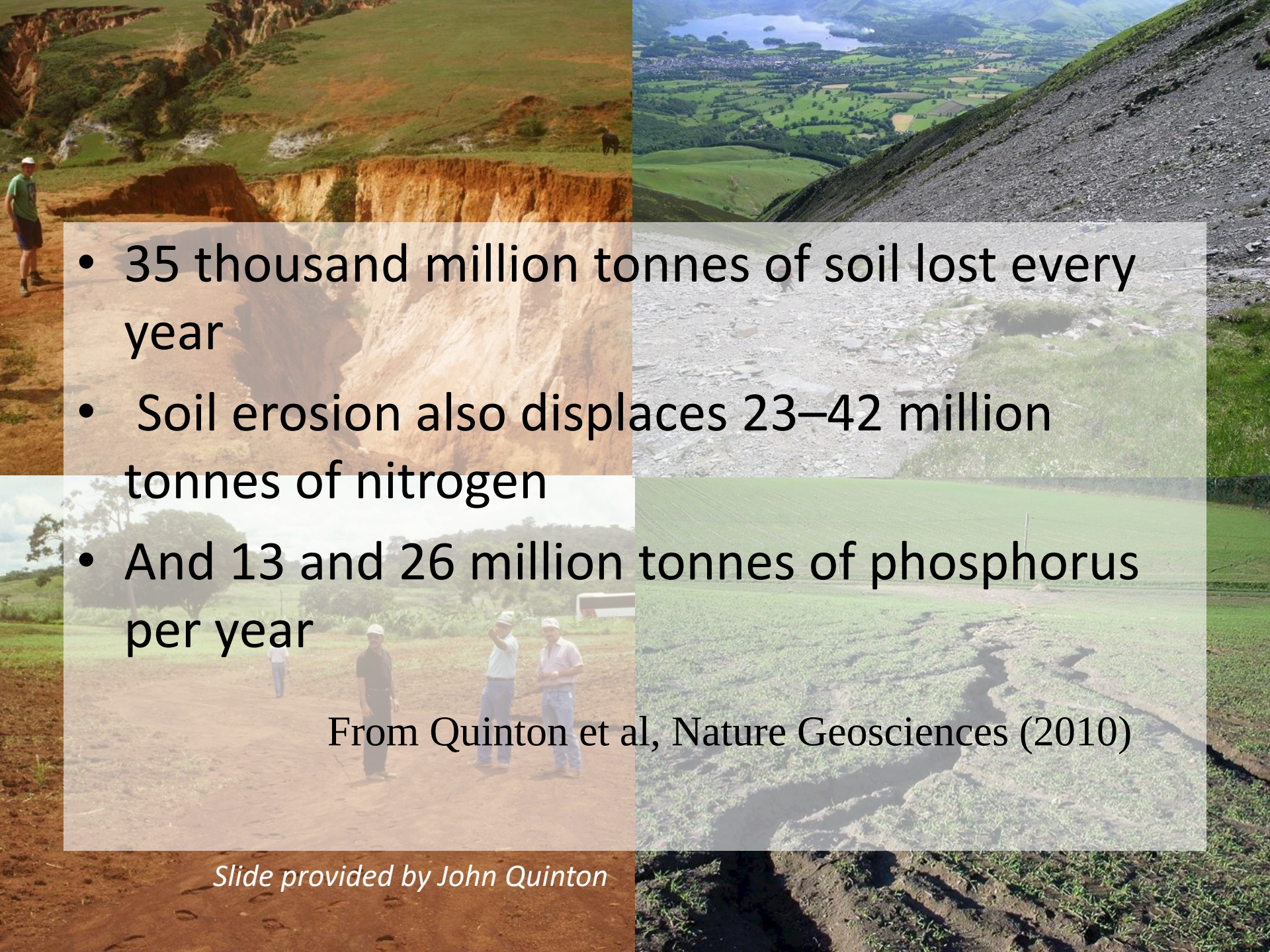
X



Effects of tillage and reseeding on phosphorus transfers from grassland P. J. Butler & P. M. Haygarth (2007)

Soil Use and Management, **23** (Suppl. 1), 71–81

- Shallow disking to 20 cm, then rolled and re-seeded
- 16 days after re-seed, 94 mm rainfall (57 mm in 22 hours)
- 7.5 tonnes of soil transferred from the plot

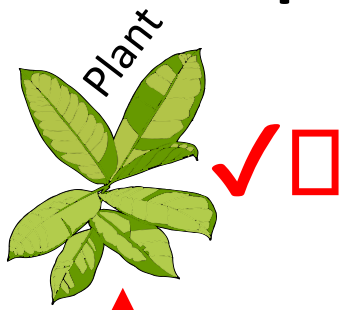


- 35 thousand million tonnes of soil lost every year
- Soil erosion also displaces 23–42 million tonnes of nitrogen
- And 13 and 26 million tonnes of phosphorus per year

From Quinton et al, Nature Geosciences (2010)

