Phosphorus Forum 2019

April 5, 2019
Barrett and O'Connor Washington Center
at Arizona State University
1800 I Street NW
Washington, DC,

phosphorusalliance.org
#PhosForum19

Made possible by the support of our members:

Founding/Current Members and Strategic Partners

- OCP
- NACWA
- OSTARA
- The Water Research Foundation
- The Sustainability Consortium™
- Renewable Nutrients
- GreenEdge® GreenTechnologies, LLC
- Biochar Now
- e2metrix
- FEECO International
- CAB Consultants Associated With Brookside

Strategic Partners

- AgSTAR
- Water Environment Federation® the water quality people®
- nebra North East Biosolids & Residuals Association

Welcome!

Sustainable Phosphorus Alliance

Agenda

8:00 am - 8:30 am	**Registration and networking**
8:30 am - 9:00 am	**Welcome** Dr. Jim Elser, Director, Sustainable Phosphorus Alliance
9:00 am - 9:45 am	**Keynote Address** Dr. Bruce Rittmann, Co-Recipient, Stockholm Water Prize
9:45 am - 10:00 am	**Coffee** Sponsored by Ostara
10:00 am - 10:30 am	**Phosphorus Field-to-Watershed Modeling Task Force Report** Dr. Peter Vadas, Soil Scientist, USDA-ARS
10:30 am - 11:00 am	**Biosolids and Manure Task Force Report** Dr. Rebecca Muenich, Research Scientist, and Dr. Matt Scholz, Program Manager, Sustainable Phosphorus Alliance
11:00 am - 12:00 pm	**Phosphorus Sustainability Challenge and Group Activity** Dr. Matt Scholz, Program Manager, Sustainable Phosphorus Alliance
12:00 pm - 1:30 pm	**Lunch and Networking** Sponsored by OCP
12:30 pm - 1:00 pm	**Lunch Speaker** Dr. Kathleen Merrigan, Executive Director, Swette Center for Sustainable Food Systems at Arizona State University
1:30 pm - 2:00 pm	**Cost Effective Method to Remove Phosphorus from Water Bodies** Mr. James Gaspard, CEO, Biochar Now
2:00 pm - 2:15 pm	**ReNEW Water Project: Resource Recovery in the US** Dr. Patrick Dube, Biosolids Program Manager, WEF
2:15 pm - 2:30 pm	**Closing Comments** Dr. Jim Elser, Director, Sustainable Phosphorus Alliance
2:30 pm - 3:00 pm	**Room open for networking**

Thanks to Ostara and to OCP for coffee & lunch sponsorship!

2019 is a very special year for phosphorus

Happy 350th Birthday, Phosphorus*!

*actually, it's our KNOWLEDGE of P that is 350 years old. The P itself is billions of years old!

A recipe (Ingredients: 5000 liters of urine)

- Step 1: Boil urine to reduce it to a thick syrup.
- Step 2: Heat until a red oil distills up from it, and draw that off.
- Step 3: Allow the remainder to cool, where it consists of a black spongy upper part and a salty lower part.
- Step 4: Discard the salt, mix the red oil back into the black material.
- Step 5: Heat that mixture strongly for 16 h.
- Step 6: First white fumes come off, then an oil, then phosphorus.
- Step 7: The phosphorus may be passed into cold water to solidify

What Happens When You Boil Urine

Hennig Brand (1630 – c. 1692 or c. 1710)

Very poor at chemistry
(5000 liters of urine should
have produced 550 g of P.
He only got 120 g.)

Lousy chemist but a worthy goal:
turn the useless into the valuable.

Phosphoheaven or Phosphogeddon?

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

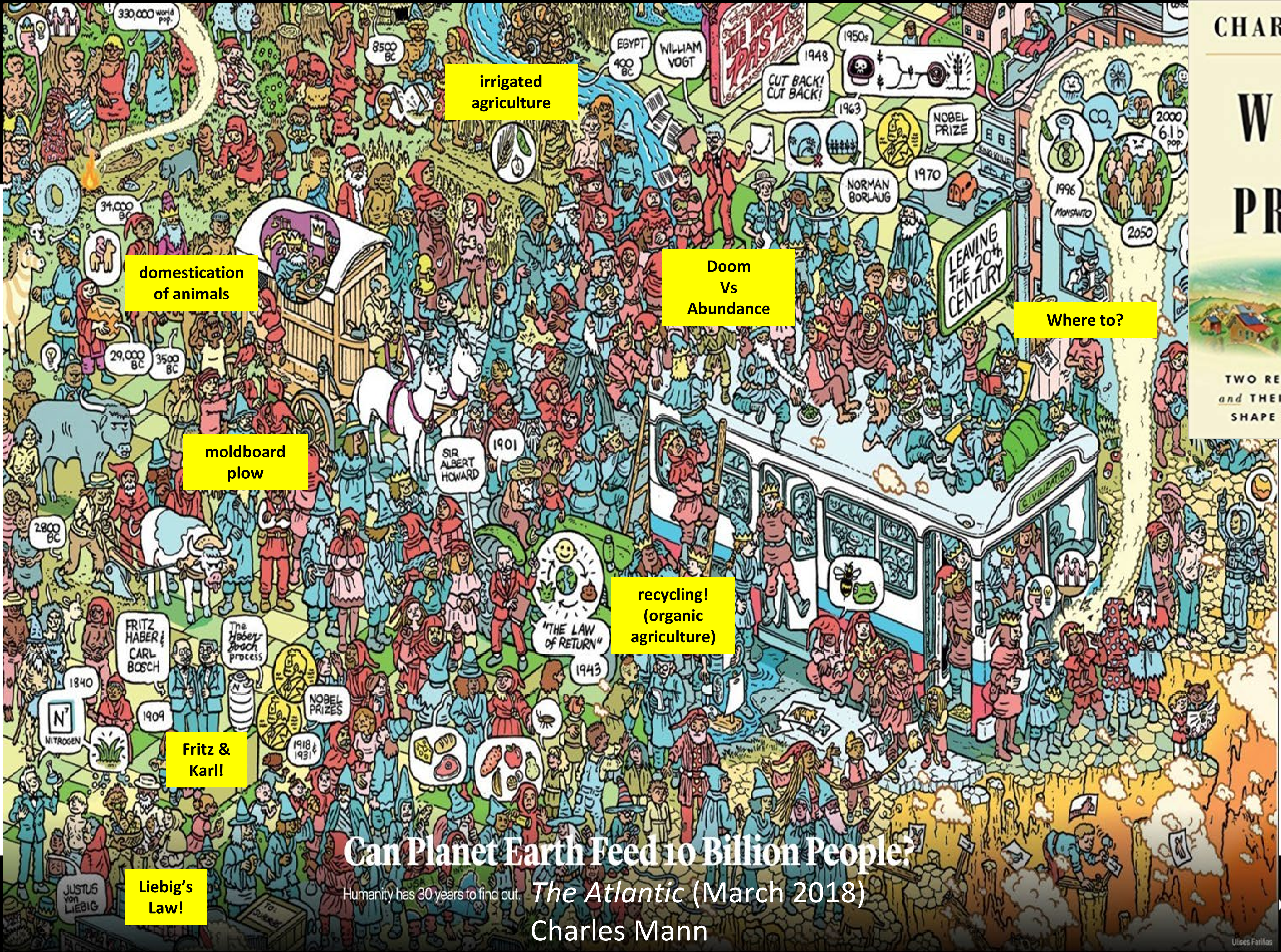
Elser & Haygarth
Title TBA

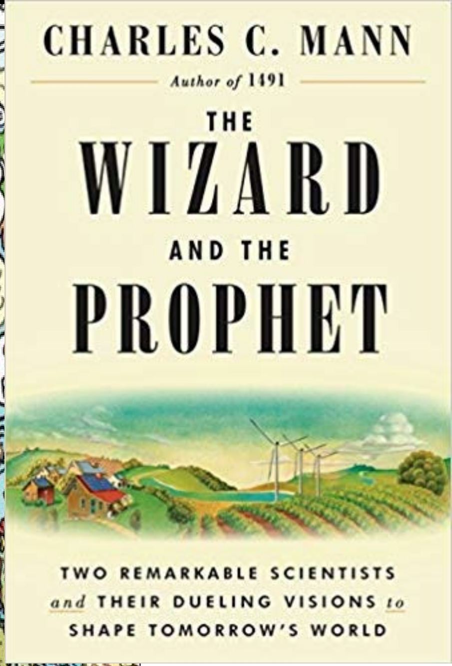
- Oxford University Press
- Aiming for 2019 – the 350th anniversary
- General audience
- 10 Chapters

My Drive > Phosphorus Book

Name ↑

- Chapter 1 - Phosphorus Knowing
- Chapter 2 - Phosphorus Becoming
- Chapter 3 - Phosphorus Living
- Chapter 4 - Phosphorus Feeding
- Chapter 5 - Phosphorus Growing
- Chapter 6 - Phosphorus Moving
- Chapter 7 - Phosphorus Sustainability Awakening
- Chapter 8 - Phosphorus Transforming: Part 1
- Chapter 9 - Phosphorus Transforming: Part 2
- Chapter 10 - Phosphorus Sustaining



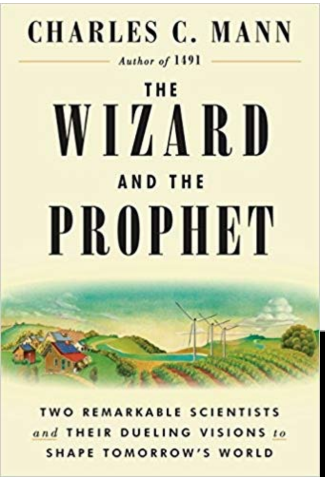


The Atlantic (March 2018)
Charles Mann

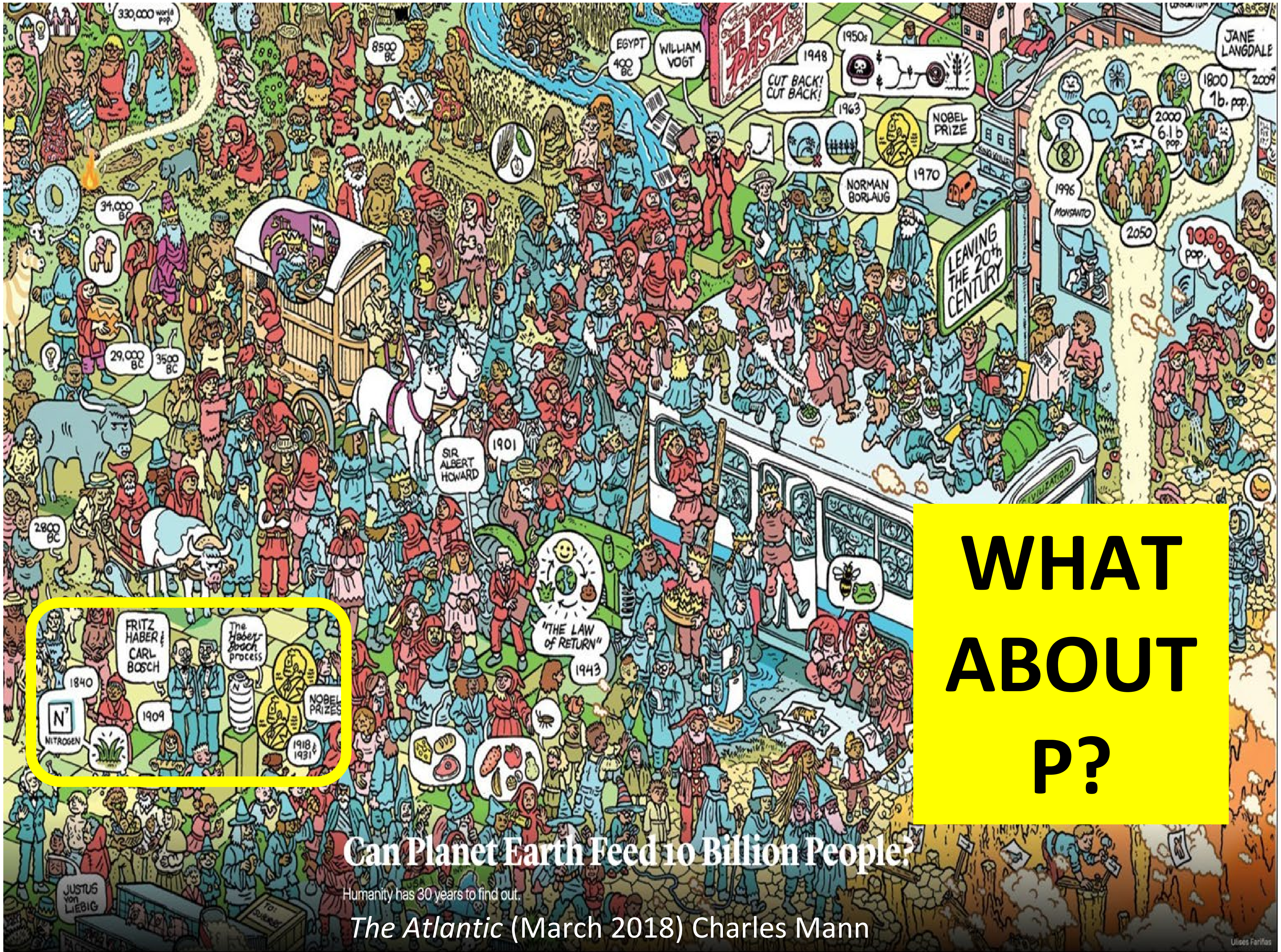
rus Alliance

Prophets vs Wizards

Wizards **Prophets**



The Atlantic (March 2018)
Charles Mann (Illustrations by Ulises Fariñas)



WHAT ABOUT P?

The Atlantic (March 2018) Charles Mann

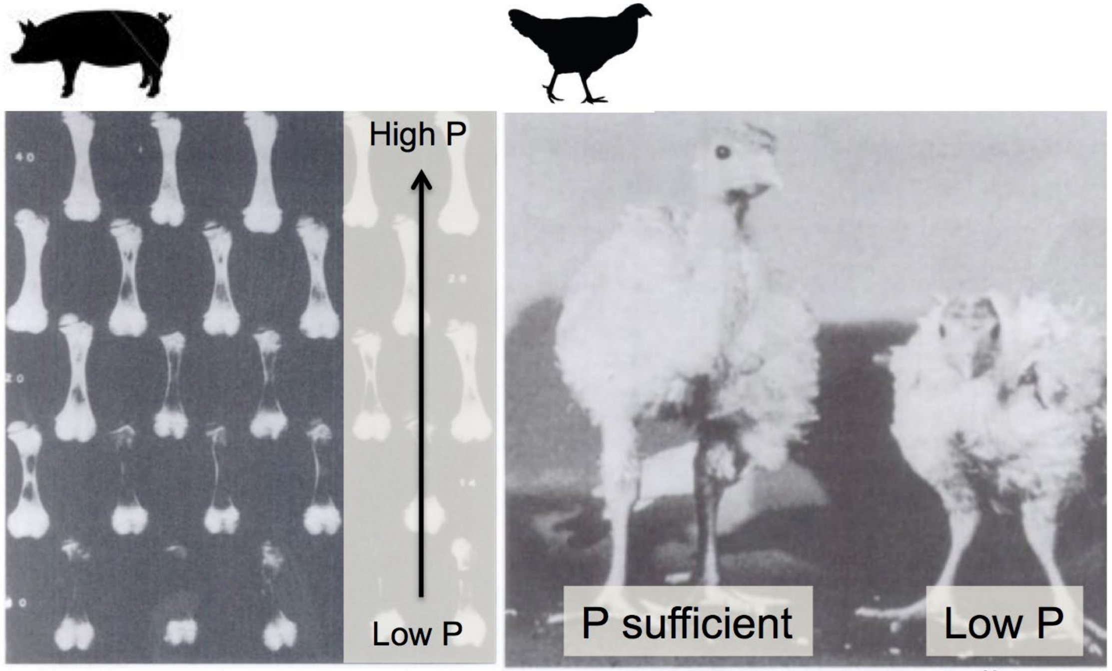
Ch 1: Phosphorus Knowing
Ch 2: Phosphorus Becoming
Ch 3: Phosphorus Living
Ch 4: Phosphorus Feeding

Got phosphorus?

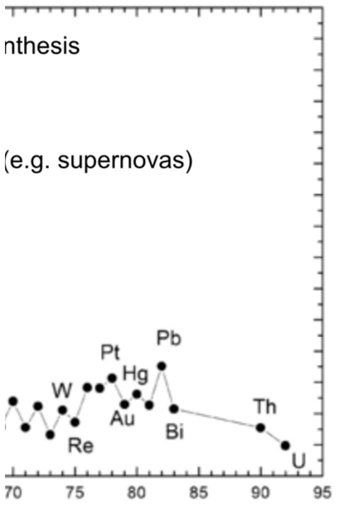
~1.35 pounds, or 0.62 kilograms: that's how much you have in your body, right now.

~75 pounds, or 34 kilograms: that's how much ...e in your (average) lifetime.

Adenine Thymine NH_2



Source: McDowell (2000)



Can Planet Earth Feed 10 Billion People?

Humanity has 30 years to find out. *The Atlantic* (March 2018)

Charles Mann

...rus Alliance

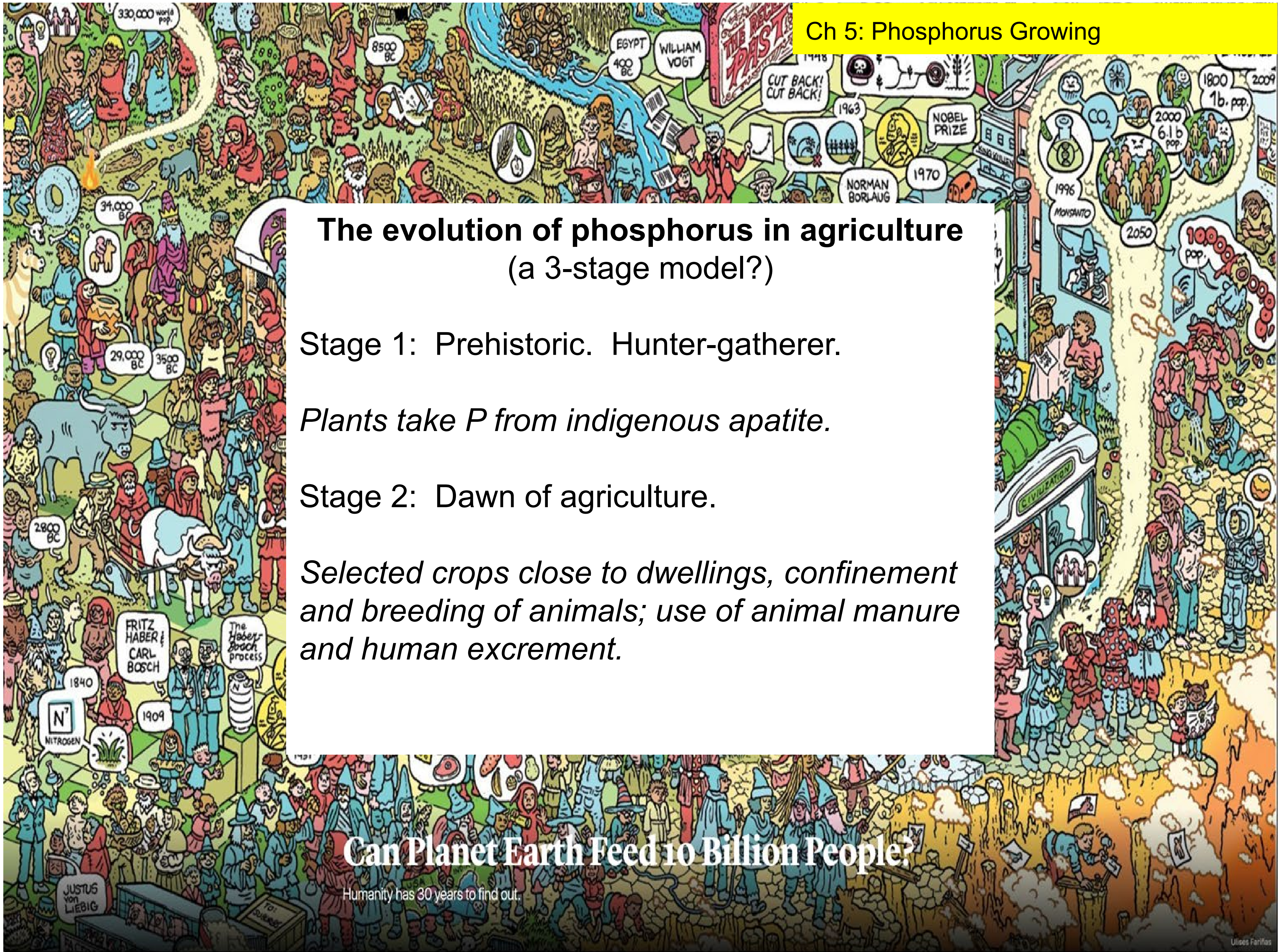
The evolution of phosphorus in agriculture
(a 3-stage model?)