Slide provided by John Quinton

Phosphorus Mobilisation from Soil



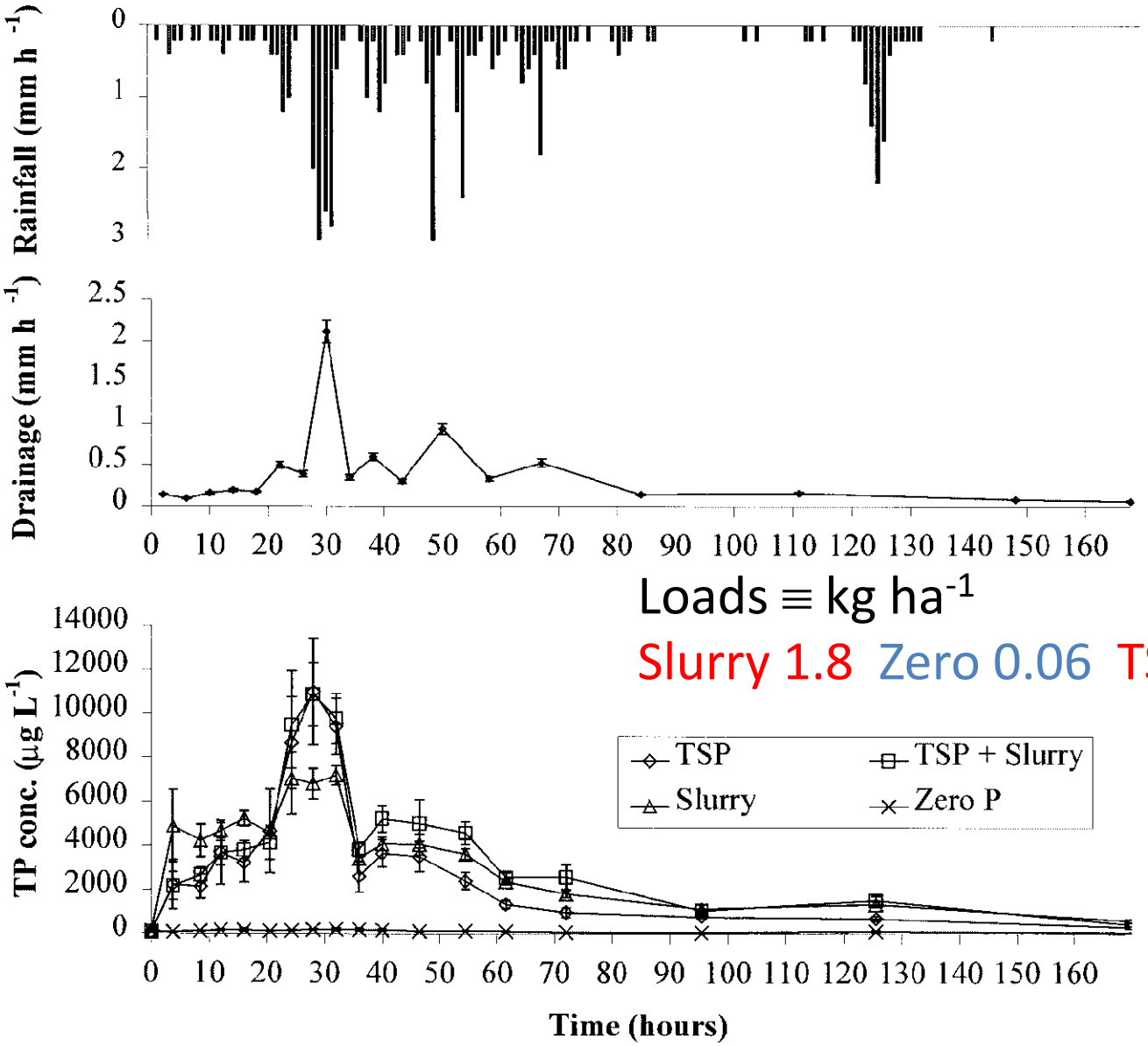
✓

X

- Mobilization
  - Physical Detachment
  - Incidental
  - Solubilisation

Rapid Incidental Phosphorus Transfers from Grassland

Neil Preedy,* Kevin McTiernan, Rachel Matthews, Louise Heathwaite, and Phil Haygarth

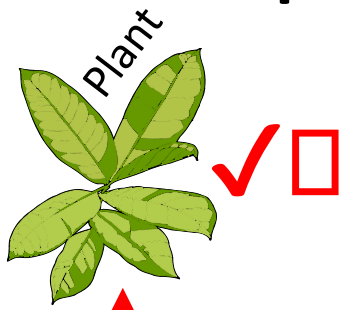


Loads ≡ kg ha^{-1}

Slurry 1.8 Zero 0.06 TSP 1.8


M771 AFV
ZA-X Perfect
1402
AMAZONE

Phosphorus Mobilisation from Soil



✓

X

- Mobilization
  - Physical Detachment
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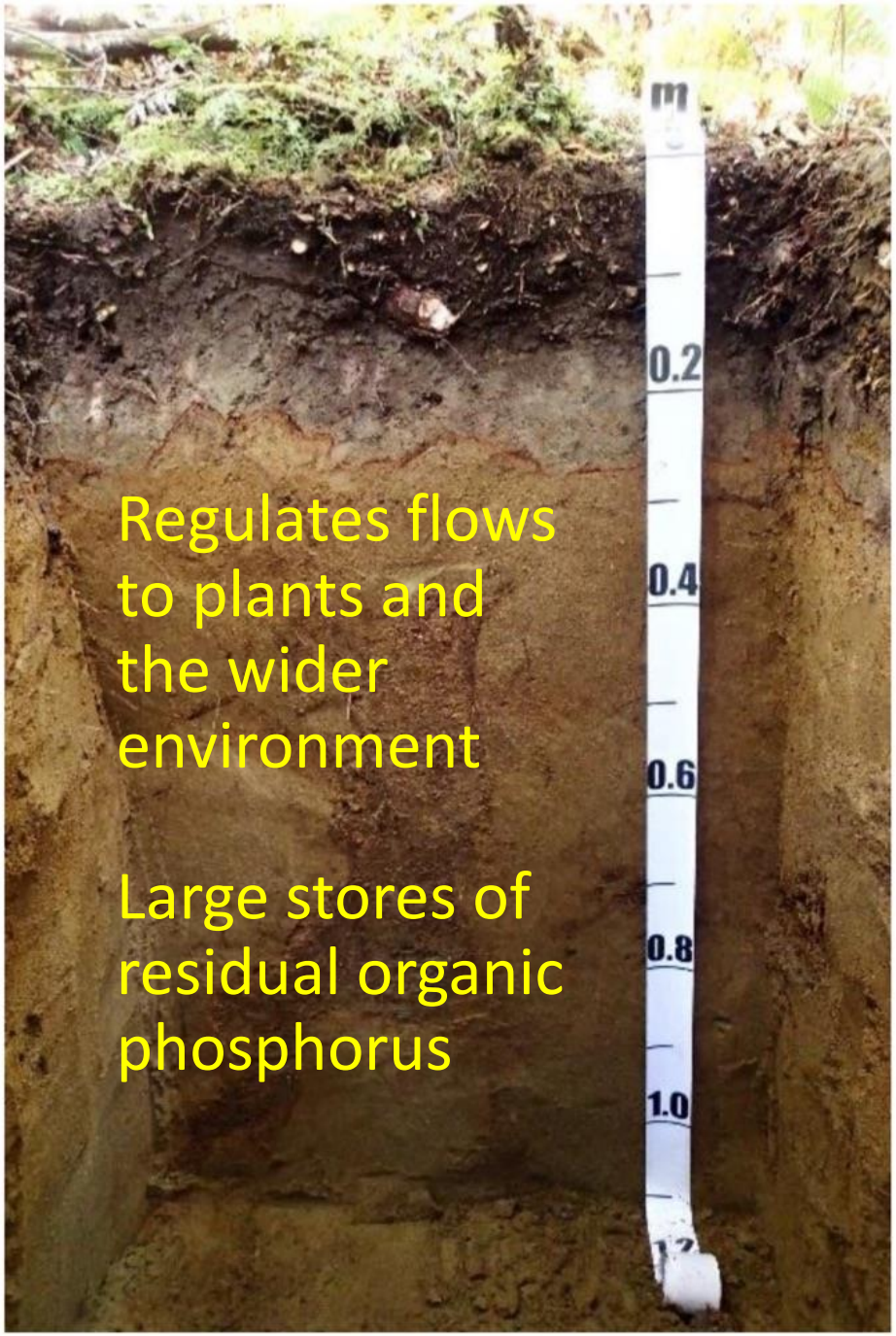
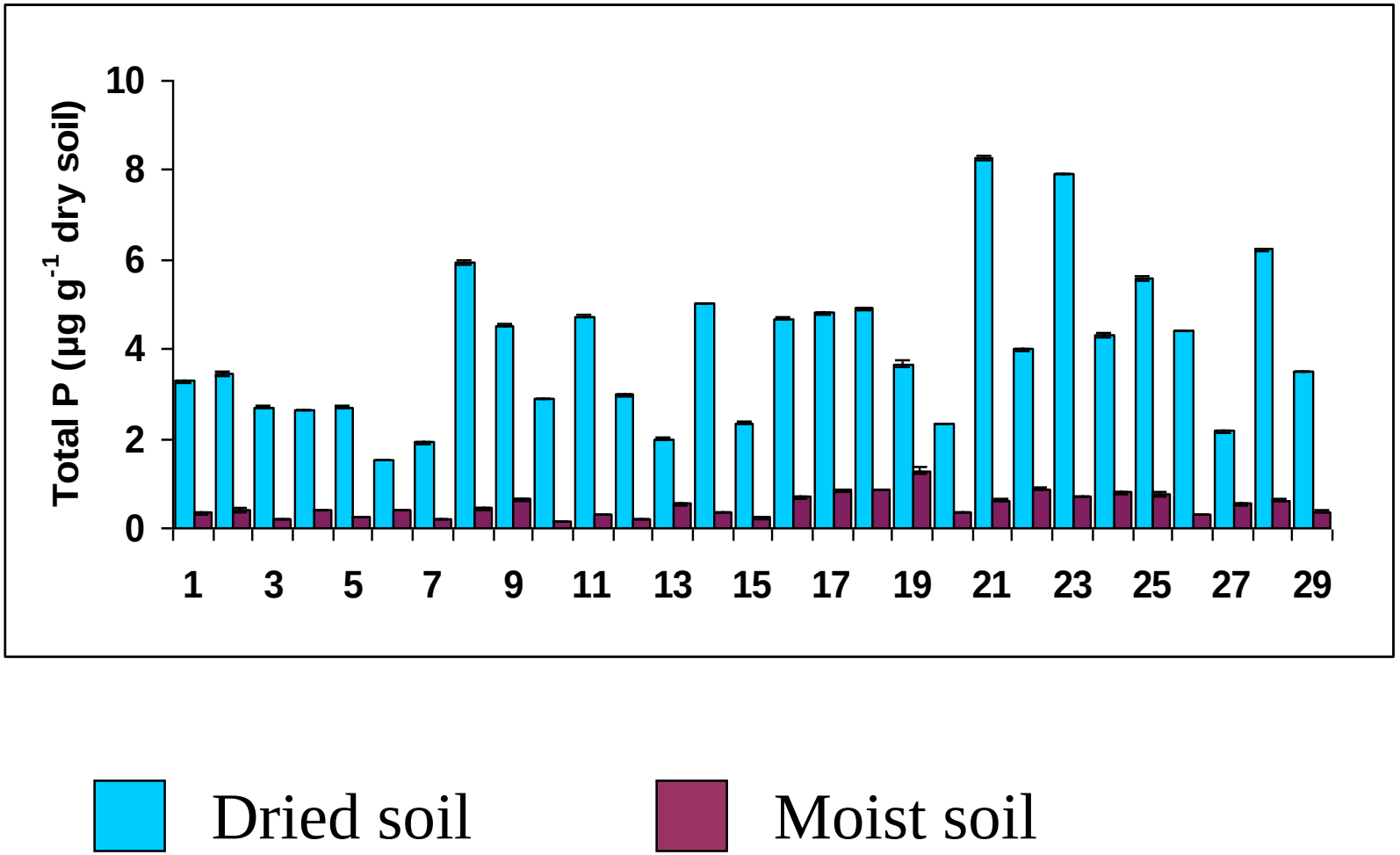
SOIL