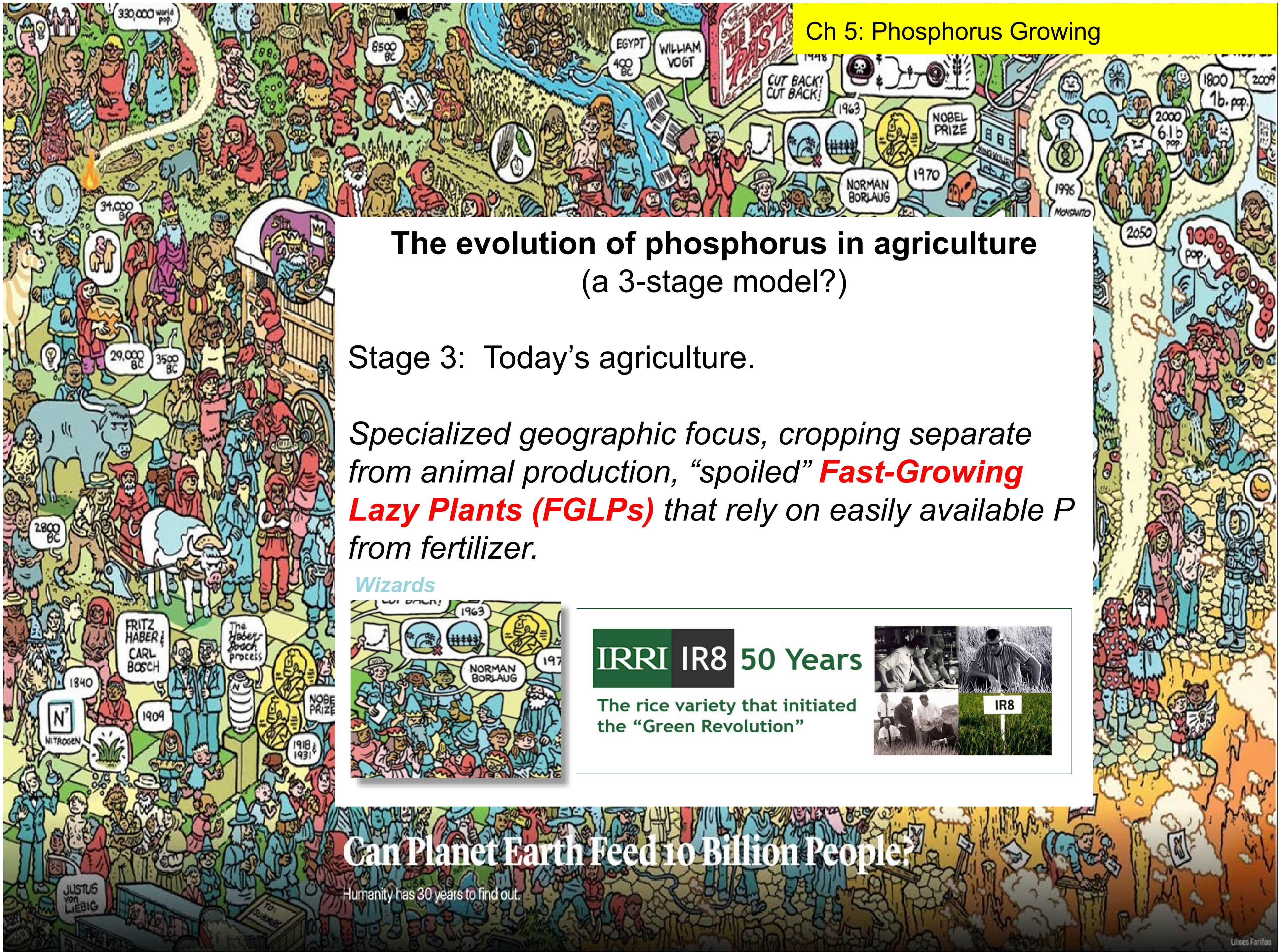
Stage 1: Prehistoric. Hunter-gatherer.

Plants take P from indigenous apatite.

Stage 2: Dawn of agriculture.

Selected crops close to dwellings, confinement and breeding of animals; use of animal manure and human excrement.





The evolution of phosphorus in agriculture

(a 3-stage model?)

Stage 3: Today's agriculture.

*Specialized geographic focus, cropping separate from animal production, "spoiled" **Fast-Growing Lazy Plants (FGLPs)** that rely on easily available P from fertilizer.*

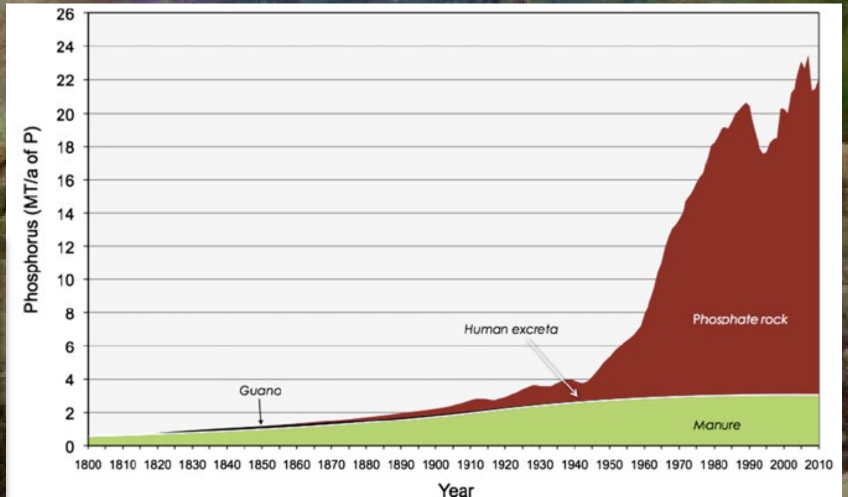
Wizards

IRRI IR8 50 Years

The rice variety that initiated the "Green Revolution"

Ch 5: Phosphorus Growing

Wizards



Wizards

source: wikimedia commons

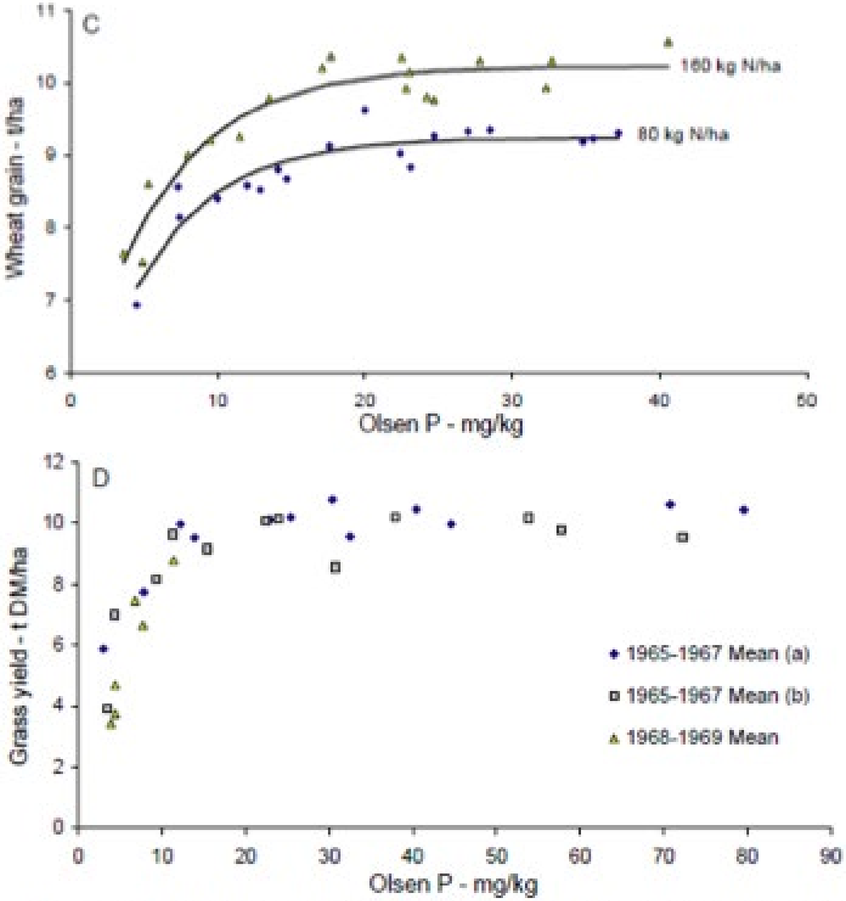
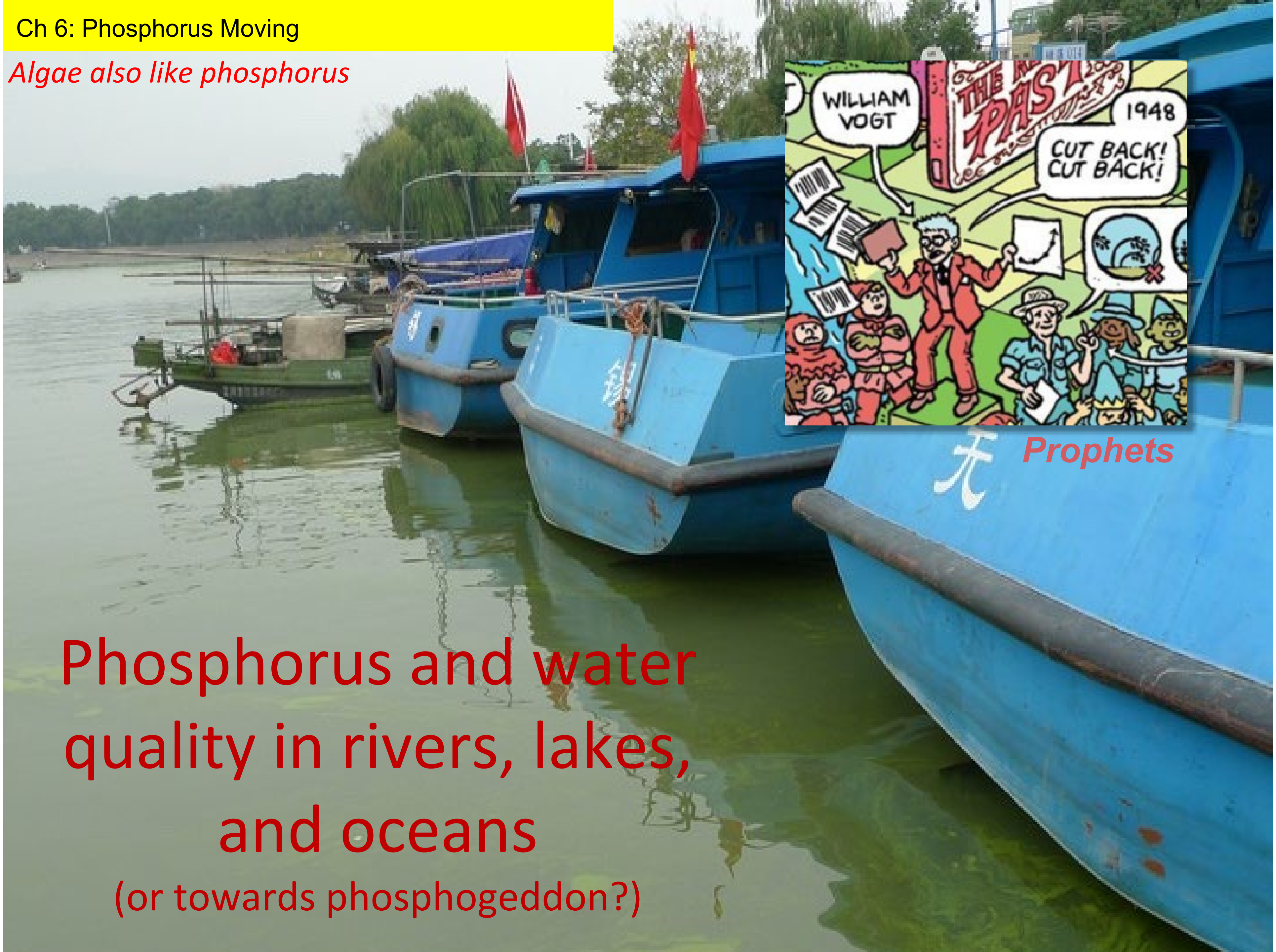


Figure 5: *Relationship between Olsen P and the yield of three arable crops and of grass. (Johnston, 2001; Johnston et al., 2001a).*

Algae also like phosphorus



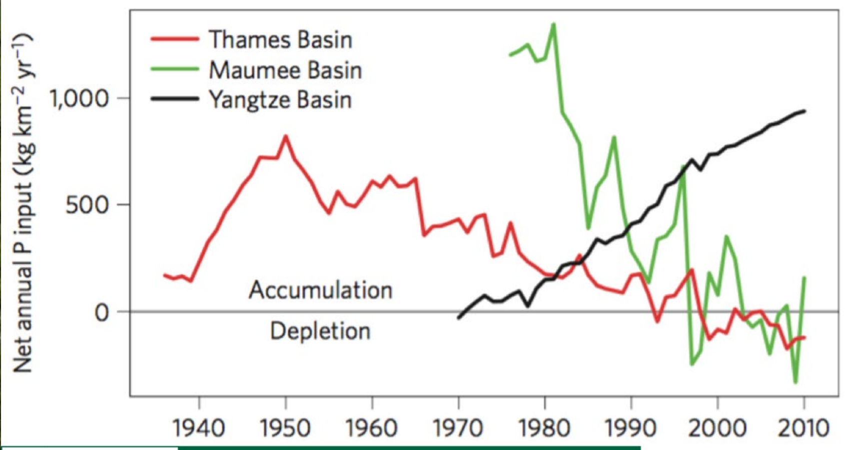
Prophets

Phosphorus and water quality in rivers, lakes, and oceans

(or towards phosphogeddon?)

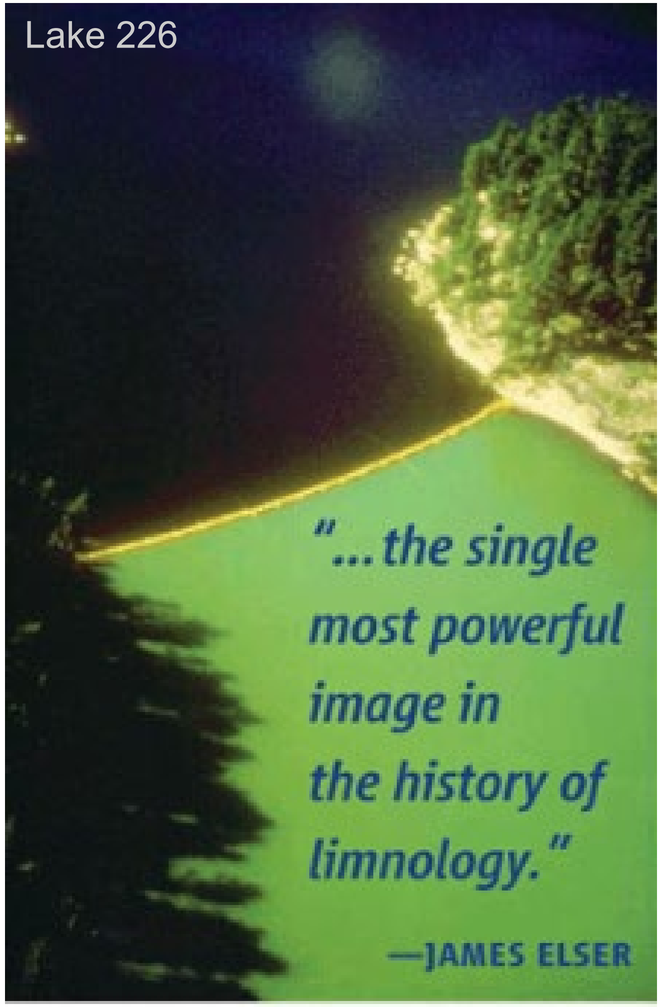
- Cleaning up phosphorus from point sources in detergents and sewage *(a success story from the last century)*
- The emergence of non-point (diffuse) pollution - a 21st century ‘wicked’ problem

The emergence of the legacy concept



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]



Prophets

Cleaning up diffuse P water pollution

Complex - but success stories emerging…

Is there an opportunity to redesign the landscape for sustainable intensification?

Prophets

Climate change to accelerate phosphogeddon?

- Predicted increase in winter P loads due to climate change (up to 30% by 2050s)
- 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

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]

#stormdesmond

Catastrophic flooding & P release

The New York Times

Lagoons of Pig Waste Are Overflowing After Florence. Yes, That's as Nasty as It Sounds.

A hog farm in eastern North Carolina on Monday. The pink area is a lagoon of pig excrement. Rodrigo Gutierrez/Reuters

Amid flooding, Omaha puts 65M gallons of untreated sewage into river

The Associated Press Apr 1, 2019 Updated 1 hr ago

This March 17 photo released by the U.S. Air Force shows an aerial view of Areas surrounding Offutt Air Force Base affected by floodwaters in Nebraska.

TECH. SGT. RACHELLE BLAKE, US AIR FORCE VIA AP

MOST POPULAR

Prophets

A dark phosphogeddon?