is the hub of the global **PHOSPHORUS** *cycle*



Solubilisation - due to dynamics of soil moisture at the soil surface (Turner and Haygarth, *Nature*, 2001)



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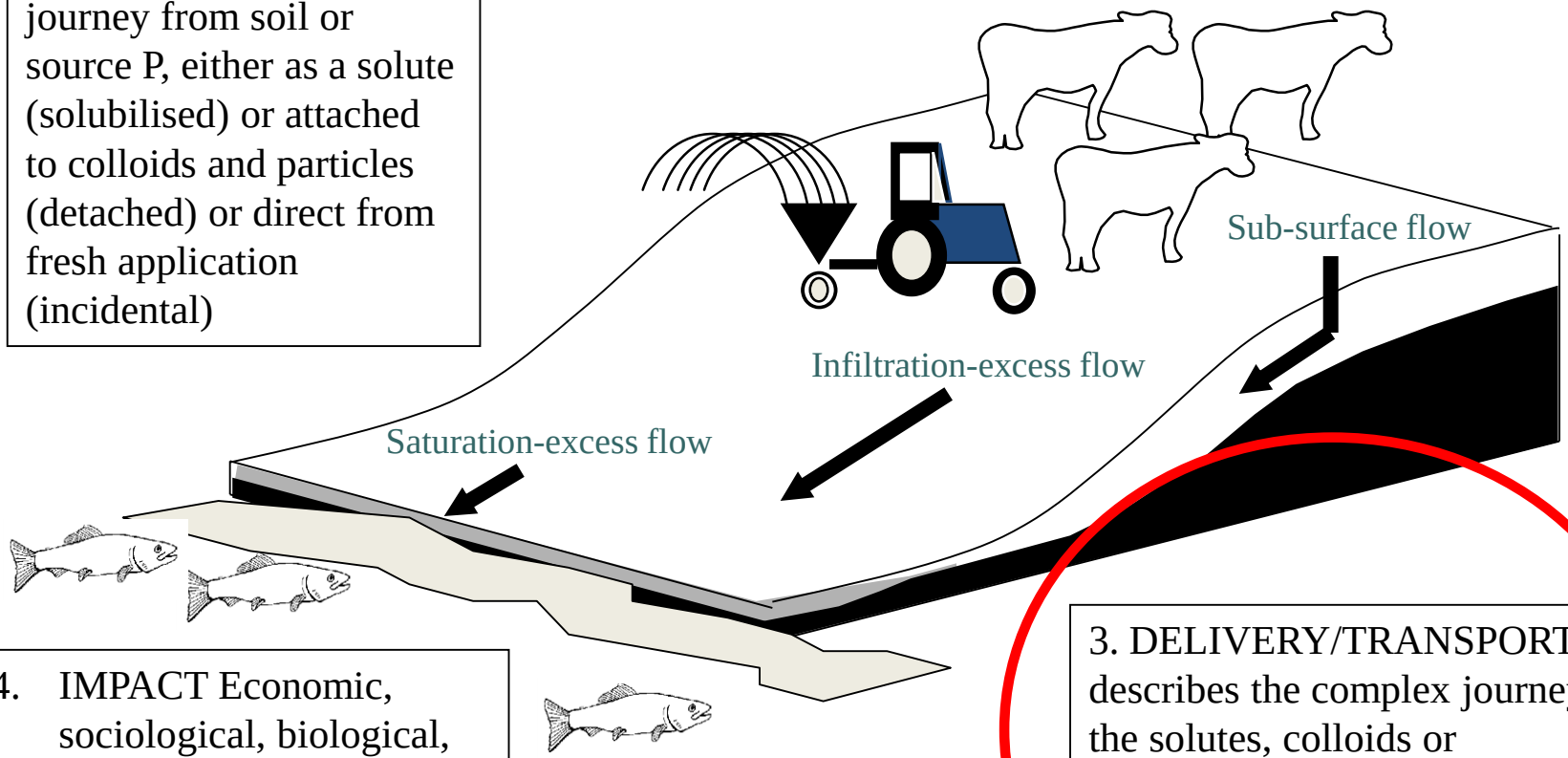

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Developing Demonstration Test Catchments as a platform for transdisciplinary land management research in England and Wales

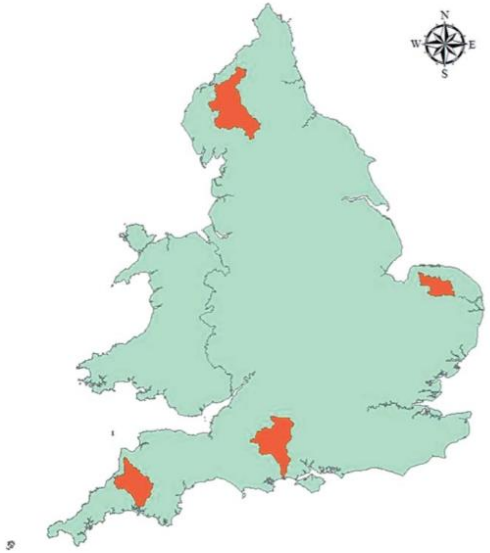


Fig. 2 The demonstration test catchments (shown clockwise from the most northerly; Rivers Eden, Wensum, Avon and Tamar).