PHILOSOPHICAL TRANSACTIONS A

rsta.royalsocietypublishing.org

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

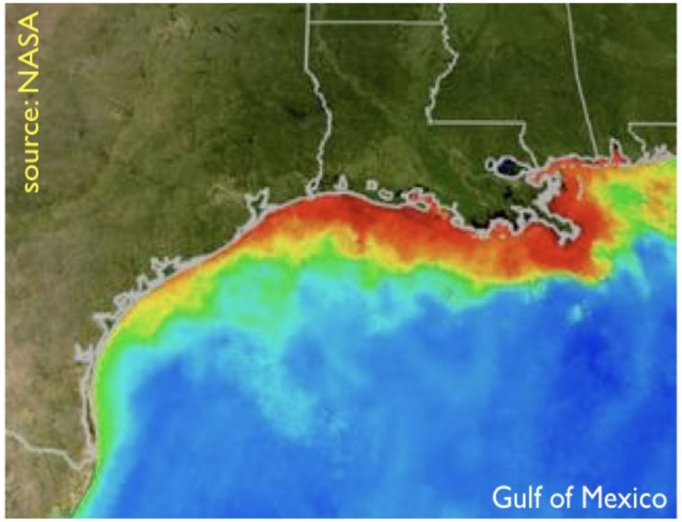
Accepted: 21 June 2017

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

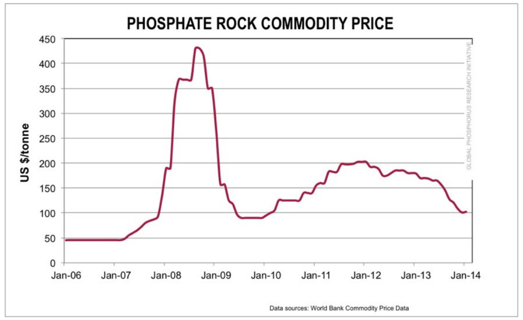
Andrew J. Watson[1], Timothy M. Lenton[1] and Benjamin J. W. Mills[2]

[1]Earth System Science Group, College of Life and Environmental Sciences, University of Exeter, Exeter EX4 4QE, UK
[2]School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK

AJW, 0000-0002-9654-8147



The global phosphorus sustainability movement 2003 - now…



SERA-17
2003

Global Phosphate Forum
2007

Global Phosphorus Research Initiative
2008

リン資源リサイクル推進協議会
Phosphorus Recycling Promotion Council
2008

International Conference on Nutrient Recovery from Wastewater Streams
2009

Welcome to the GLOBAL PHOSPHORUS NETWORK
2010

Nutrient Platform NL
2010

P
2010

SPS
2011

PhosphOR
2011

Vlaams Nutriëntenplatform
2012

INEMAD
2012

P-REX
2012

NSF
P-RCN 2013

European Sustainable Phosphorus Platform
2013

Deutsche Phosphor Plattform
2013

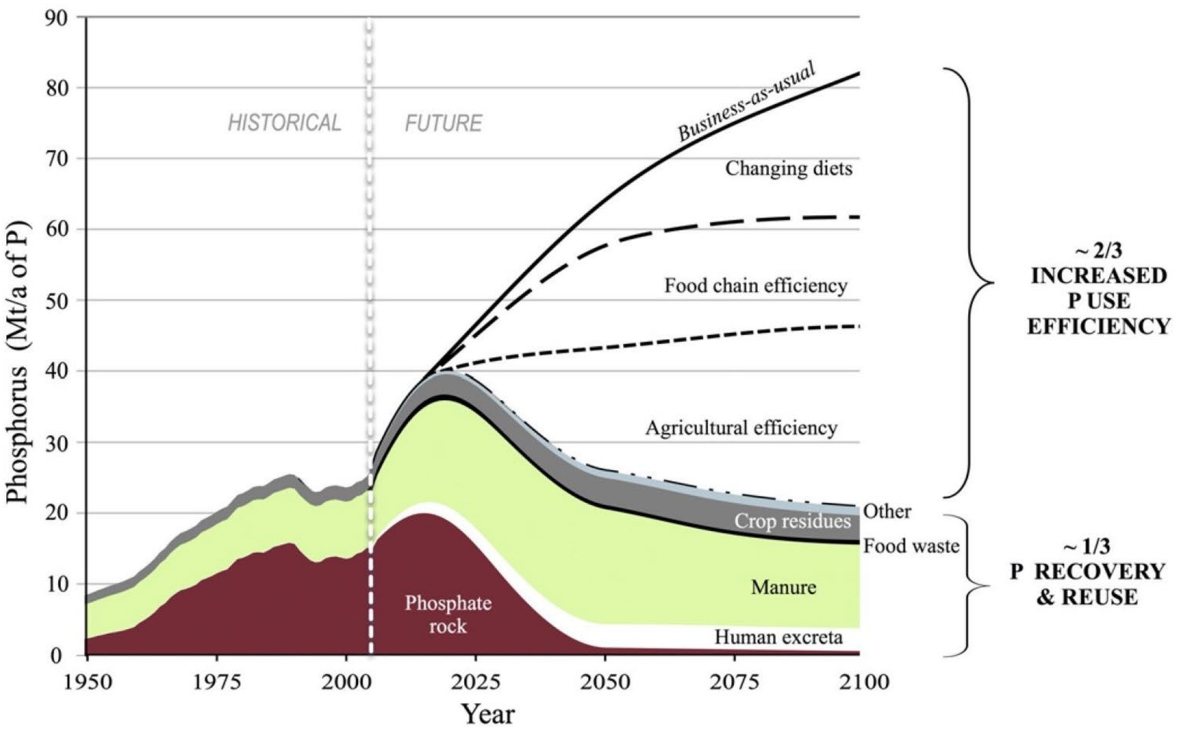
Ontario
CCME
Canadian Council of Ministers of the Environment
Le Conseil canadien des ministres de l'environnement
2013

The Grand Challenge
A $10 Million Science Prize
2014

SPA 2015

United Nations Environment Programme
UNEP
Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)
GPNM 2015 ? UNEP GPA 2016

Ch 8: Phosphorus Transforming: Part 1

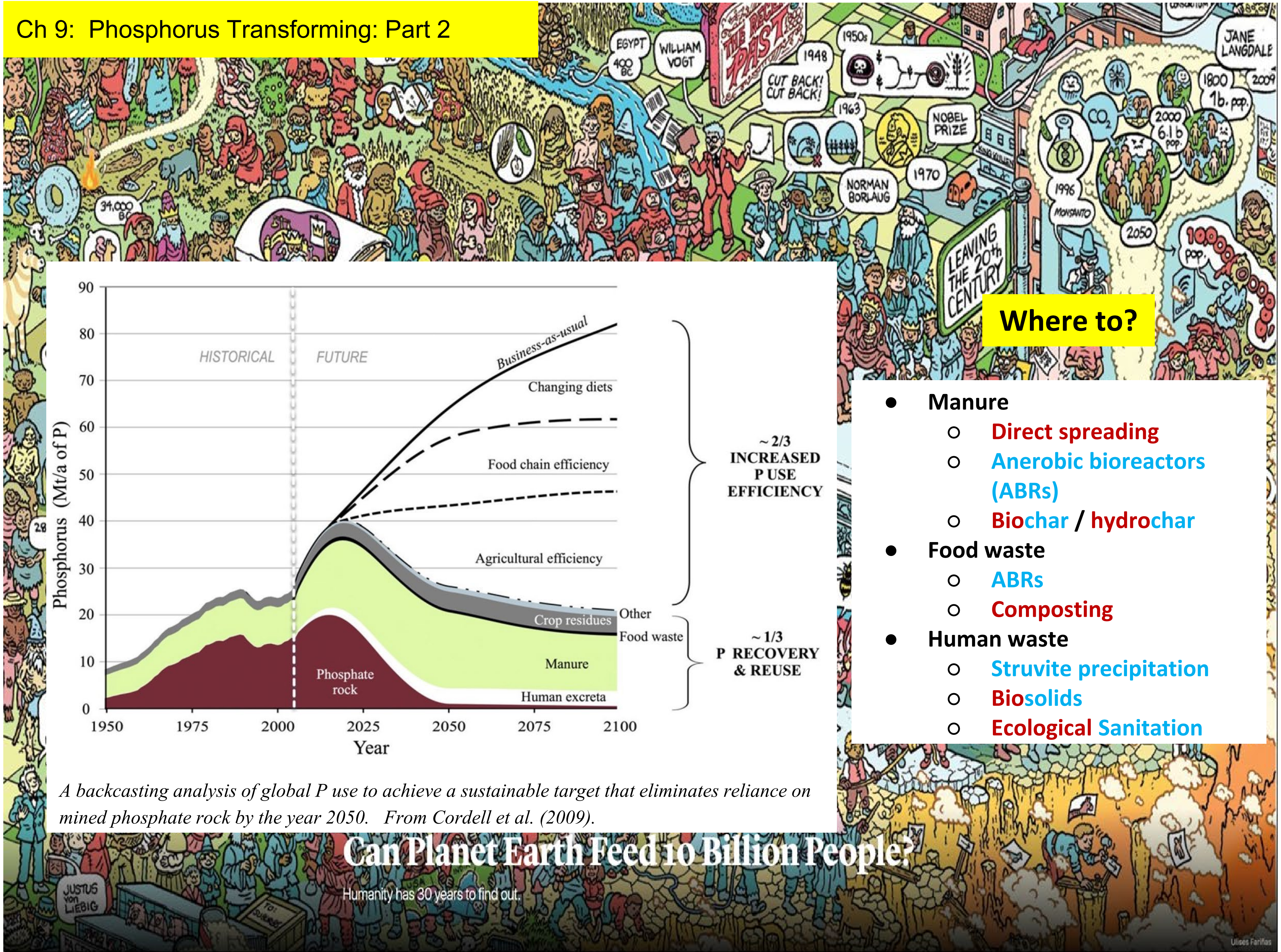


A backcasting analysis of global P use to achieve a sustainable target that eliminates reliance on mined phosphate rock by the year 2050. From Cordell et al. (2009).

Where to?

- Population size?
- P use efficiency in crops
  - 4Rs
  - Annualize crops
  - Turn FGSPs into FGIPs (GM, CRISPR-CAS 9)
- Reduce non-human-food agriculture
- P use efficiency in animal production
  - 4Rs for cows?
  - Phytase
- Food chain efficiency
  - Food waste
  - Diets
  - Artificial meat

Ch 9: Phosphorus Transforming: Part 2

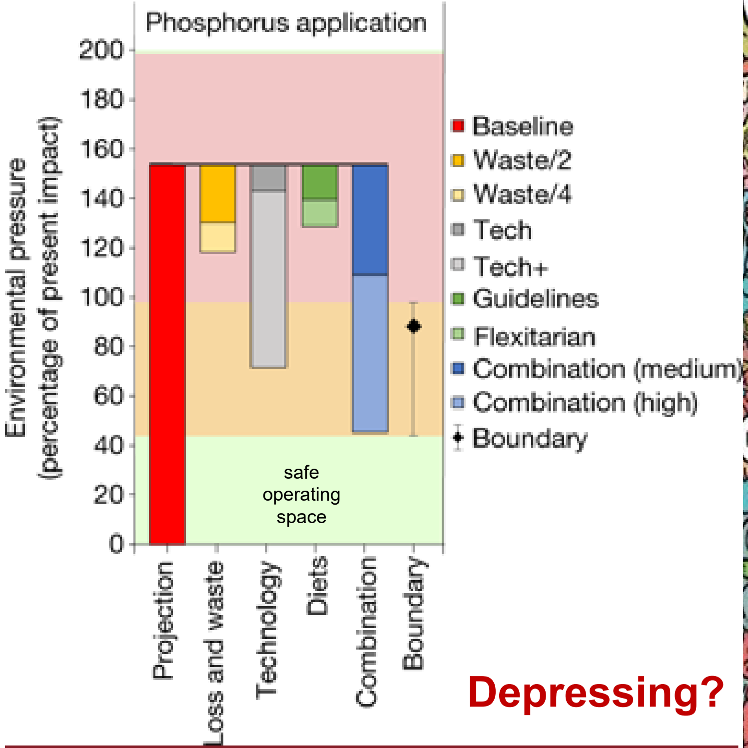


A backcasting analysis of global P use to achieve a sustainable target that eliminates reliance on mined phosphate rock by the year 2050.   From Cordell et al. (2009).

Where to?

- Manure
  - Direct spreading
  - Anerobic bioreactors (ABRs)
  - Biochar / hydrochar
- Food waste
  - ABRs
  - Composting
- Human waste
  - Struvite precipitation
  - Biosolids
  - Ecological Sanitation

Ch 10: Phosphorus Sustaining



Depressing?

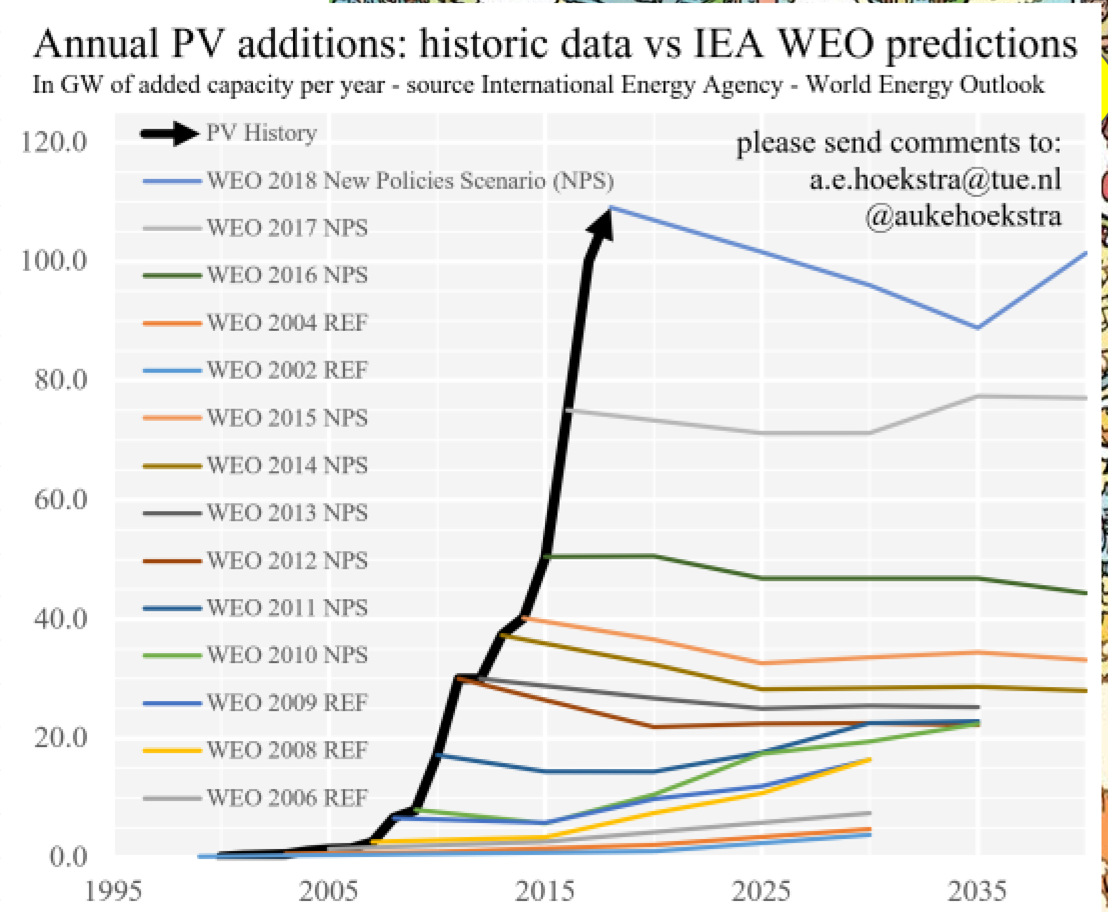
nature
International journal of science

Article | Published: 10 October 2018

Options for keeping the food system within environmental limits

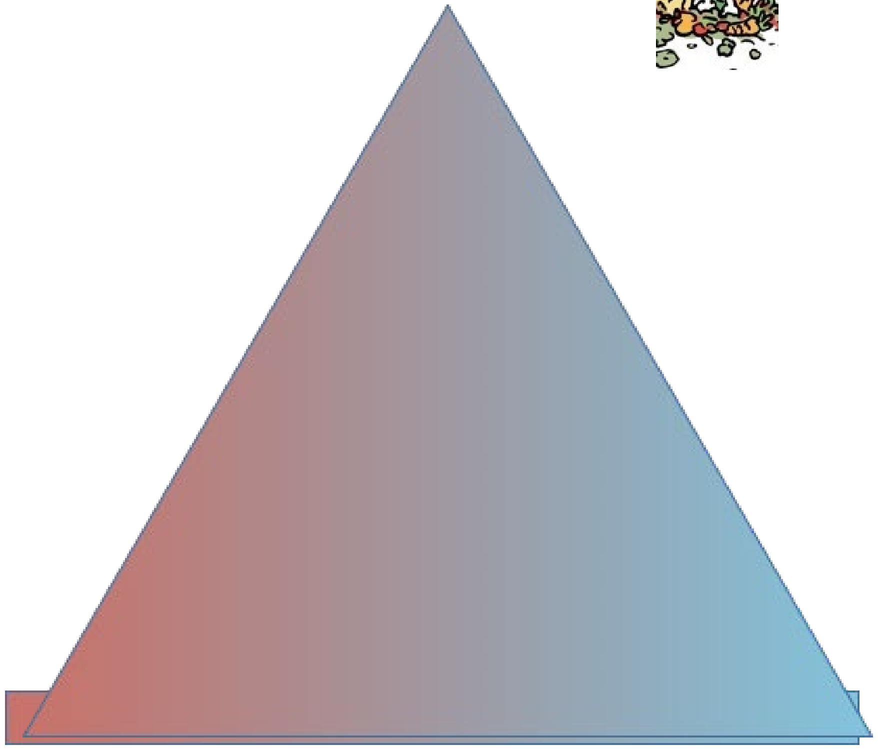
Marco Springmann, Michael Clark, Daniel Mason-D'Croz, Keith Wiebe, Benjamin Leon Bodirsky, Luis Lassaletta, Wim de Vries, Sonja J. Vermeulen, Mario Herrero, Kimberly M. Carlson, Malin Jonell, Max Troell, Fabrice DeClerck, Line J. Gordon, Rami Zurayk, Peter Scarborough, Mike Rayner, Brent Loken, Jess Fanzo, H. Charles J. Godfray, David Tilman, Johan Rockström & Walter Willett

Encouraging?



So how do we make the changes that will transform the phosphorus world?

Systems Innovators



Prophets

vs

Wizards

This why we are here today.
What systems innovations can be accelerated to achieve "Phospho-heaven"?

Agenda

8:30 – 9:00	Welcome from Jim Elser
9:00 – 9:45	Keynote from Bruce Rittmann
9:45 – 10:00	Coffee sponsored by Ostara
10:00 – 10:30	Phosphorus Field-to-Watershed Modeling Task Force Report by Peter Vadas
10:30 – 11:00	Biosolids and Manure Task Force Report by Rebecca Muenich
11:00 – 12:00	Phosphorus Sustainability Challenge by Matt Scholz
12:00 – 1:30	Lunch sponsored by OCP
12:30 – 1:00	Keynote from Kathleen Merrigan
1:30 – 2:00	Algae Removal Program by James Gaspard
2:00 – 2:15	ReNEW Water Project by Patrick Dube
2:15 – 2:30	Closing comments from Jim Elser
2:30 – 3:00	Room open for networking

Minimizing P Loss, Maximizing Value

Bruce E. Rittmann
Director, Biodesign Swette Center for Environmental Biotechnology
Regents' Professor of Environmental Engineering
Arizona State University

Rittmann@asu.edu

environmentalbiotechnology.org

Biodesign Swette Center for Environmental Biotechnology

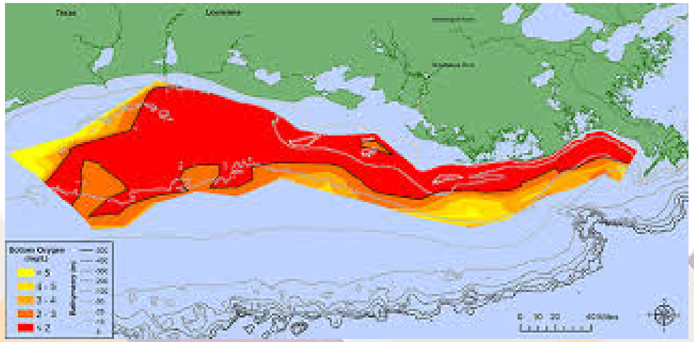
www.biodesign.asu.edu

Context: Outputs from the Sustainable-P Research Coordination Network

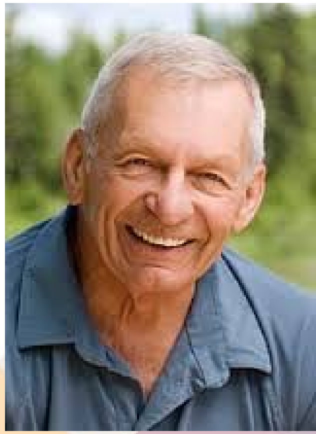
1. Sustainable Phosphorus Alliance (SPA)
2. Elser, J. J. and B. E. Rittmann (2013). “The dirty way to feed 9 billion people.” Future Tense article in *Slate*. Washington, DC, December 25., 2013.

What's the main driver for P sustainability?

- It is not running out of phosphate!
- It is the impact of phosphate discharges on water quality.
  - Eutrophication
  - Hypoxia -- ~ 450 hypoxic zones worldwide



David Schindler (U. Alberta) won the first Stockholm Water Prize for documenting the role of phosphate inputs on eutrophication



The SWP Award Ceremonies

August 29, 2018, The Blue Room, Stockholm City Hall

Bruce Rittmann

Crown Princess Victoria

Mark van Loosdrecht,
Delft Technical University

The "Royal Dinner" in the Gold Room

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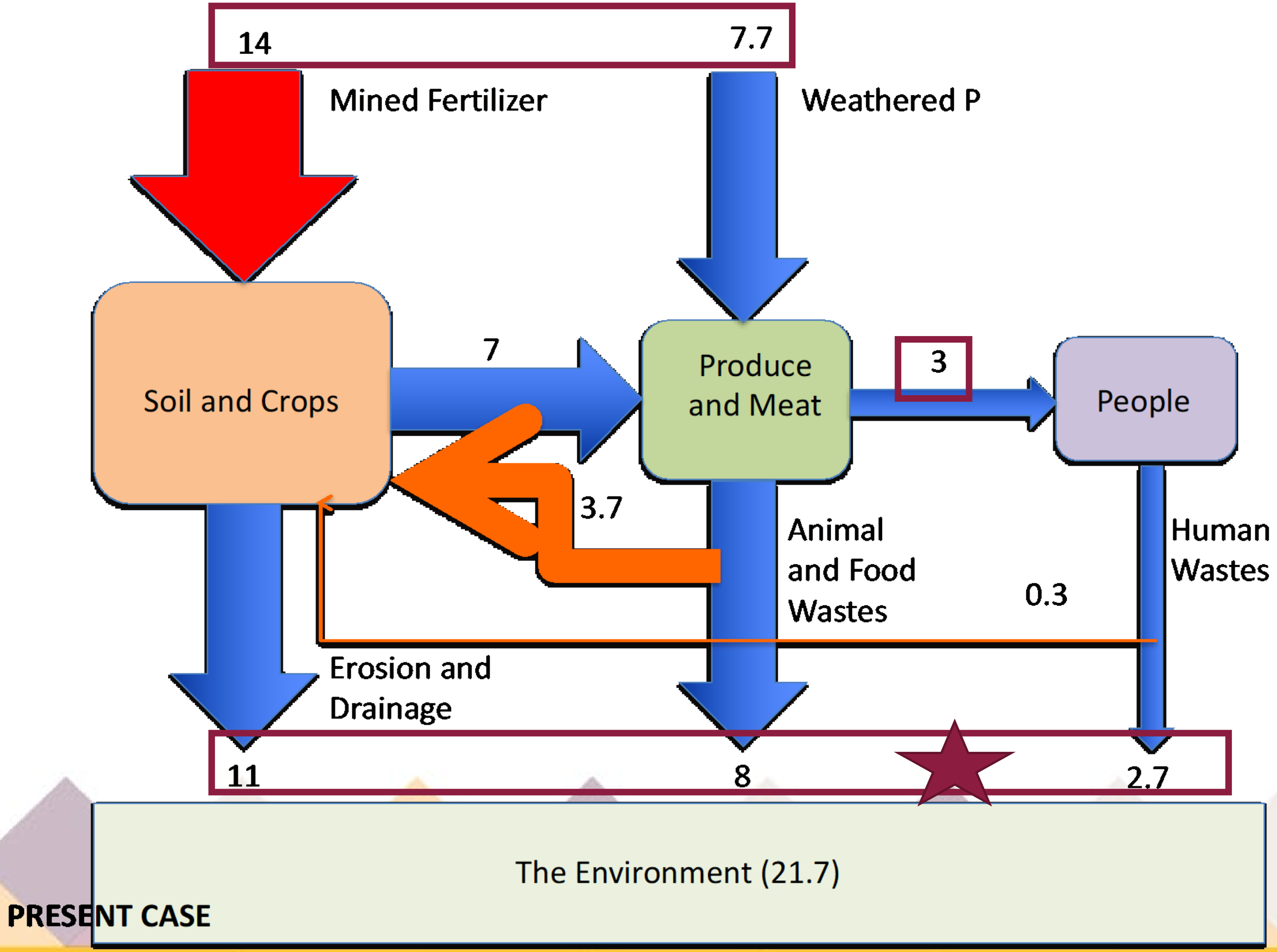
Global P flows now (million metric tonnes per year)



IIllustrations by Elser and Rittmann based on published work by Dana Cordell and co-workers.

Organic Wastes

Address the ~50% of P from organic waste streams

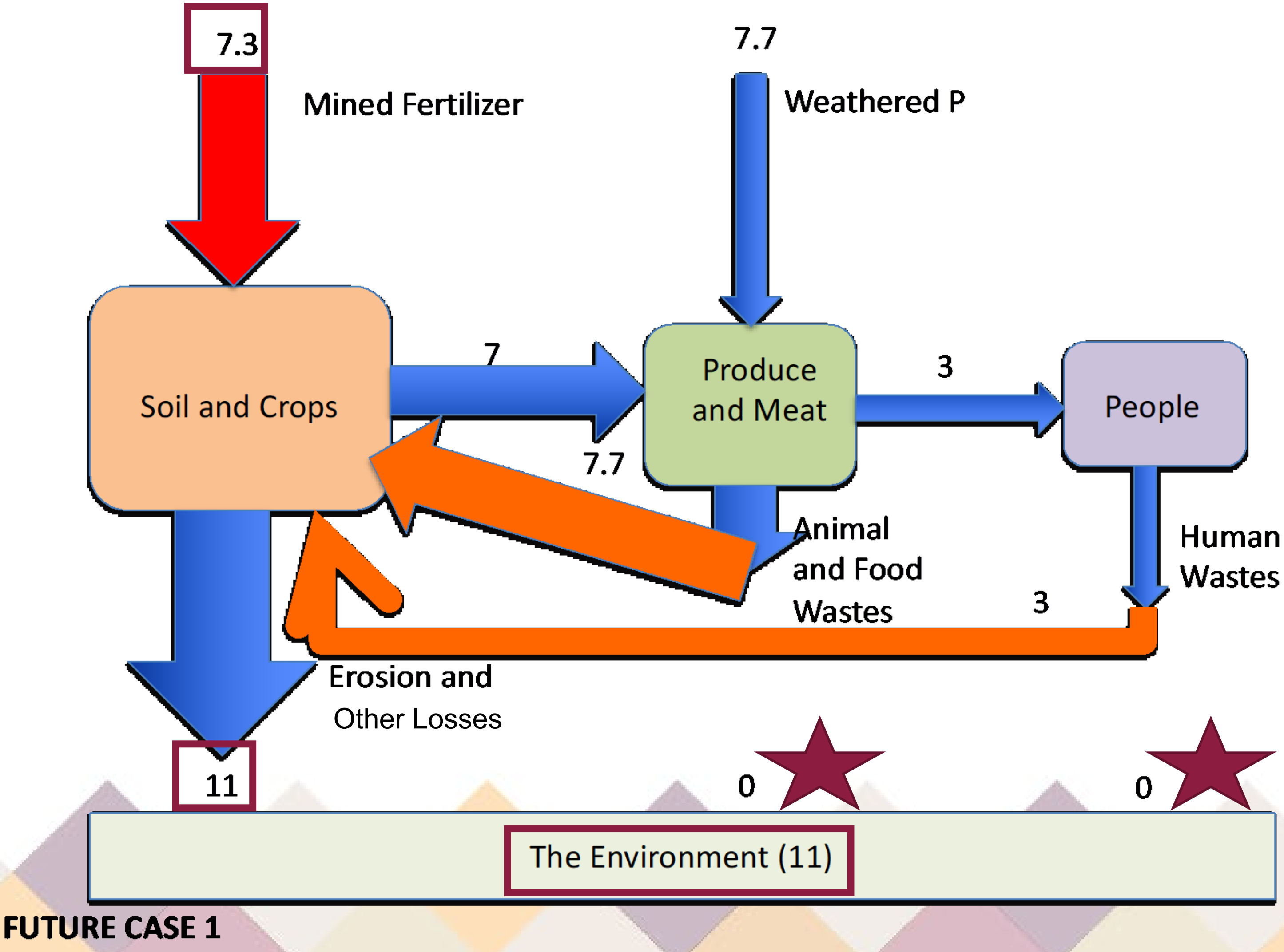
Can get value from ENERGY and P

Future Case 1 – Capture P and energy from organic wastes

Recover 100% of animal, food, and human wastes.

This cuts fertilizer use by 48%.

It cuts environmental inputs by 49%.



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The BIG ENERGY is in animal wastes

Major Sources in the USA today	Million Dry Tons Per Year (USA)	Percent
Animal Wastes	335	55*
Food Processing	113	19
Pulp and Paper	149	25
Municipal Wastewater	7	1
Total	604	100

*Equals about 5% of total USA energy demand

Animal Wastes in the USA

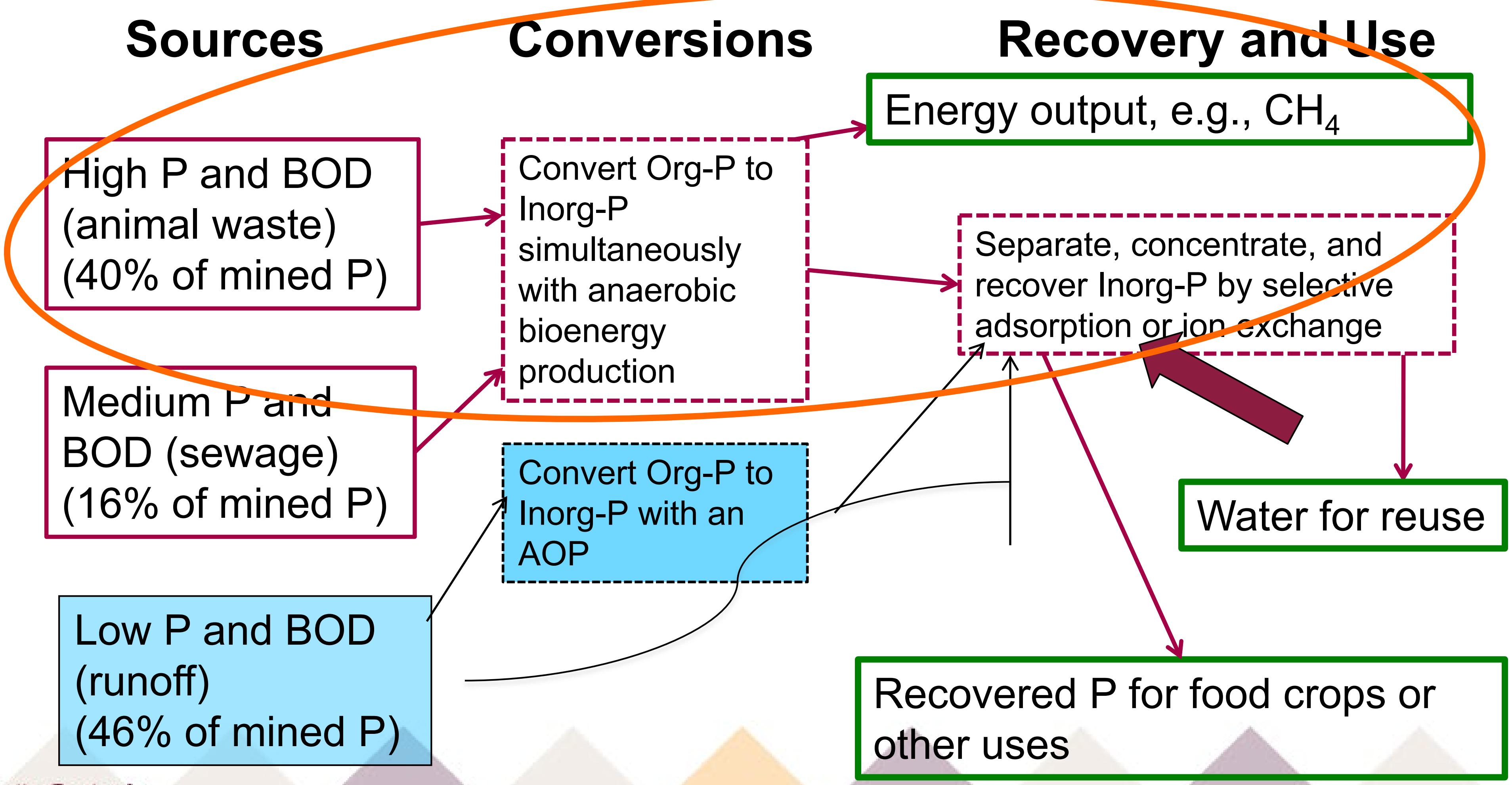
Animal Type	Amount, millions dry tons per year	Percentage of all Biomass
Cattle	253	42
Swine	31	5
Poultry	51	8
Total	335	55

Only about 3.6 million tons per year (~1%) are subject to energy recovery today – low-hanging fruit

For animal wastes, anaerobic digestion

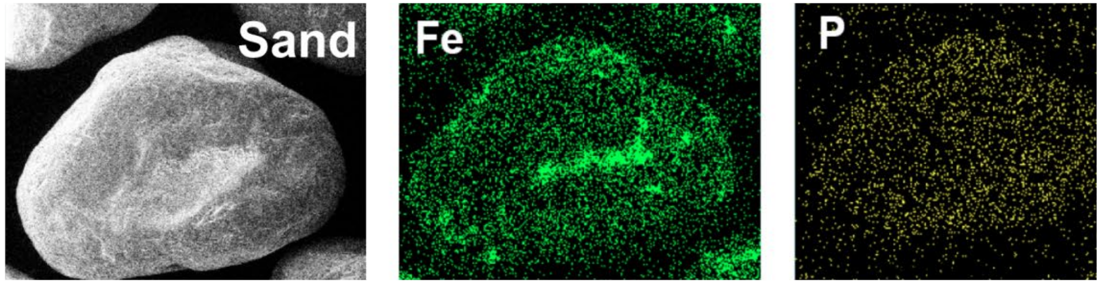
- Well-known and proven; simple or sophisticated
- Generates widely useful methane gas (CH_4); it's C-neutral, too.
- Enhanced by effective pre-treatment to digest more solids and make more CH_4
- Releases inorganic phosphate for capture

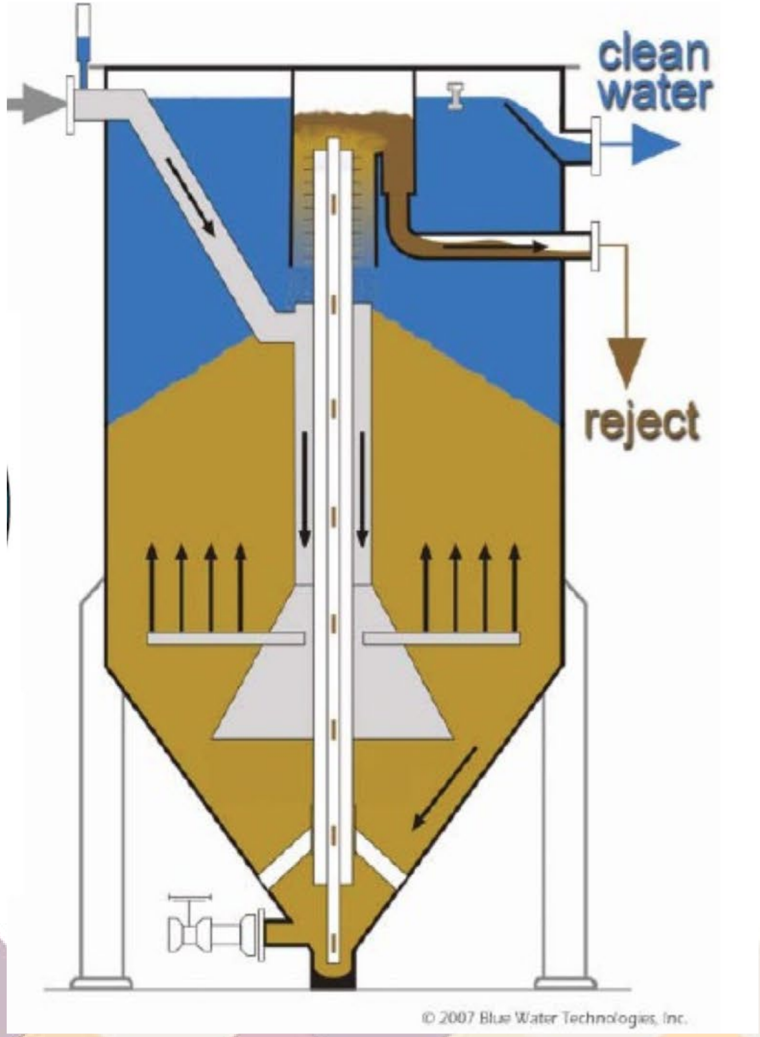
P-recovery strategy (similar for N)