1. Understanding the nature of the problem (catchment function and response)

- Sources of agricultural pollution
- Transport and transformations of pollutants
- Impact of pollution on ecology and other receptors
- Extrapolating findings to the wider catchment and nationally (spatial and temporal variation in risk)

2. Designing and targeting mitigation interventions

- Cost-effectiveness of mitigation measures
- Developing approaches to design and target catchment pollution mitigation strategies
- Measure cost, design and maintenance
- Environmental outcomes of mitigation

3. Working with stakeholders and influencing behaviour change

- Land manager behaviour and practices
- Attitudes to pollution and its mitigation
- Requirements for financial and technical support
- Collaborative, stakeholder-led approaches to catchment management

4. Developing improved monitoring and research techniques to inform, monitor and evaluate policy

- Improving monitoring approaches
- Developing approaches to up-scale up and extrapolate the results of research/investigations
- Testing models and decision support tools
- Improving research coordination

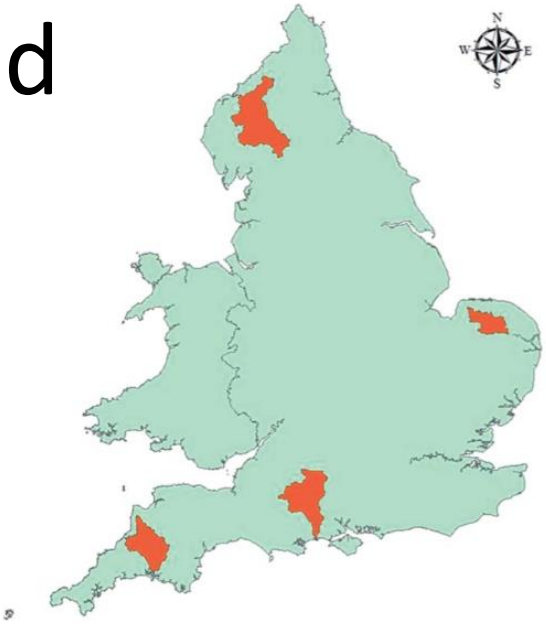
Cite this: *Environ. Sci.: Processes Impacts*, 2014, **16**, 1618

ROYAL SOCIETY OF CHEMISTRY

Environmental Science
Processes & Impacts

D. F. McGonigle,*[a] S. P. Burke,[b] A. L. Collins,[de] R. Gartner,[f] M. R. Haft,[g] R. C. Harris,[a] P. M. Haygarth,[h] M. C. Hedges,[f] K. M. Hiscock[c] and A. A. Lovett[c]

Demonstration Test Catchments in England



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Stakeholder-defined: current phosphorus pollution sources and their mitigation

Stakeholder meetings in each catchment - discussed and selected likely land management options from a range of possibilities.

Short term P dynamics in the EdenDTC

Science of the Total Environment 523 (2015) 178–190

Contents lists available at ScienceDirect

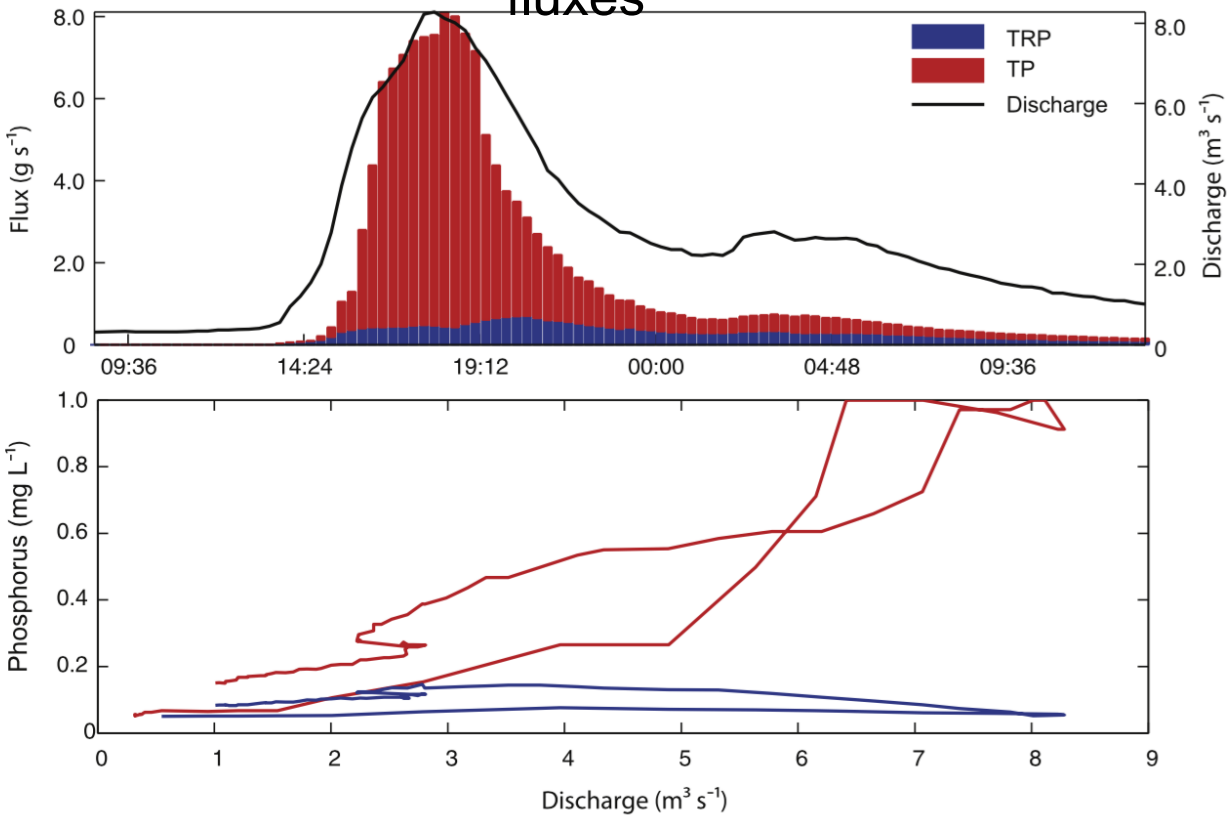
Science of the Total Environment

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

Dominant mechanisms for the delivery of fine sediment and phosphorus to fluvial networks draining grassland dominated headwater catchments

M.T. Perks [a,*], G.J. Owen [b], C.McW.H. Benskin [c], J. Jonczyk [b], C. Deasy [c,d,e], S. Burke [f], S.M. Reaney [d], P.M. Haygarth [c]

"high magnitude events were observed to exhibit threshold- like behavior…….results in the movement of vast phosphorus fluxes"



Newby Beck, River Eden, England

Fig. 6. An example of the figure-of-eight (clockwise loop) hysteresis dynamics exhibited for total phosphorus (TP) and total reactive phosphorus (TRP) during infrequent but high magnitude events. Fig. 6a illustrates the synchronicity of both TP and TRP fluxes in the catchment, with TRP becoming less dominant as runoff increases rapidly. Fig. 6b illustrates the timing of concentration pulses which lead to the production of the figure-of-eight (clockwise loop) hysteresis.