Hydrous Ferric Oxide Filter

BluePRO® technology from Blue Water Technologies





Run-off

Address the ~50% of P from run-off

Much harder to do, but necessary

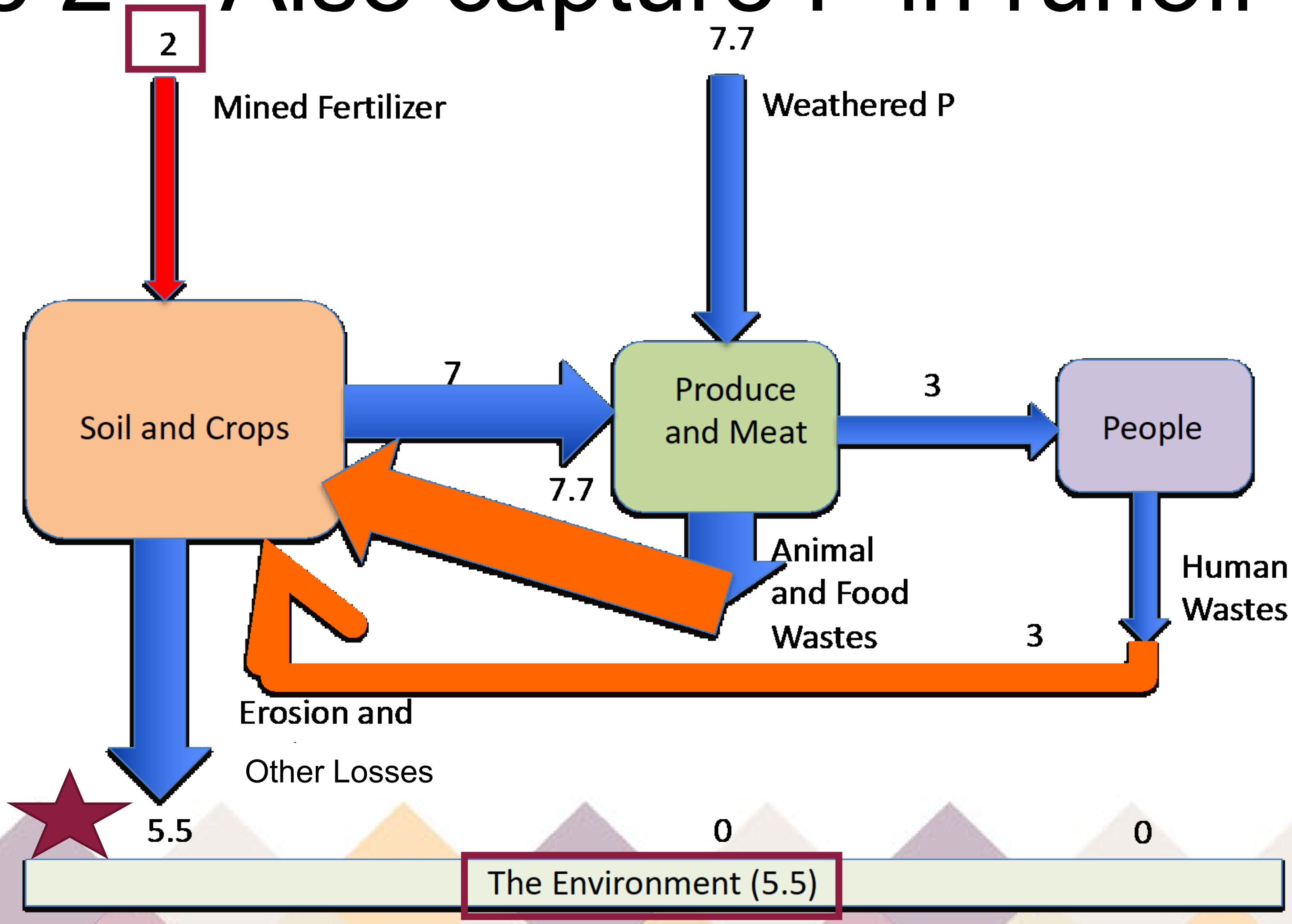
Future Case 2 – Also capture P in runoff

Recover 100% of animal, food, and human wastes.

Reduce erosion and other losses losses by 50%.

It cuts mined P use by 86%.

It cuts environmental P loading by 80%.



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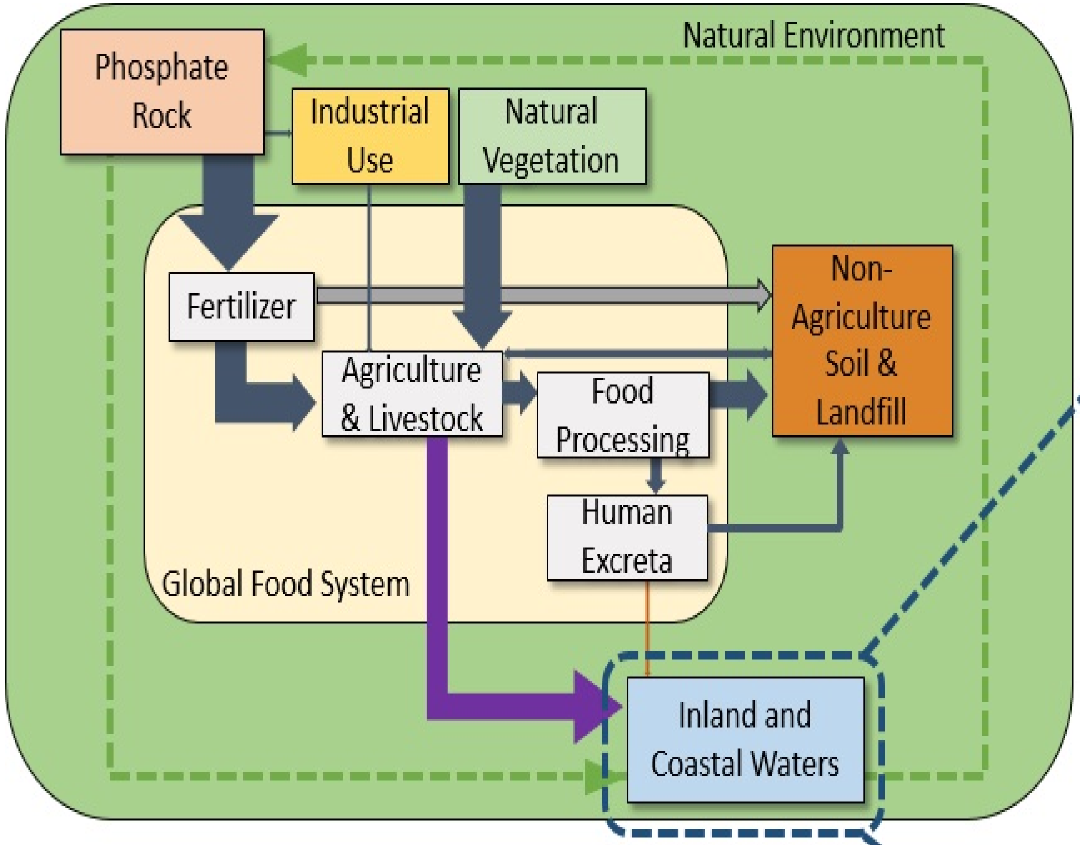
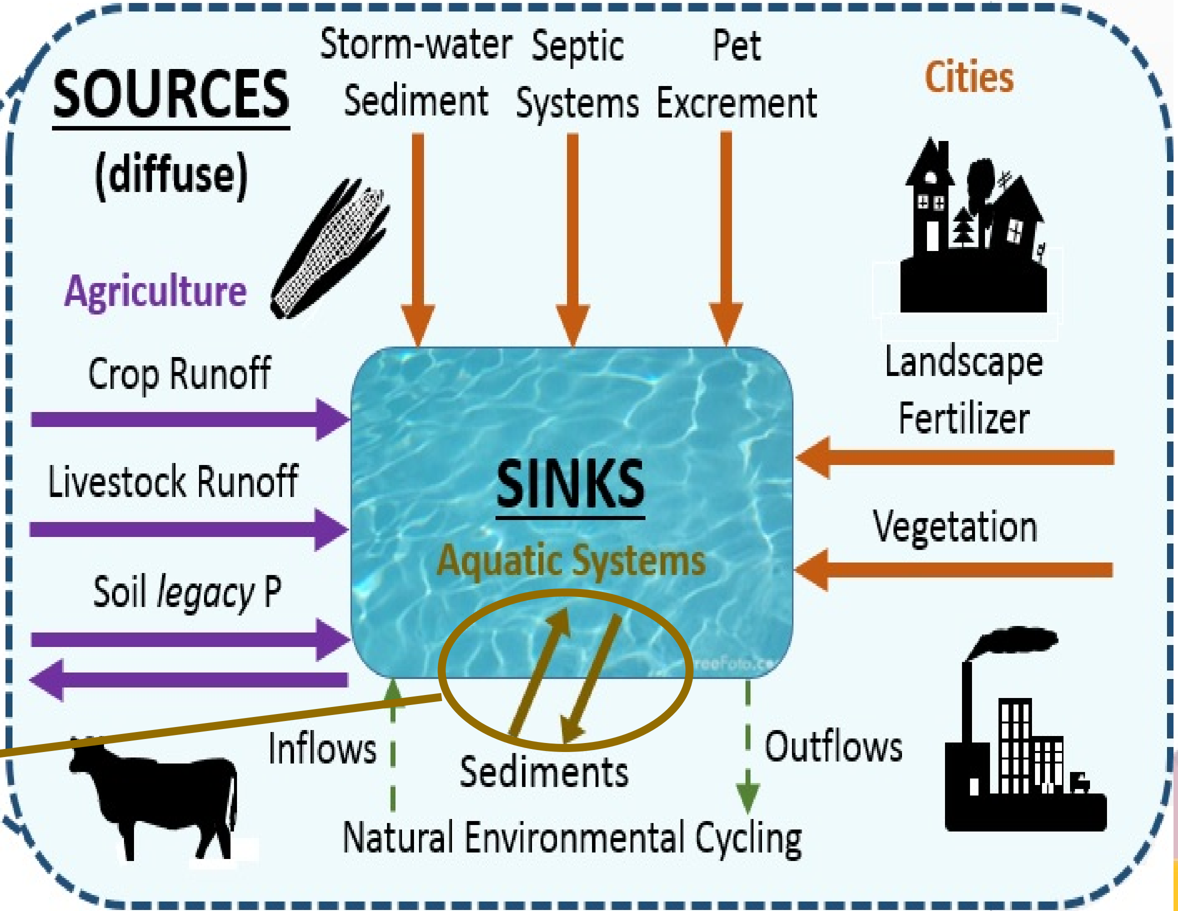
4. Macintosh, K. A., B. K. Mayer, R. W. McDowell, S. M. Powers, L. A. Baker, T. H. Boyer, and B. E. Rittmann (2018). "Managing diffuse phosphorus at the source versus at the sink." *Environ. Sci. Technol*. 52: 11995-12009.

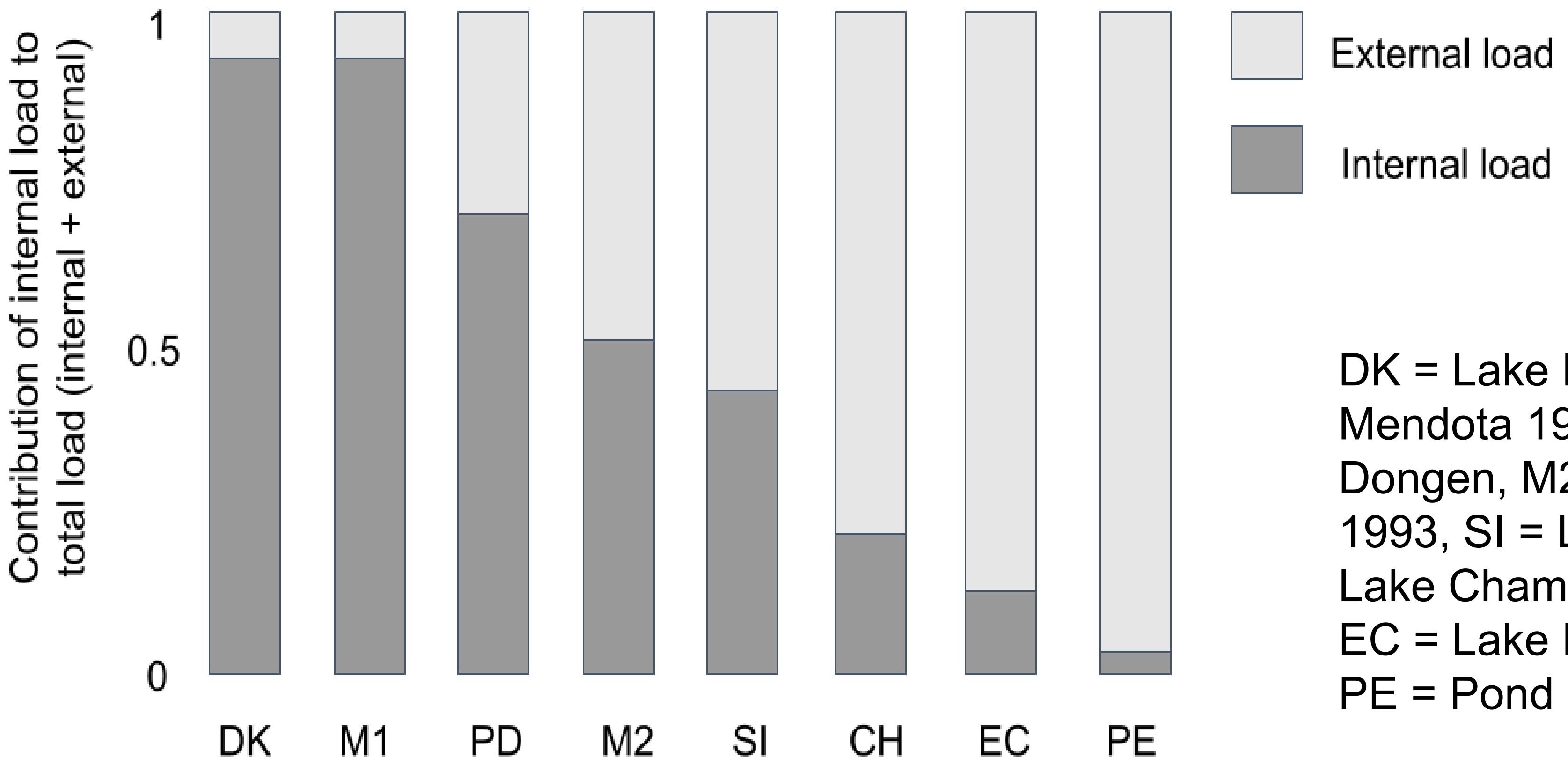
P sources are many and complex





Internal loads can be important
i.e., cumulative, legacy run-off

Relative P loads vary widely



DK = Lake De Kuil, M1 = Lake Mendota 1992, PD = Pond Dongen, M2 = Lake Mendota 1993, SI = Lake Simcoe, CH = Lake Champlain-Missisquoi Bay, EC = Lake Erie-central basin, and PE = Pond Eindhoven.

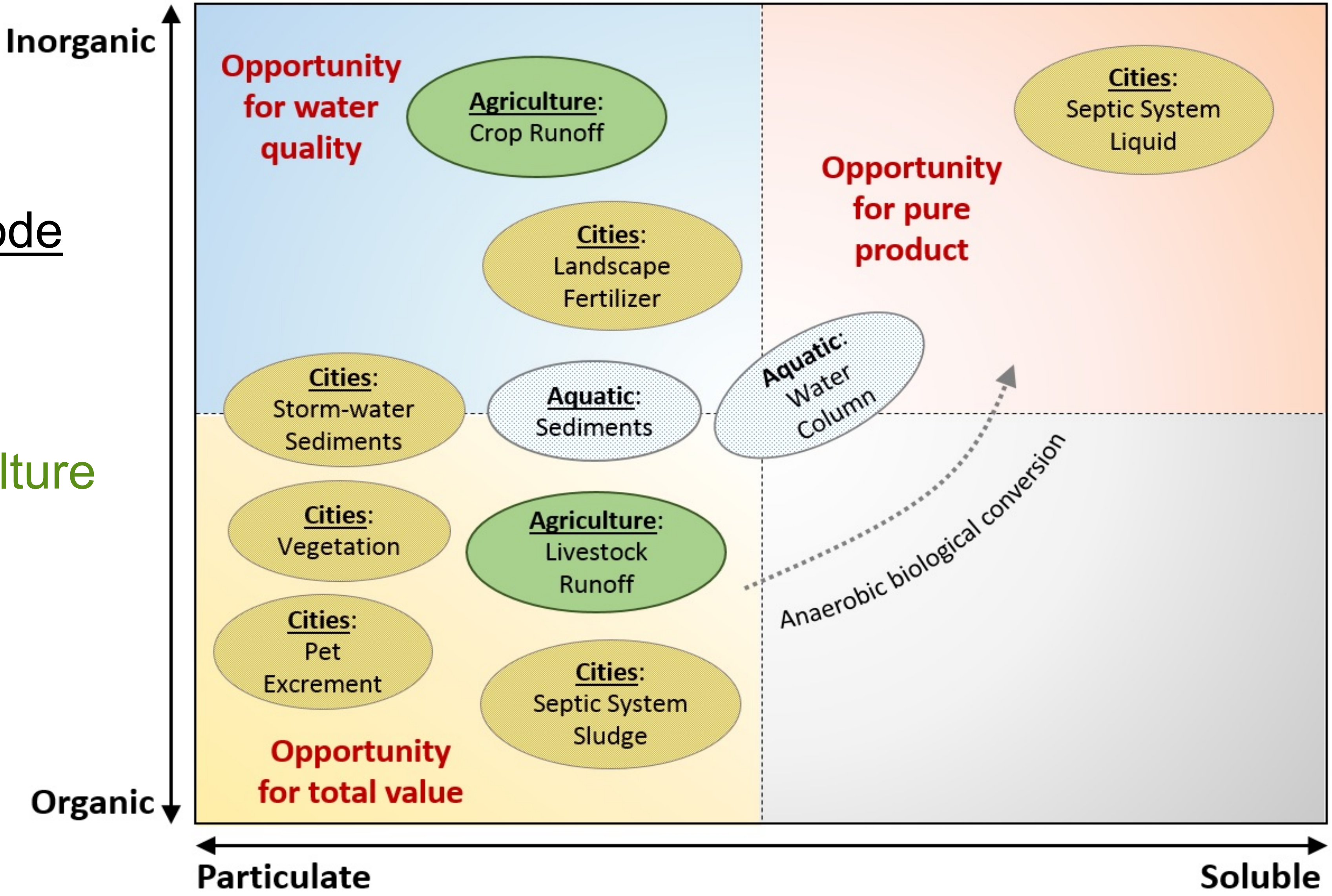
P-form matrix identifies opportunities

Source Color Code

Brown for urban

Green for agriculture

Grey for internal

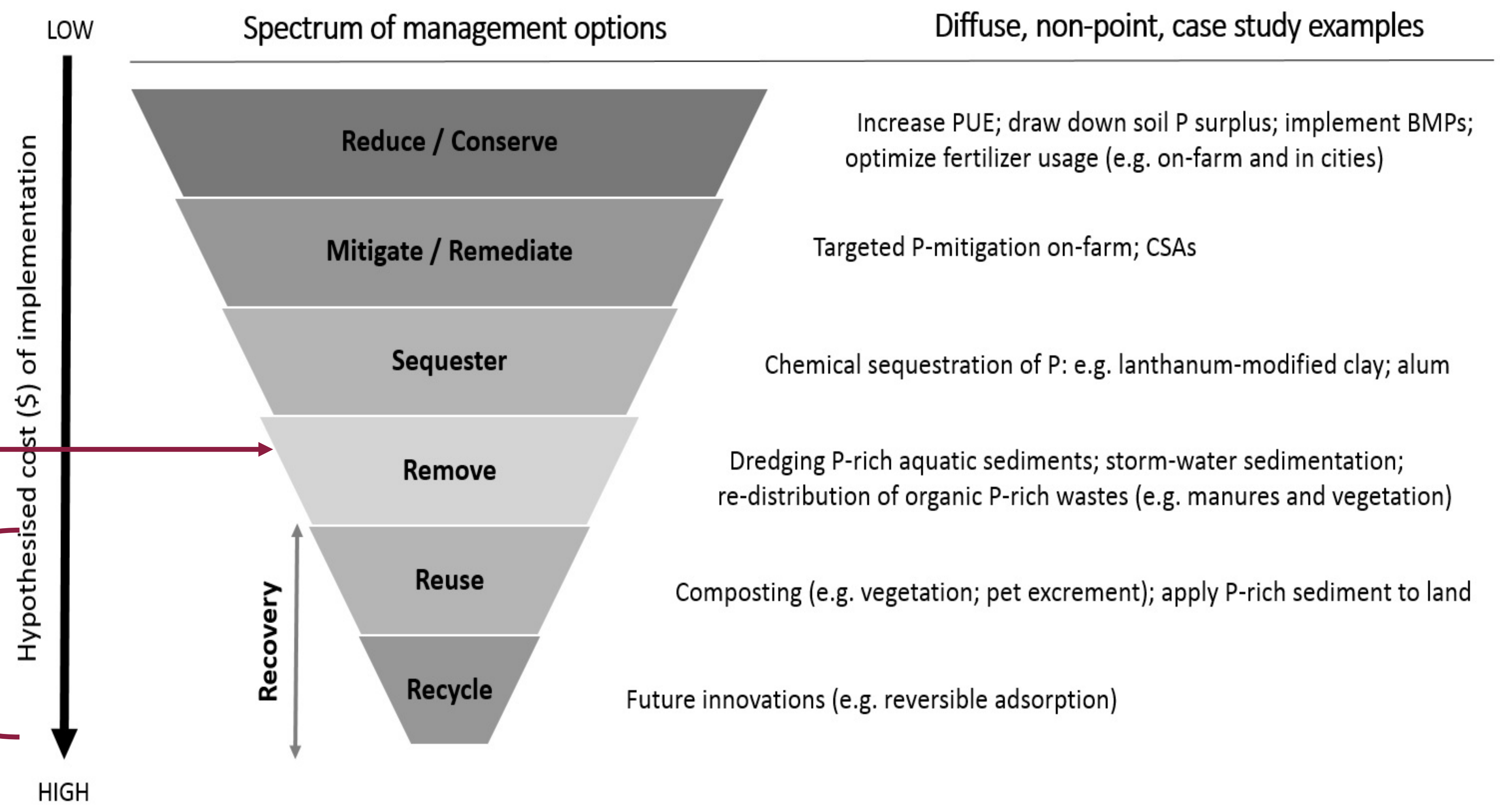


Tiered system of options for diffuse-P management

Mostly today

Key for internal sources

Needed for full implementation of Future Case 2



Diet

Require less P use by producing less grain for animals

A social issue, not technical

Context: Outputs from the Sustainable-P Research Coordination Network

1. Sustainable Phosphorus Alliance (SPA)
2. Elser, J. J. and B. E. Rittmann (2013). "The dirty way to feed 9 billion people." Future Tense article in *Slate*. Washington, DC, December 25., 2013.
3. Mayer, B., L. Baker, T. Boyer, P. Dresche, J. Gifford, M. Hanjra, P. Parameswaran, J. Stoltfus, P. Westerhoff, and B. E. Rittmann (2016). "Total value of phosphorus recovery." *Environ. Sci. Technol.* 50: 6606-6620.
4. Macintosh, K. A., B. K. Mayer, R. W. McDowell, S. M. Powers, L. A. Baker, T. H. Boyer, and B. E. Rittmann (2018). "Managing diffuse phosphorus at the source versus at the sink." *Environ. Sci. Technol*. 52: 11995-12009.
5. Metson, G., E. Bennett, and J. J. Elser (2012). "The role of diet in phosphorus demand." Environ. Res. Letters 7: 044043.

Future Case 3: Also change diet

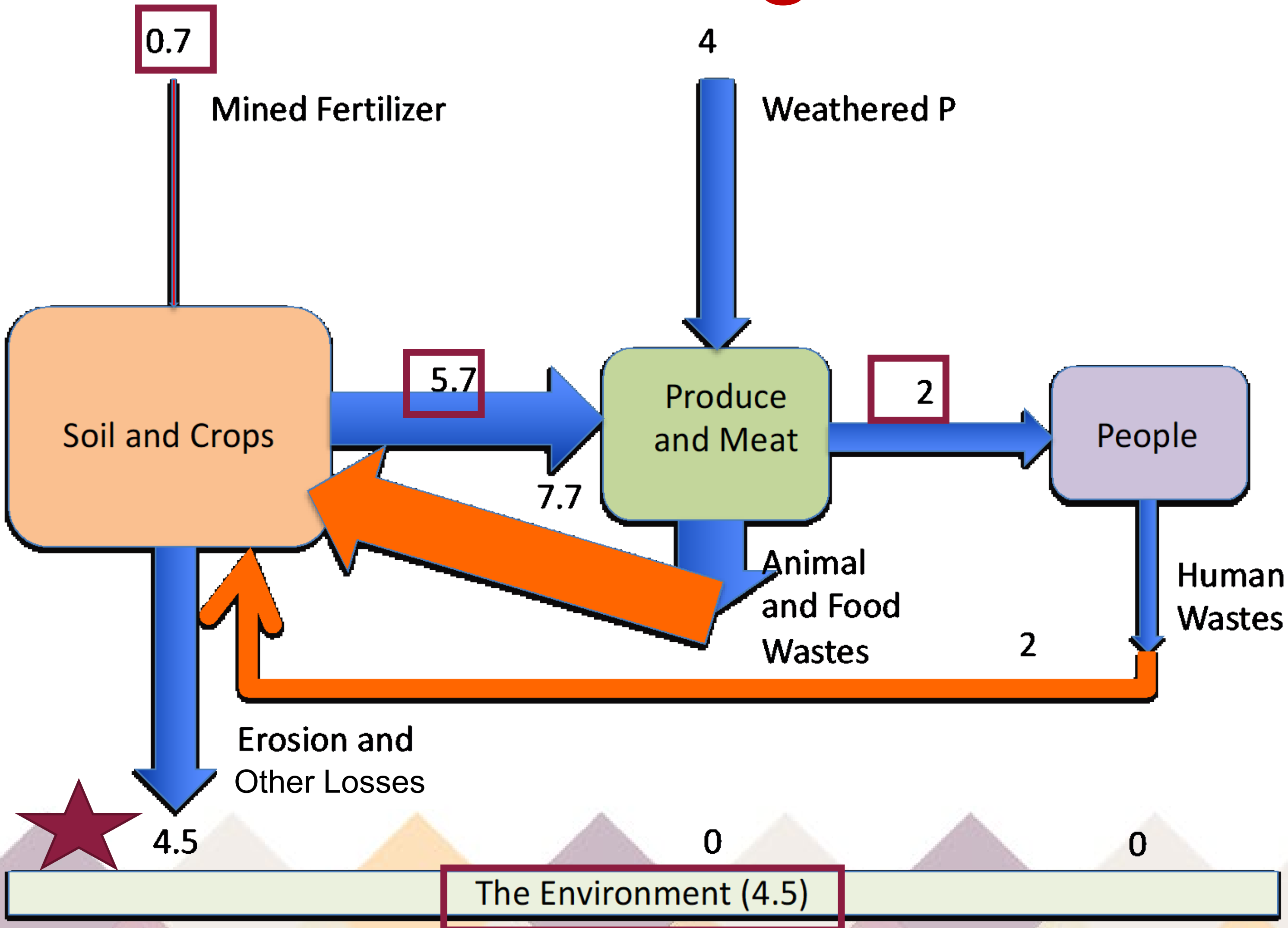
Recover 100% of animal, food, and human wastes.

Reduce erosion and other losses by 50%.

Cut meat consumption by 50%.

This cuts fertilizer use by 95%.

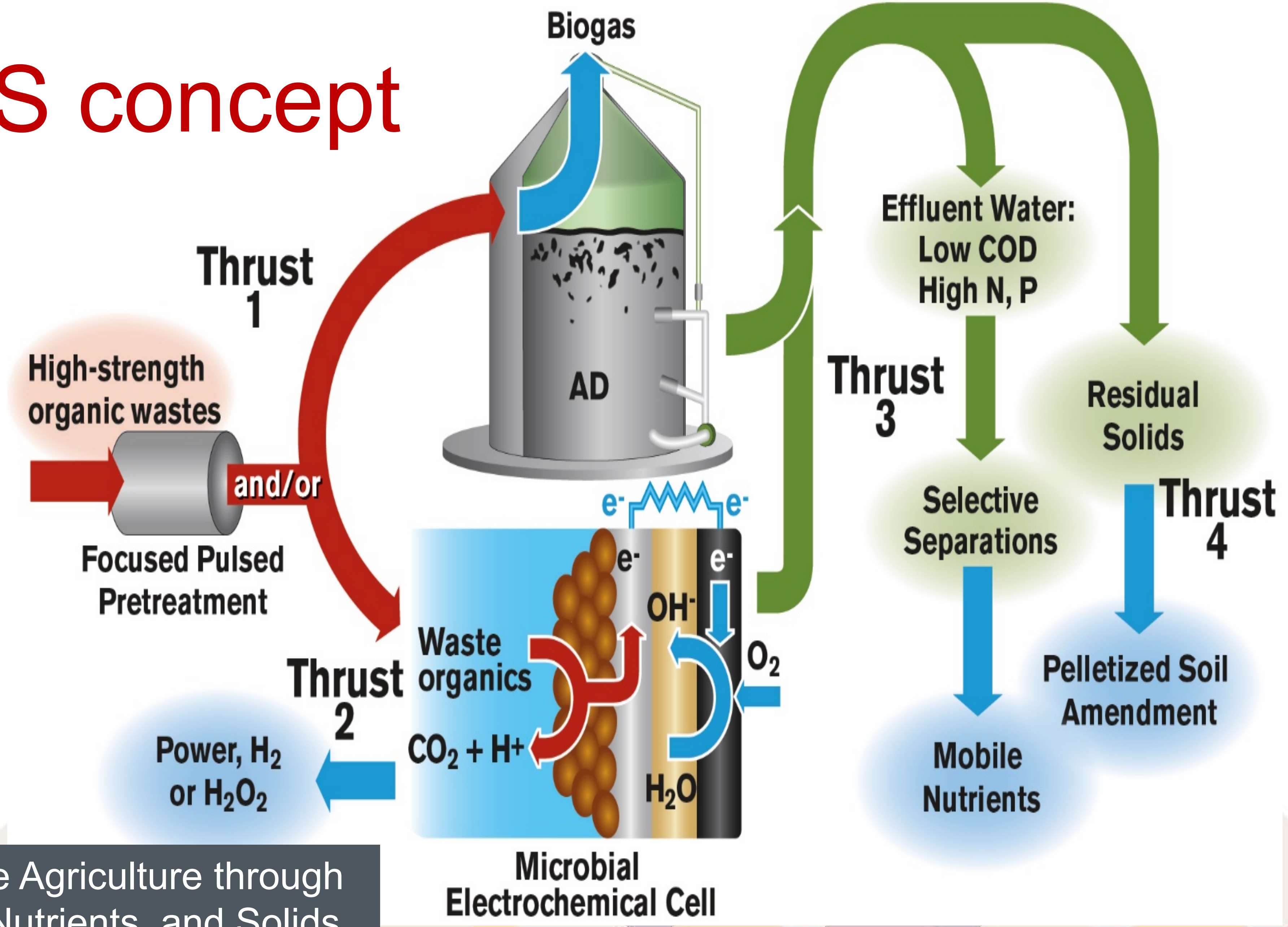
It cuts environmental P discharge by 80%.



Take-home lessons

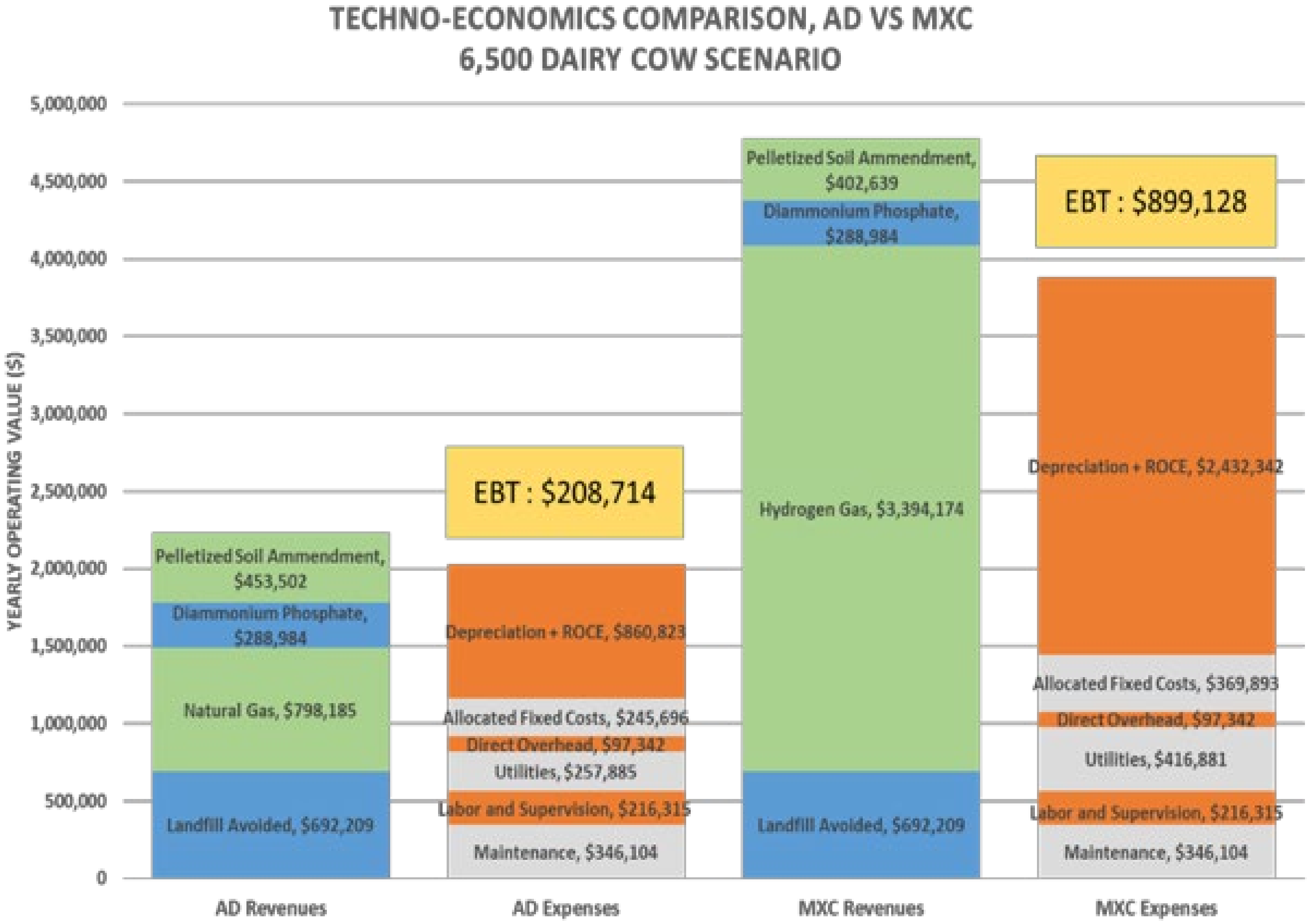
- The first big step is to capture P and energy from organic waste streams, particularly animal wastes

PARENS concept



PARENS = Profitable Agriculture through Recovered Energy, Nutrients, and Solids

Value Proposition for PARENS



EBT = earnings before taxes

Take-home lessons

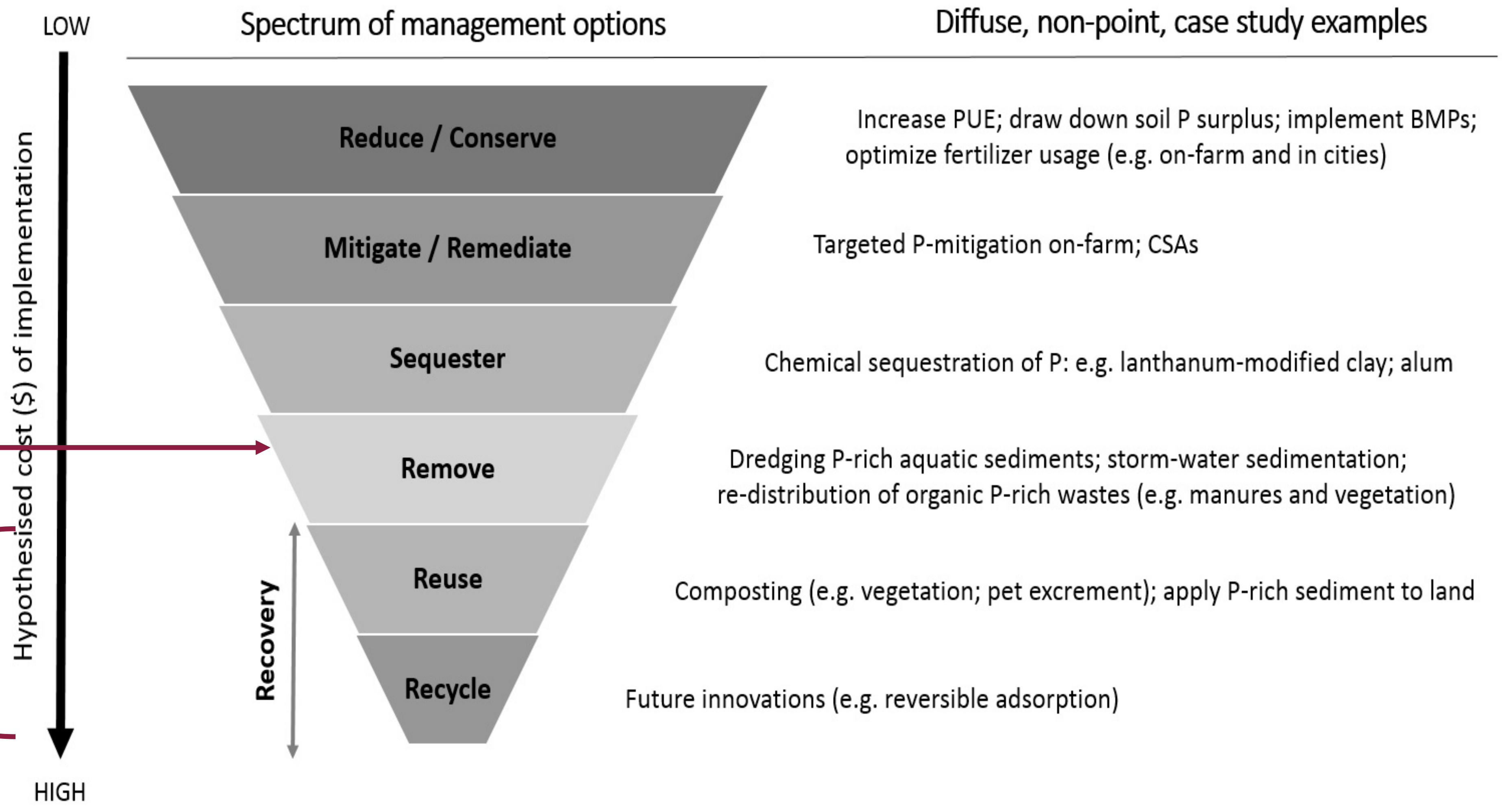
- The first big step is to capture P and energy from organic waste streams, particularly animal wastes. It is at hand now.
- The second big step to remove and (hopefully) recover P from diffuse sources, such as run-off and sediments. This is hard to do, but we have to start.