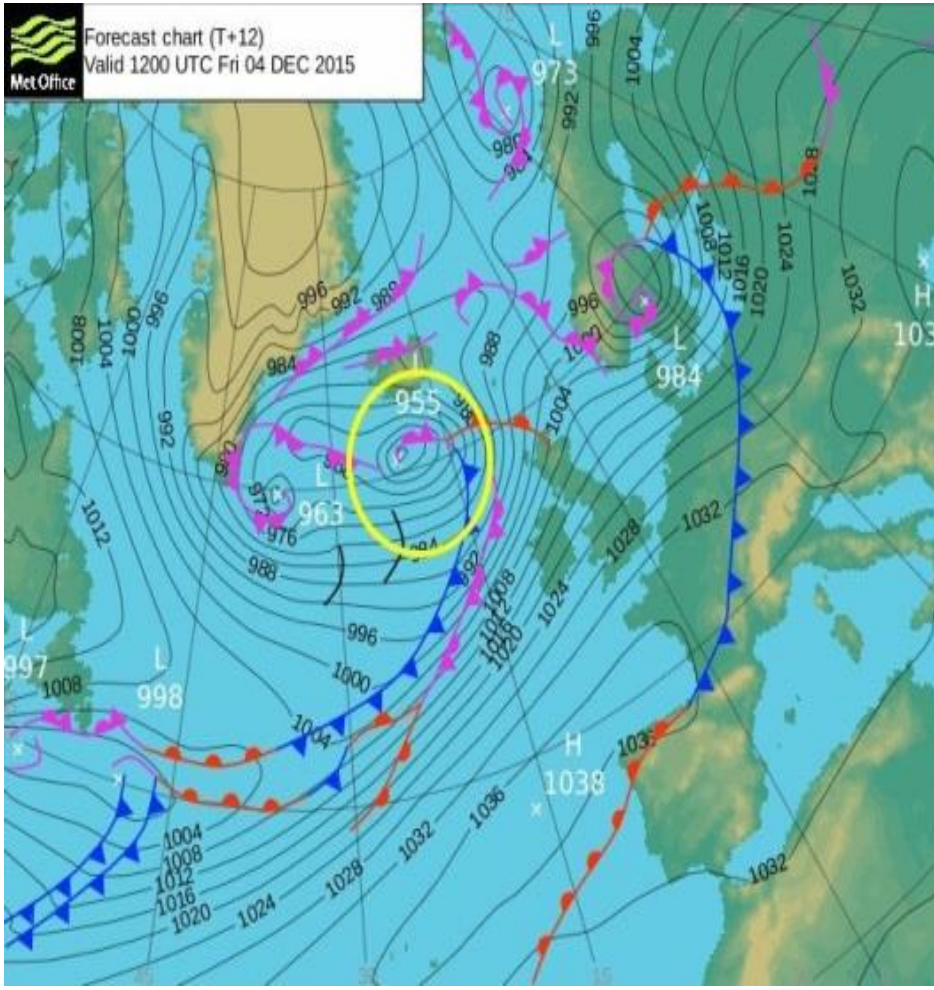
Phosphorus transfers in climate change?

Prof Phil Haygarth @ProfPHaygarth · 5 Dec 2015
Wading home through the Keer

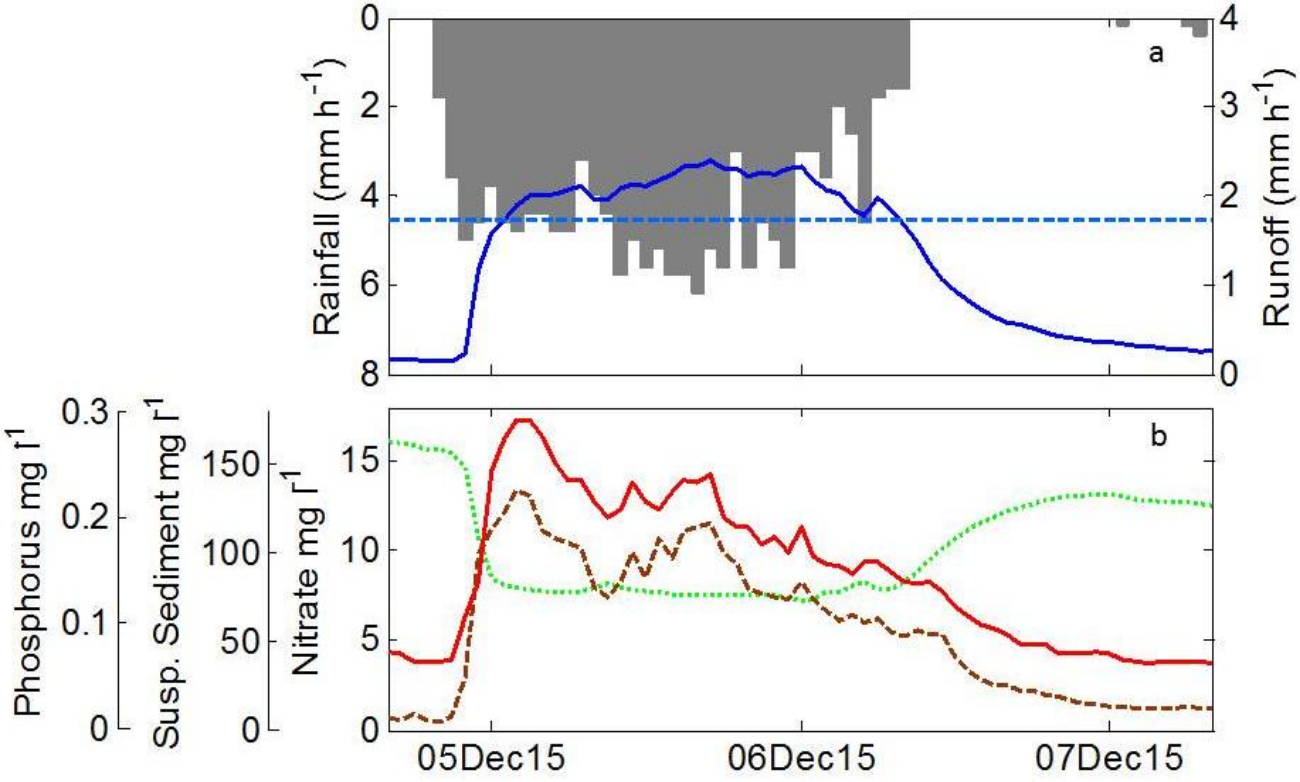
@ProfPHaygarth
#stormdesmond

Storm Desmond, why did it rain so much?