Tiered system of options for diffuse-P management

Mostly today

Key for internal sources

Needed for full implementation of Future Case 2



Take-home lessons

- The first big step is to capture P and energy from organic waste streams, particularly animal wastes. It is at hand now.
- The second big step to remove and (hopefully) recover ~ 50% of P from diffuse sources, such as run-off and sediments.   This is hard to do, but we have to do it.
- To finish the job, we probably will need to shift the human diet away from so much meat. This is bucking international trends, but it has good P-mitigation leverage.

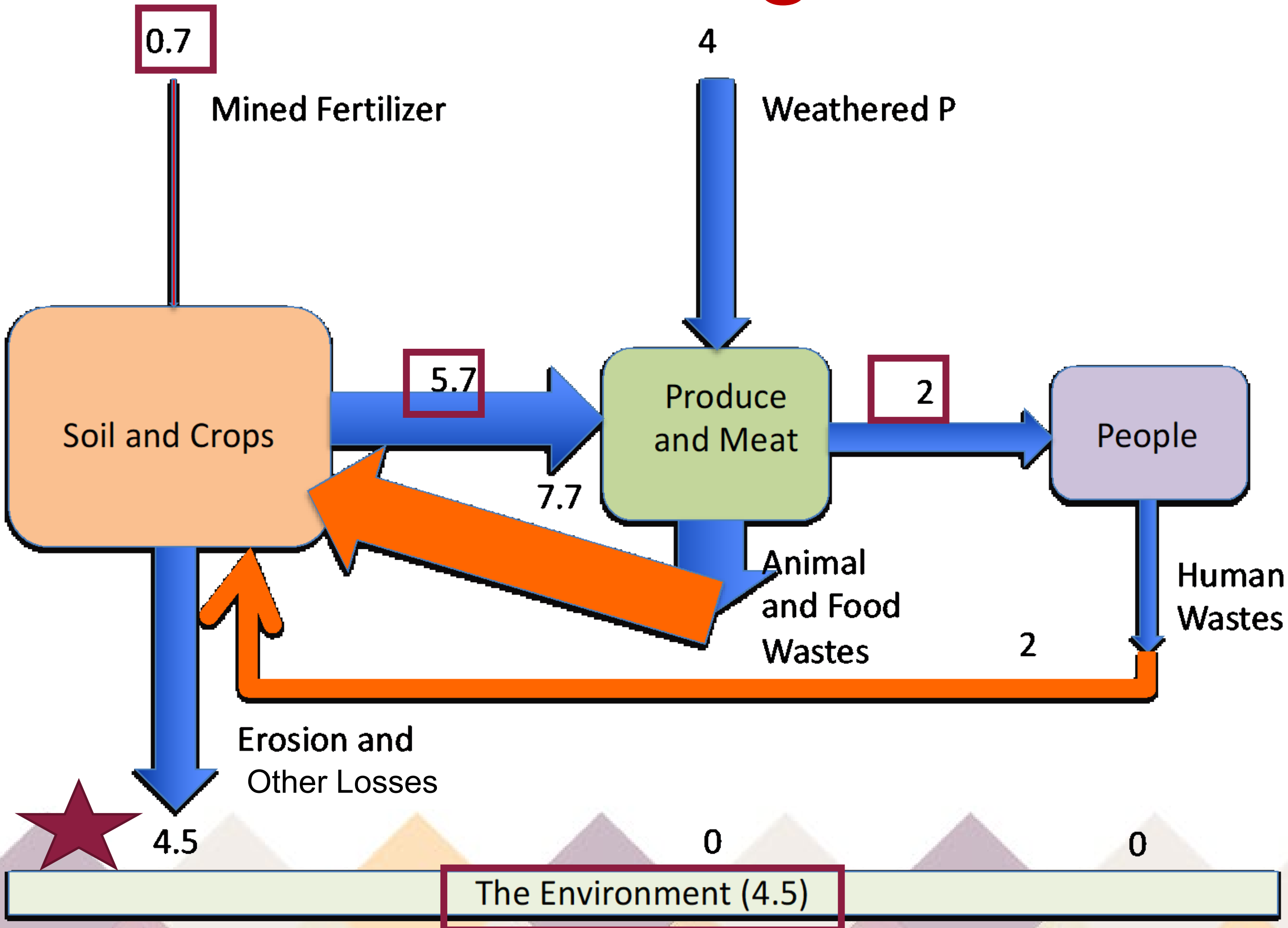
Future Case 3: Also change diet

Recover 100% of animal, food, and human wastes. Reduce erosion and drainage losses by 50%.

Cut meat consumption by 50%.

This cuts fertilizer use by 95%.

It cuts environmental P discharge by 80%.



Bonus: a spiffy animation for *Slate*

CURRENT

Minimizing P Loss, Maximizing Value

Bruce E. Rittmann
Director, Biodesign Swette Center for Environmental Biotechnology
Regents' Professor of Environmental Engineering
Arizona State University

Rittmann@asu.edu

environmentalbiotechnology.org

Auxiliary Slides

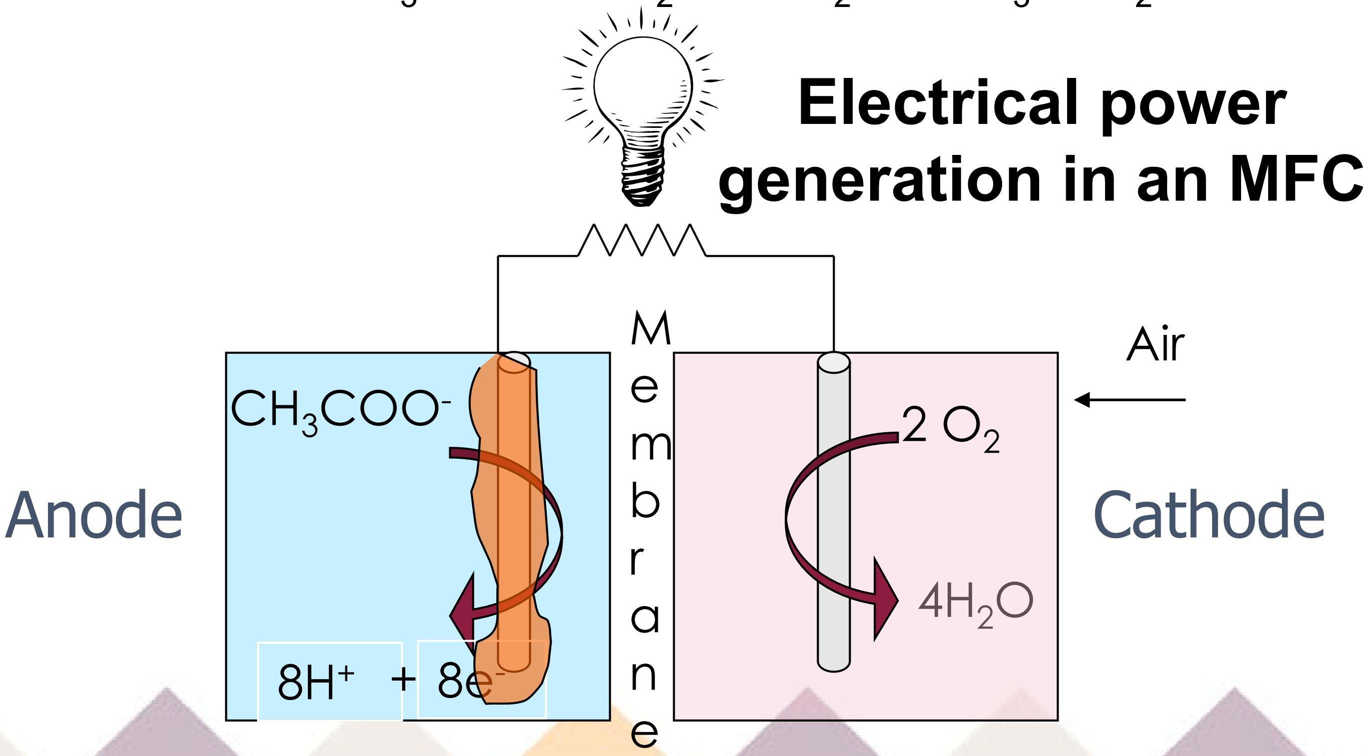
Biomass pre-treatment technologies

R&D Issues

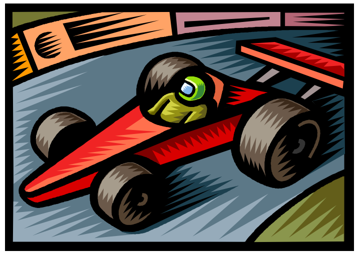
Technology	Description/Scale	Comments
Thermal	•High-temperature treatment (150-220°C) •Full-scale success	•Achieve solids reduction •Capital intensive •Energy neutral/negative
Mechanical (including ultrasound)	•Shear, pressure, homogenization, or ultrasonic physical attack of membrane •Pilot scale success	•Achieve benefits of cell lysis at small scale •High energy consumption •Restricted to WAS only
Chemical	•Addition of acids/bases/enzymes/oxidants to attack membrane •Lab/pilot scale success	•Achieve benefits of lysis •High chemical/capital costs •Chemical removal/neutralization
Electrical	•Generation of free radicals by electrolysis of water •Pilot scale demonstrations	•High energy consumption •Discontinued technology
Electromechanical – Pulsed electric fields (PEF)	•Electroporation of cell membranes resulting in osmotic lysing; disruption and fragmentation •Lab/pilot/full scale	•Demonstrated in multiple labs and at full scale •Energy positive

The Microbial Fuel Cell (MFC) for generating electrical power

e^- donor half reaction:	$CH_3COO^- + 3\,H_2O \rightarrow CO_2 + HCO_3^- + 8H^+ + 8e^-$	- 0.29 V
e^- acceptor half reaction:	$2\,O_2 + 8H^+ + 8e^- \rightarrow 4\,H_2O$	0.81 V
Net reaction:	$CH_3COO^- + 2O_2 \rightarrow CO_2 + HCO_3^- + H_2O$	1.10 V



The reaction potential drives all biological, chemical, and electrochemical processes in MFC => **typical recovered potentials are 0.3 - 0.6 V**

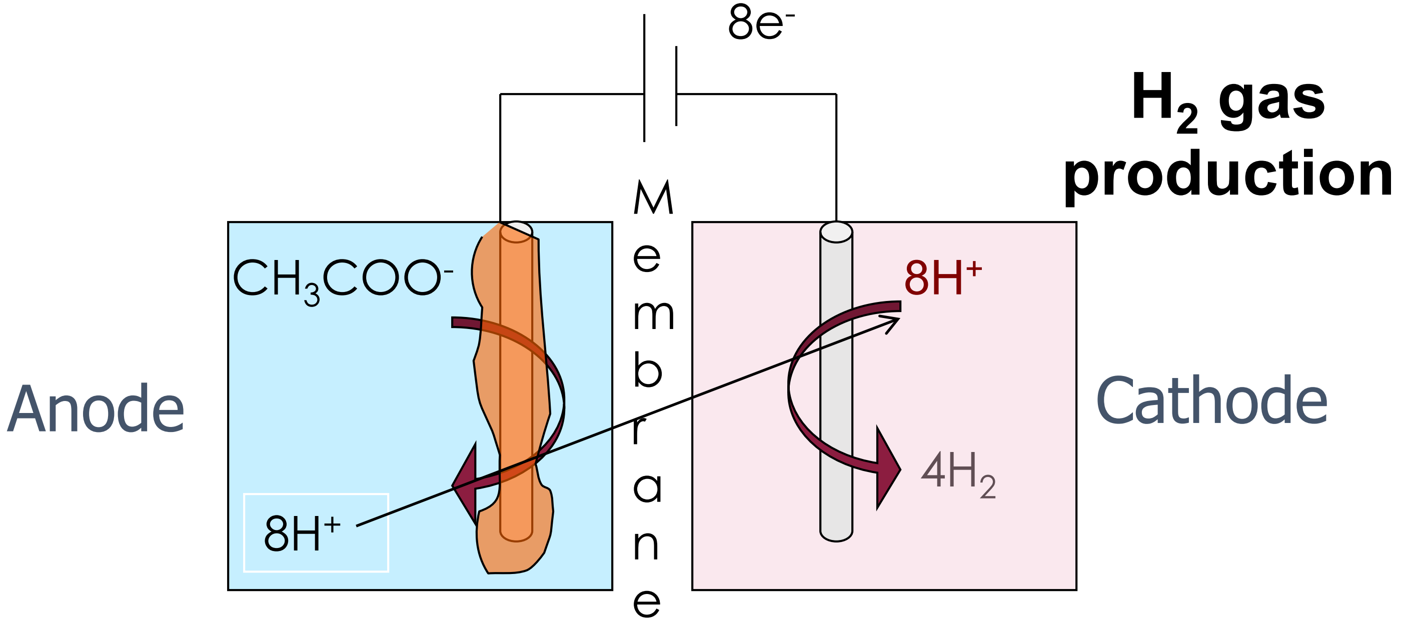


Modifying the MFC to an MEC to Produce H_2

e^- donor half reaction: $CH_3COO^- + 3\ H_2O \rightarrow CO_2 + HCO_3^- + 8H^+ + 8e^-$ -0.29 V

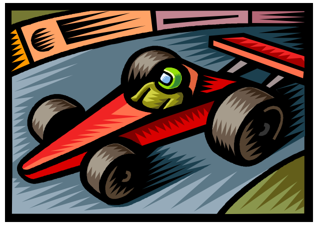
e^- acceptor half reaction: $8H^+ + 8e^- \longrightarrow 4\ H_2$ -0.41 V

Net reaction: $CH_3COO^- + 3H_2O \rightarrow CO_2 + HCO_3^- + 4\ \mathbf{H_2}$ -0.12 V



In a **Microbial Electrolysis Cell (MEC)**, we exclude O_2 and add power (applied voltage) to have a low enough cathode potential to produce H_2.

H_2 from an MEC or CH_4?



- H_2 can be used to power chemical fuel cells, say to drive your car of the future.
- H_2 is a major feedstock to the chemical industry for reductions, or hydrogenations.
- H_2 can be used for water-pollution control to reduce oxidized contaminants, like nitrate, perchlorate, selenate, and TCE ➔ The MBfR technology.
- The economic value of H_2 is 5 - 10 times greater than CH_4 on an e^- (or BOD) basis!

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Phosphorus Field-to-Watershed Modeling Task Force Report

Sustainable Phosphorus Alliance

Peter Vadas
USDA-ARS, Madison, WI

August 2018 Meeting – Columbus, OH

- 16 researchers and policy experts to discuss how to dovetail in-field P measurements and modeled P fate and transport to more effectively reduce agricultural P loss to water bodies.
- Topics
  - Soil test P measurements and fertilizer recommendations relationships
  - Trends of edge-field and in-stream water quality observations for Maumee River basin
  - Existing models to simulate soil P fate and transport in Maumee basin
- Areas for collaborative research
  - Legacy vs Incidental P loss – relative importance to P loading to Lake Erie
  - Identifying “hotspots” of elevated P export
  - Coupling models for production of organic residuals with watershed models to account for P recycling

Task Force Participants

Legacy and Incidental P Losses

- **Lead: Peter Vadas (USDA)**
- **Team: Margaret Kalcic (OSU); Laura Johnson (Heidelberg Univ.), Rebecca Muenich (ASU); Tan Zou (UMd); Kevin King, Chad Penn (USDA); Josh McGrath (UKY))**

Identifying P Loss Hotspots with Hydrologic Models

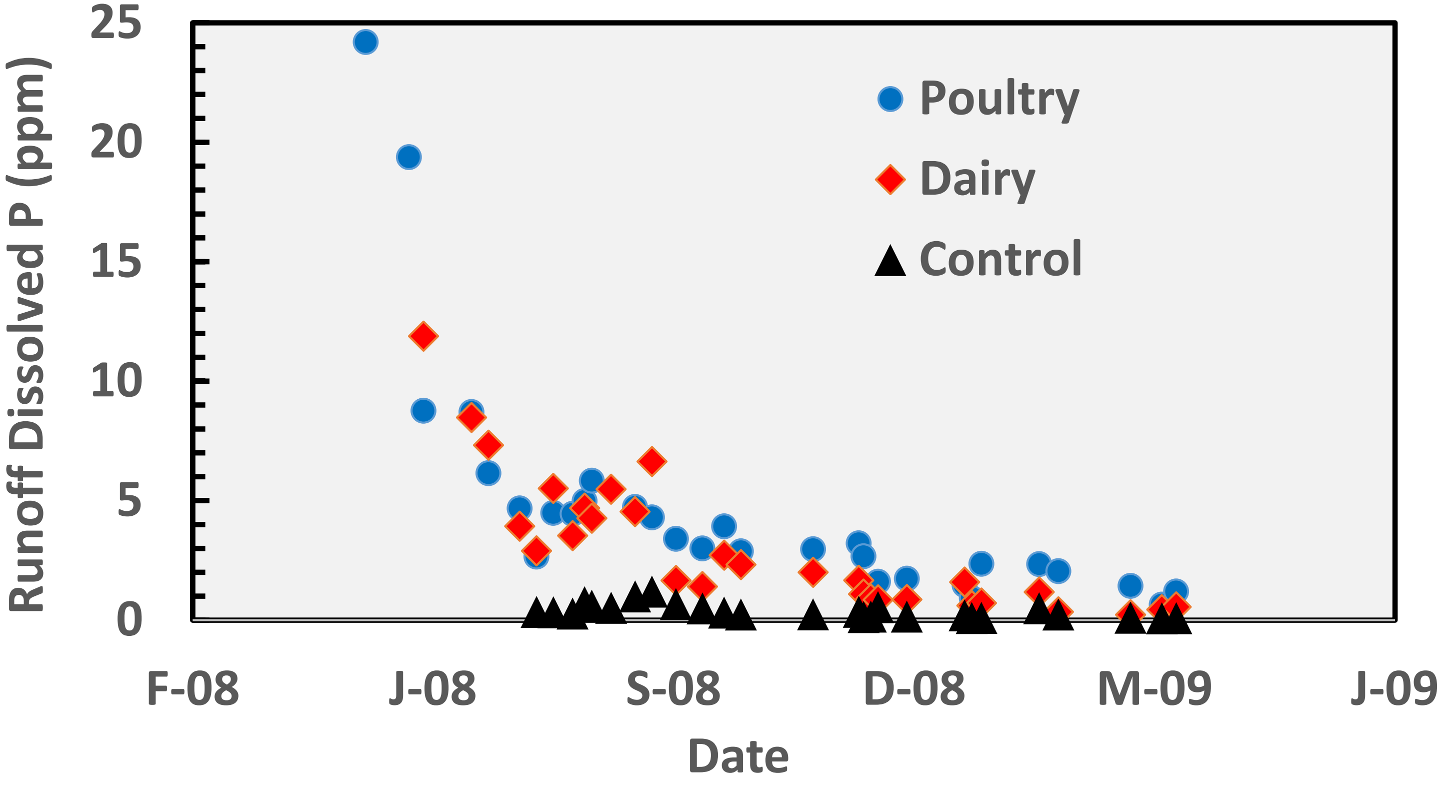
- **Lead: Rem Confessor (Heidelberg Univ.)**
- **Team: Peter Vadas (USDA), Margaret Kalcic (OSU); Rebecca Muenich (ASU); Grey Evenson (OSU); Carl Bolster (USDA)**