- The winds came from the Caribbean and Gulf of Mexico in the West Atlantic
- ‘Anomaly’ ocean temperatures are 1-2 C higher in the W. Atlantic = more ‘fuel to the front’
- The frontal system and rainfall totals that alligned itself with the wind and just stayed around longer than ‘normal’



Storm Transfers: Newby Beck Morland, Eden, N England, Dec 5-7 2018



Hydrograph, sedigraph and chemograph at Newby Beck monitoring station (54.59°N, 2.62°W) in the River Eden during Storm Desmond, 4th – 6th December 2015

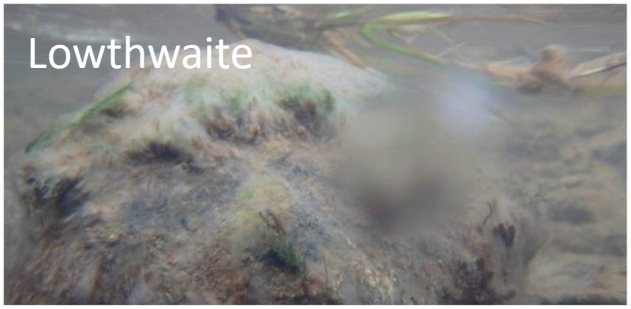
Storm Transfers: Newby Beck Morland, Eden, N England, Dec 5-7 2018

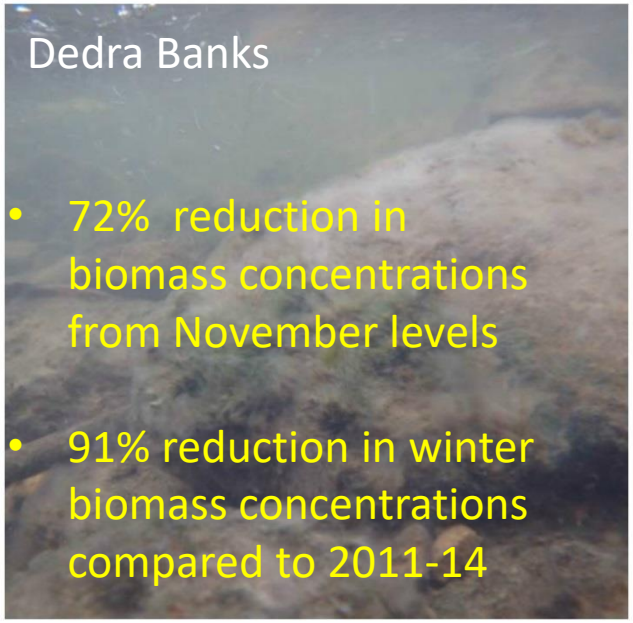
	Sediment (t)	Total P (kg)	Total Reactive P (kg)	Nitrate (t)
Storm Desmond export	84	194	78	8.9
Annual export	380 - 680	1670 – 2320	650 – 920	68 - 94
% of annual	12 - 22	8 - 12	8 - 12	9 - 13
During Desmond:	mg/l	mg/l	mg/l	mg/l
Min Conc.	5*	0.062*	0.037*	7.2
Max Conc.	134	0.288	0.096	15.7*
Time averaged conc.	61	0.151	0.065	9.9
Flow weighted conc.	81	0.186	0.074	8.4

*Minimum concentrations of SS, TP, TRP and maximum nitrate were recorded at the beginning of the event (i.e. they represent initial values before response started)

Impact on instream biomass concentrations – M. Snell

Phytobenthos November 2015



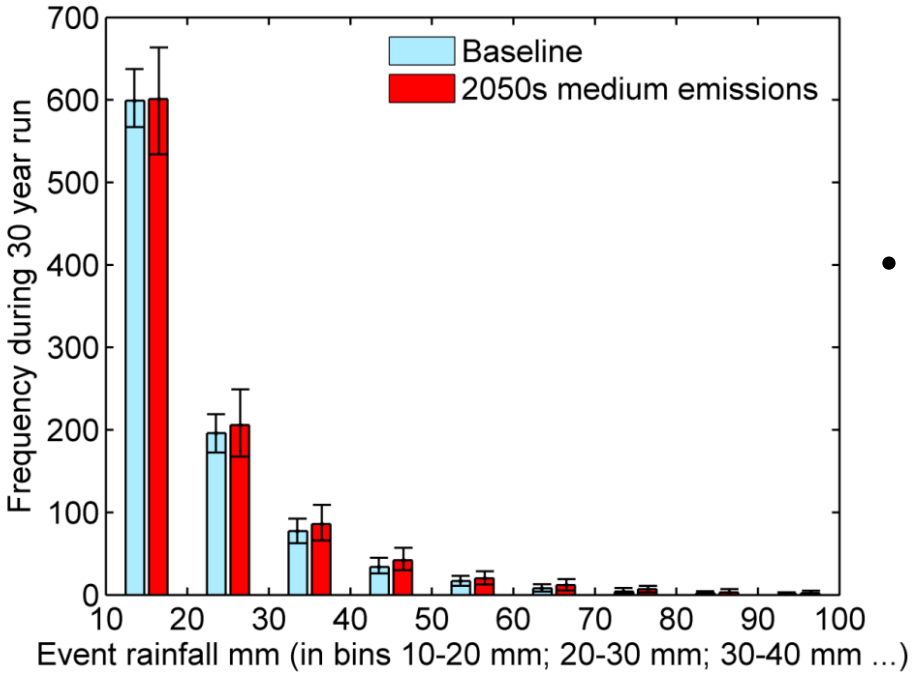


Phytobenthos December 2015

Climate change and phosphorus transfers? (Ockenden *et al* 2016)

Newby Beck	Baseline	2050s
No. of events > 10 mm (for 30 year run, mean over 100 runs)	944	986
Percentage of total rainfall in events > 10 mm	62%	67%
Event rainfall 95th percentile (mean over 100 runs)	46	50
Event rainfall 99th percentile (mean over 100 runs)	70	79
Maximum Event rainfall (mean over 100 runs)	119	140

- UK climate predictions indicate a shift in distribution to larger events (rainfall >10 mm)



Historical in the R Eden:
1960-2013:
31% increase Winter
16% decrease Summer

- *Future **predictions** for 2050:*
  - *Winter increases by 8-17%*
  - *Summer decreases by 9-26%*
    (fewer summer storms, but more intense, more wetting and drying)

nature COMMUNICATIONS

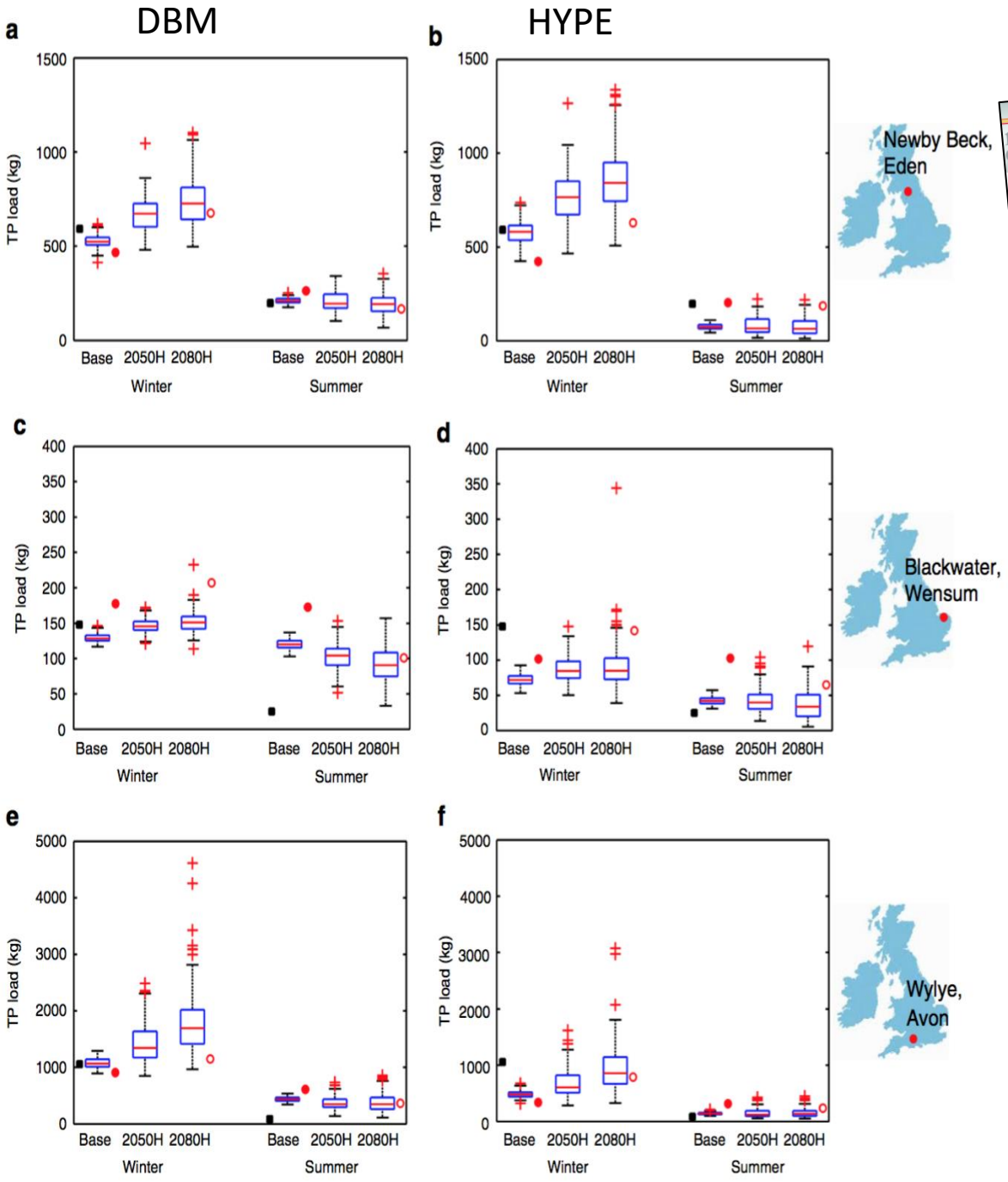
ARTICLE

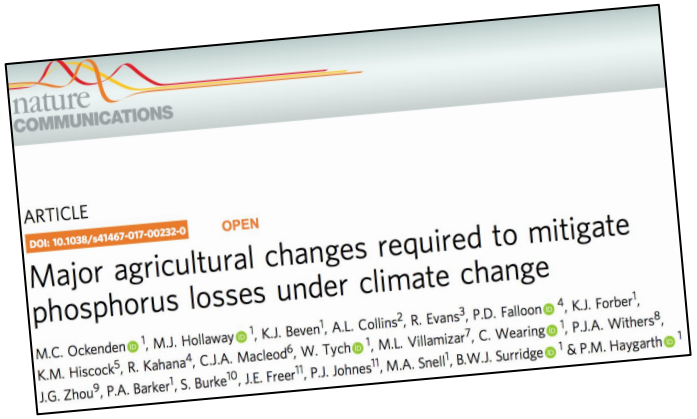
DOI: 10.1038/s41467-017-00232-0 OPEN

Major agricultural changes required to mitigate phosphorus losses under climate change

M.C. Ockenden[1], M.J. Hollaway[1], K.J. Beven[1], A.L. Collins[2], R. Evans[3], P.D. Falloon[4], K.J. Forber[1], K.M. Hiscock[5], R. Kahana[4], C.J.A. Macleod[6], W. Tych[1], M.L. Villamizar[7], C. Wearing[1], P.J.A. Withers[8], J.G. Zhou[9], P.A. Barker[1], S. Burke[10], J.E. Freer[11], P.J. Johnes[11], M.A. Snell[1], B.W.J. Surridge[1] & P.M. Haygarth[1]

The full paper can be accessed here:
https://www.nature.com/articles/s41467-017-00232-0





Range of likely winter and summer total phosphorus loads predicted by Data Based Mechanistic models (DBM) and process-based model HYPE for three UK DTC catchments (Ockenden et al., 2017).

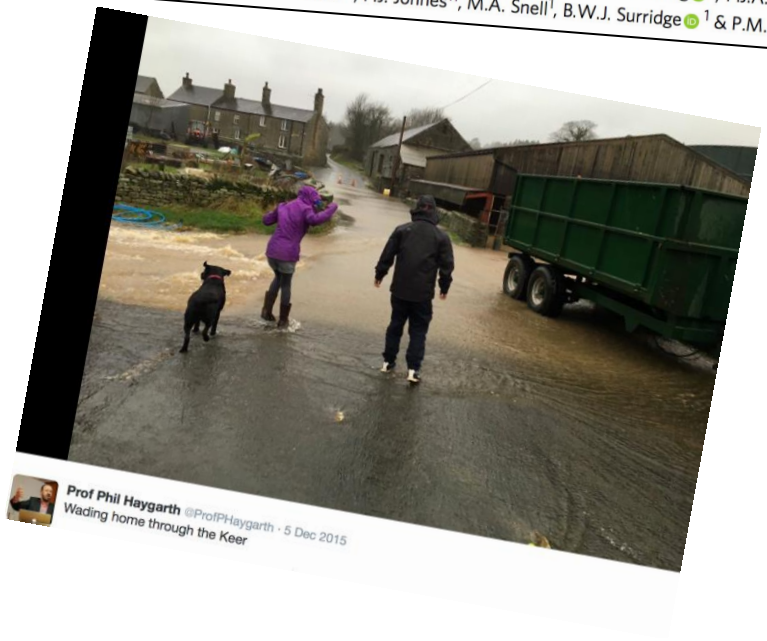
Example Output: *Medium Carbon Emissions, 2080s….*

Total Predicted Annual P load, % change in relation to current 'baseline'

	Eden (Newby)
HYPE	19
DBM	16

Climate change and phosphorus transfers?

- **Total Predicted Annual P load, 10-36% increase in relation to current 'baseline'** (HYPE Model, Medium Carbon Emissions, 2080s….)
- This predicted increase in winter P loads ***is greater than the technically feasible reduction from mitigation measures estimated in previous studies***
- ***Only large-scale agricultural changes (e.g. 20–80% reduction in P inputs) will limit the projected impacts of climate change on P loads in these catchments***
- Are we prepared for this?



Mitigating Diffuse Phosphorus Transfer from Agriculture According to Cost and Efficiency

P. M. Haygarth* Lancaster University
H. ApSimon Imperial College London

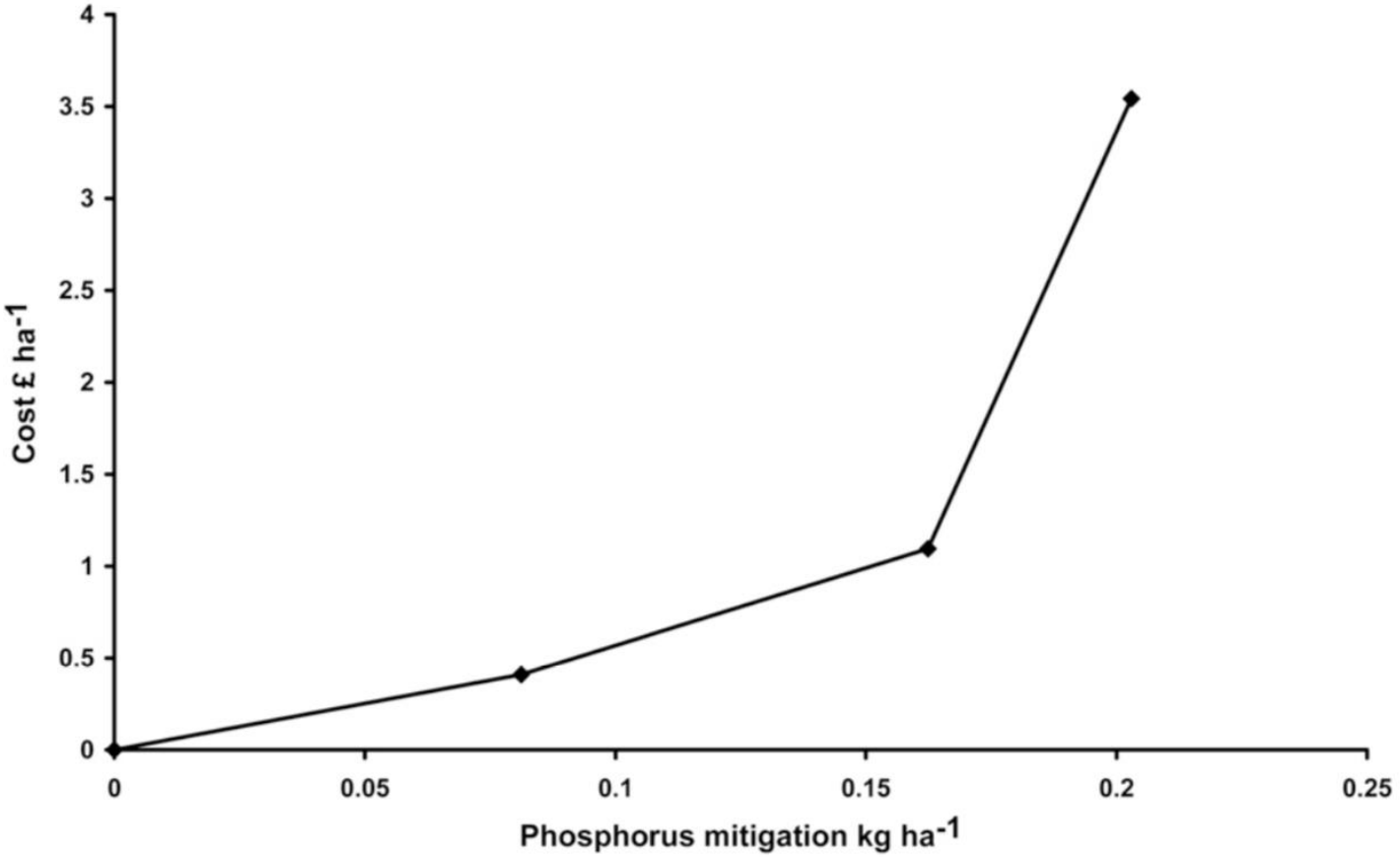


Fig. 1. Example cost curve of mitigation methods that can be combined in upland (from "grassland all") typologies.

Soil Use and Management

doi: 10.1111/sum.12242

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A method-centric 'User Manual' for the mitigation of diffuse water pollution from agriculture

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A turning point in the global phosphorus cycle

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Research

Check for updates

Cite this article: Watson AJ, Lenton TM, Mills BJW. 2017 Ocean de-oxygenation, the global phosphorus cycle and the possibility of human-caused large-scale ocean anoxia. *Phil. Trans. R. Soc. A* 20160318.
http://dx.doi.org/10.1098/rsta.2016.0318

Accepted: 21 June 2017

Ocean de-oxygenation, the global phosphorus cycle and the possibility of human-caused large-scale ocean anoxia

Andrew J. Watson[1], Timothy M. Lenton[1] and Benjamin J. W. Mills[2]

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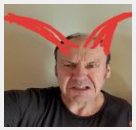
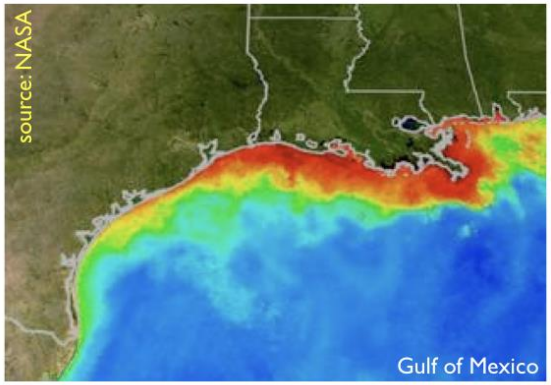
- Green revolution released P into earth system
- Uncertainties over future supplies
- Transfers to water and oceans
- Accelerating with climate change

Prophets

A dark phosphogeddon?





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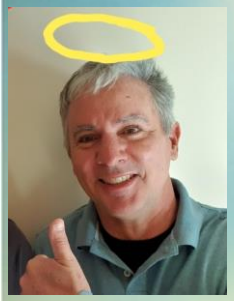
Phosphoheaven or Phosphogeddon?

Telling the Story of the Opportunities and Challenges to Mend Our Broken Phosphorus Cycle

Jim Elser

University of Montana &
Arizona State University, USA

@DrLimnology



Phil Haygarth

Lancaster University, UK

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Building resilience?

Prof Phil Haygarth @ProfPHaygarth · 5 Dec 2015
Wading home through the Keer

- ***Plan for change***
- Maritime regions seem vulnerable
  - Temperature dynamics!
  - Hydrological dynamics!
  - Soil loss!
- Crops vulnerable!
- Phosphorus and other nutrient cycles accelerating…

"The history of every Nation is eventually written in the way in which it cares for its soil."

Franklin D. Roosevelt
President of the United States 1933-1945

SLIDE FROM JOHN QUINTON

Thanks to the team …..

@ProfPHaygarth

landwaterblog.blogspot.com