Coupling Process and Hydrologic Models

- **Lead: Céline Vaneeckhaute (Université Laval)**
- **Team: Rebecca Muenich (ASU); Rem Confessor (Heidelberg Univ.)**

Legacy vs Incidental P loss

- **Legacy – loss of P already in the soil from historical P applications**
- **Incidental – loss of P from newly applied fertilizer and manure**

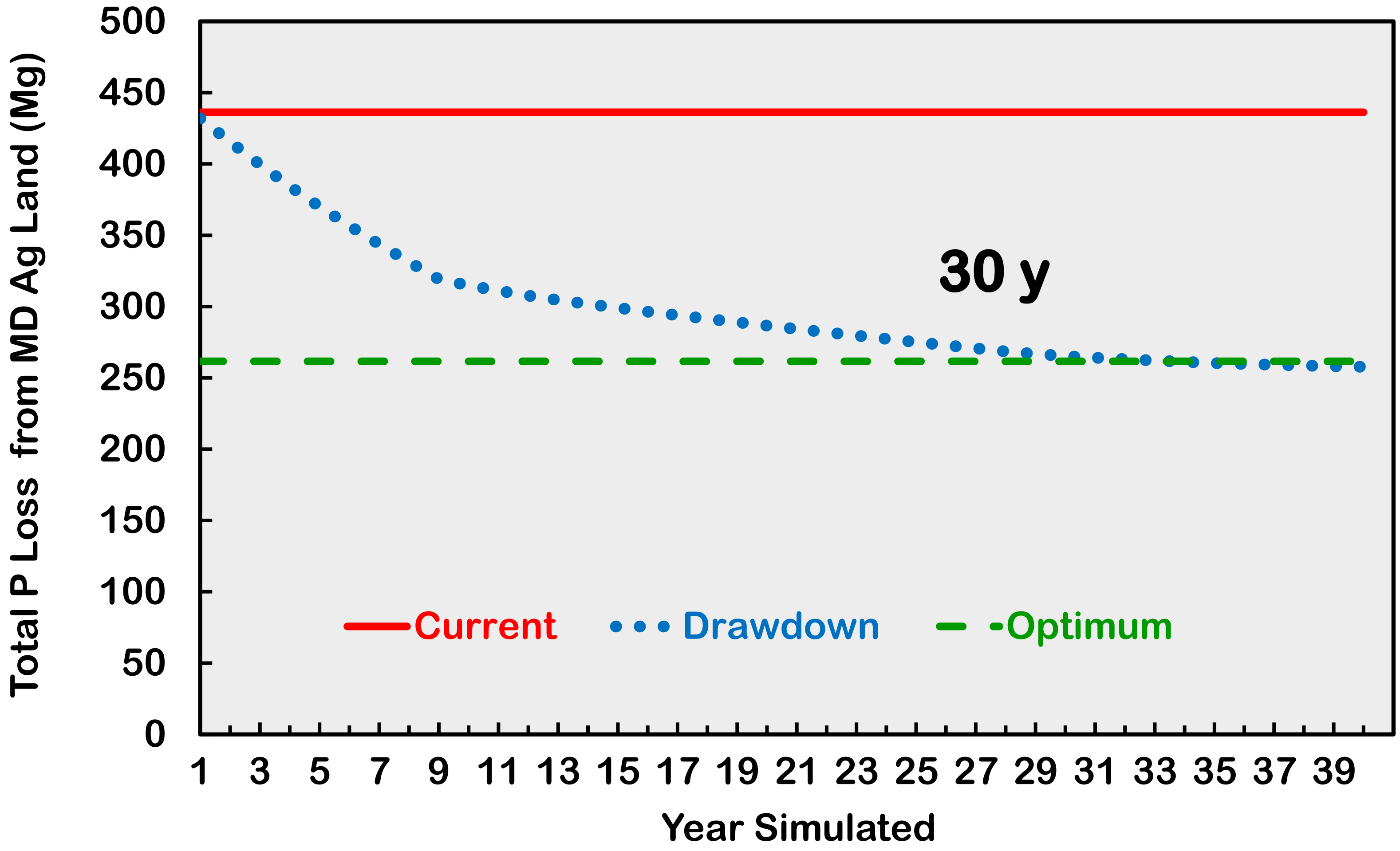


- **What is relative contribution of each?**
- **How long does incidental signal last?**
- **How does better information help set priorities and targets?**

Legacy vs Incidental P loss

- **Use field data and simulation models to tell us how best to manage these two P sources**
- **Suite of *harmonized* models available**
  - ***APLE* – annual time step, field scale, rapid, user friendly to explore broad scenarios**
  - ***SurPhos* – daily time step, field scale, user-friendly to explore event based dynamics**
  - ***SWAT* – daily time step, basin scale, more data intensive to explore spatial and transport dynamics**
  - **Use field data to test models – use models to expand scenarios and details**

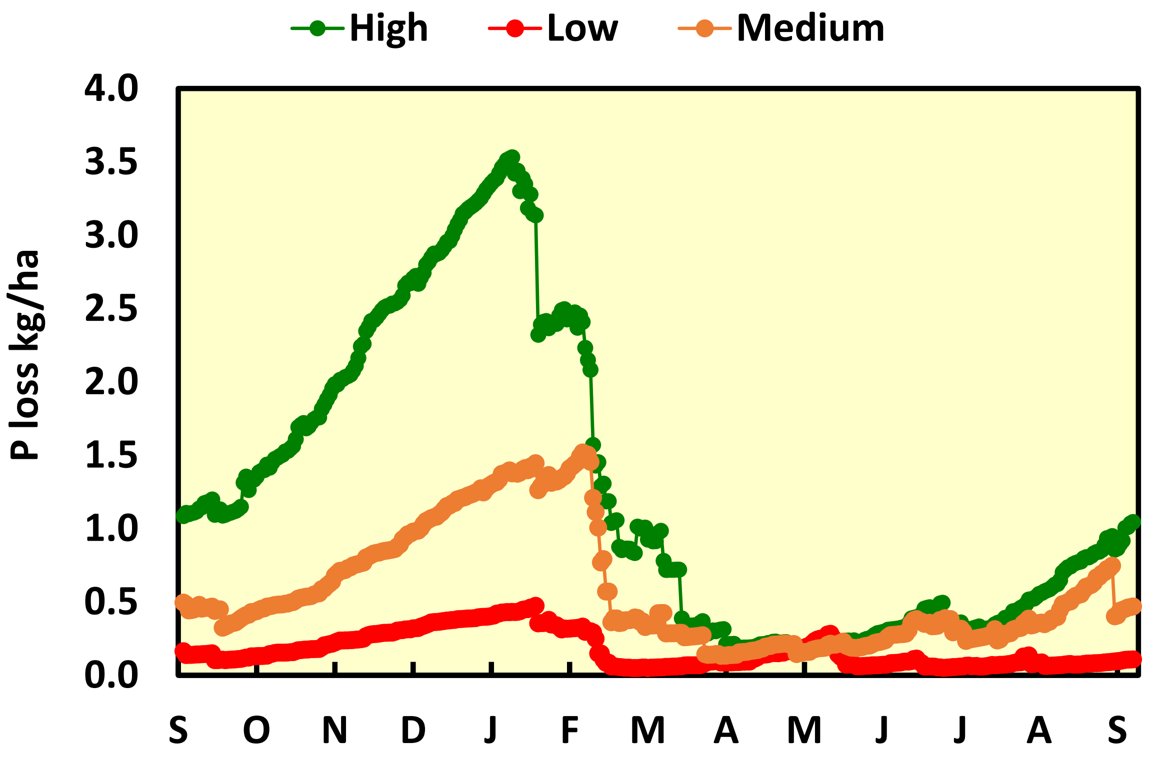
APLE application: How much can reducing legacy soil P decrease P loss from MD ag land to Chesapeake Bay



42% less P loss

Sustainable Phosphorus Alliance

SurPhos application: How does day of year manure is applied change P loss



Runoff Group	Winter P Loss (kg/ha/y)	Non-Winter P Loss (kg/ha/y)	Season Diff.	Runoff Diff. over Low
Low	0.28	0.11	2.5x	--
Med.	1.01	0.35	2.9x	3.4x
High	2.40	0.67	3.6x	7.5x

SWAT Application: **Scale analysis to watershed and find out where this makes the most difference and the impact at the final waterbody**

Identifying P hotspot with hydrologic models

Hotspots

Fields with high P loss due to high legacy soil P or excessive P application

***APLE application*:** **Legacy P hotspot quantification in Chesapeake Bay watershed**

Only 19% of land (>150 ppm STP) falls under P Index regulations, but responsible for 37% of legacy P loss

Soil test P (ppm)	% Land	% P Loss	Ratio P Loss to Land
Low runoff and erosion			
25-150	32.3	8.1	0.3
150-300	2.9	1.4	0.5
300-450	2.4	1.8	0.8
450-500	1.9	1.8	0.9
>500	0.6	0.8	1.4
Medium runoff and erosion			
25-150	44.4	45.4	1.0
150-300	3.9	6.8	1.7
300-450	3.2	8.0	2.5
450-500	2.7	7.7	2.9
>500	0.8	3.2	4.0
High runoff and erosion			
25-150	4.0	9.6	2.4
150-300	0.4	1.4	4.0
300-450	0.3	1.7	5.6
450-500	0.2	1.6	6.6
>500	0.1	0.7	9.2

Identifying Incidental P hotspots

***SurPhos Application*:** **How much can we reduce P loss by avoiding temporal P hotspots (runoff soon after P application) during 30 years of simulated manure application?**

Number of Runoff-free days after Application	0	2	4	6
Average annual P Loss (kg ha^{-1})	1.25	1.20	1.14	1.11
% of days (n=12,275) when application delay reduced P loss by more than 0.1 kg ha^{-1}	--	3.6	6.9	9.1
Average decrease in P loss (kg ha^{-1}), max in parentheses, when delay decreased P loss by more than 0.1 kg ha^{-1}	--	1.48 (5.97)	1.69 (5.97)	1.73 (5.97)
% of days when delay increased P loss by more than 0.1 kg ha^{-1}	--	1.2	2.2	3.3
Average increase in P loss (kg ha^{-1}), max in parentheses, when delay increased P loss by more than 0.1 kg ha^{-1}	--	0.35 (2.13)	0.45 (2.34)	0.47 (2.35)

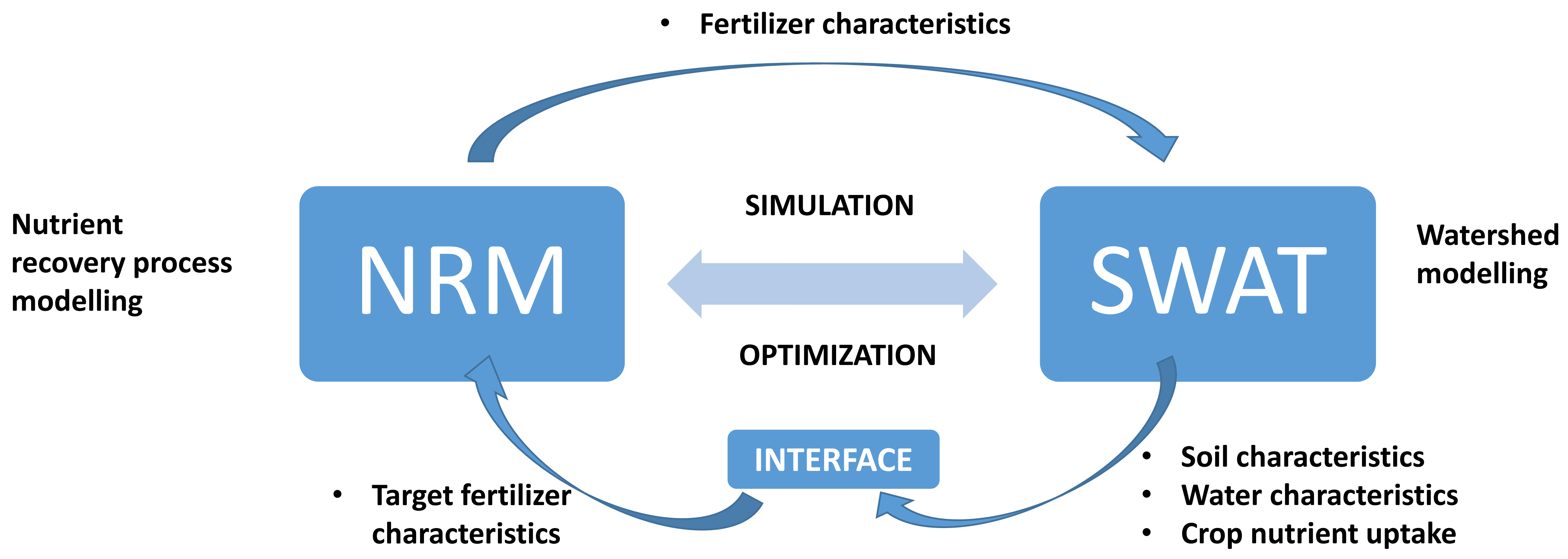
***SWAT Application*:** **Scale analysis to watershed and find out where this makes the most difference and the impact at the final waterbody**

Coupling P production models to watershed models

- <u>Objective</u>: To couple nutrient recovery process models used in wastewater treatment (e.g., NRM) with SWAT hydrologic model

- <u>Expected benefits</u>:
  - Potential to simulate and optimize nutrient behavior over the whole fertilizer production and application chain
  - Potential to adjust the fertilizer quality to the watershed or river basin quality

Concept



• Fertilizer characteristics
Nutrient recovery process modelling
NRM
SIMULATION
OPTIMIZATION
SWAT
Watershed modelling
INTERFACE
• Target fertilizer characteristics
• Soil characteristics
• Water characteristics
• Crop nutrient uptake

Research Needs

- **Development of SWAT routines to allow for more advanced physicochemical representation of fertilizer materials and runoff of fertilizer applied to soil surface.**

- **Development of an interface between NRM and SWAT to allow for easy data exchange and to calculate target fertilizer characteristics based on the soil and water quality and crop nutrient uptake.**

- **Development of an appropriate optimization algorithm for the integrated tool.**

Questions?

Sustainable Phosphorus Alliance

PhosphorusAlliance.org

YouTube

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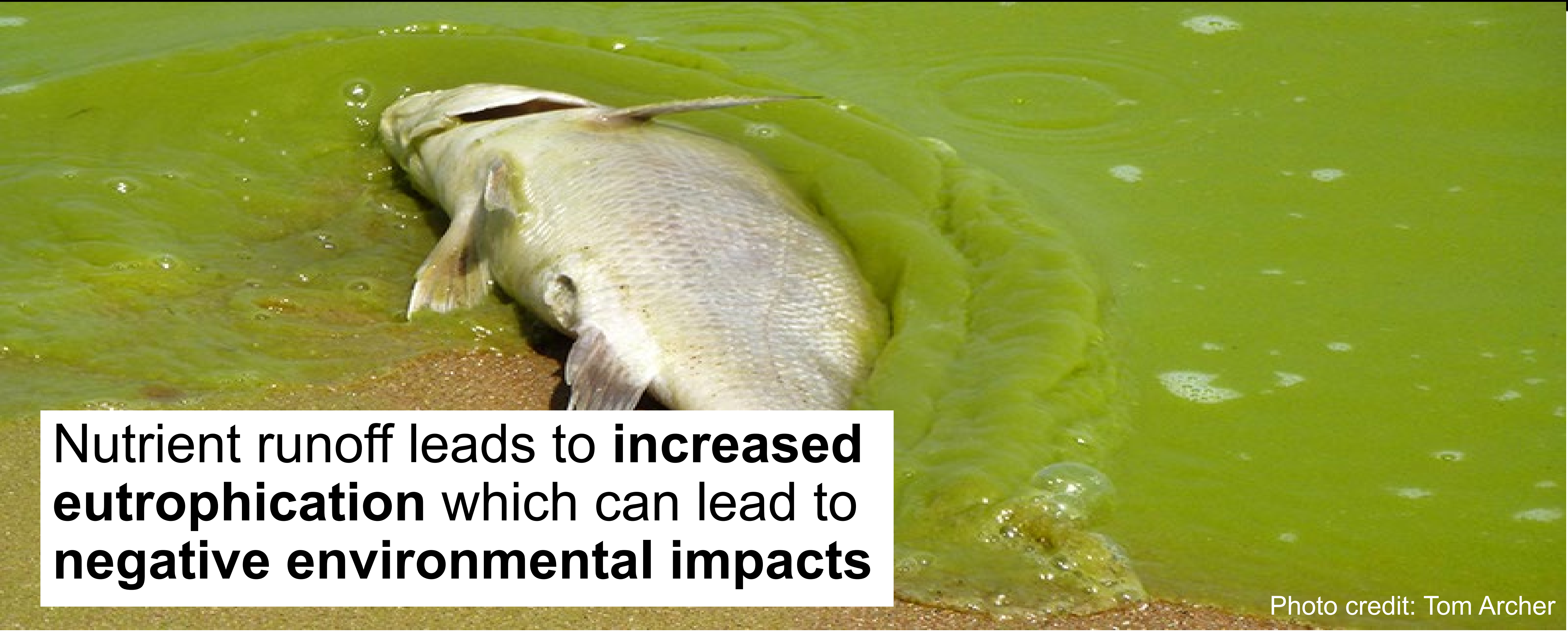
Biosolids and Manure Task Force Report

Sustainable Phosphorus Alliance

Arizona State University

Rebecca Muenich, Eleanor Rauh, Carl Churchill, Matt Scholz

Project Motivation



Nutrient runoff leads to **increased eutrophication** which can lead to **negative environmental impacts**

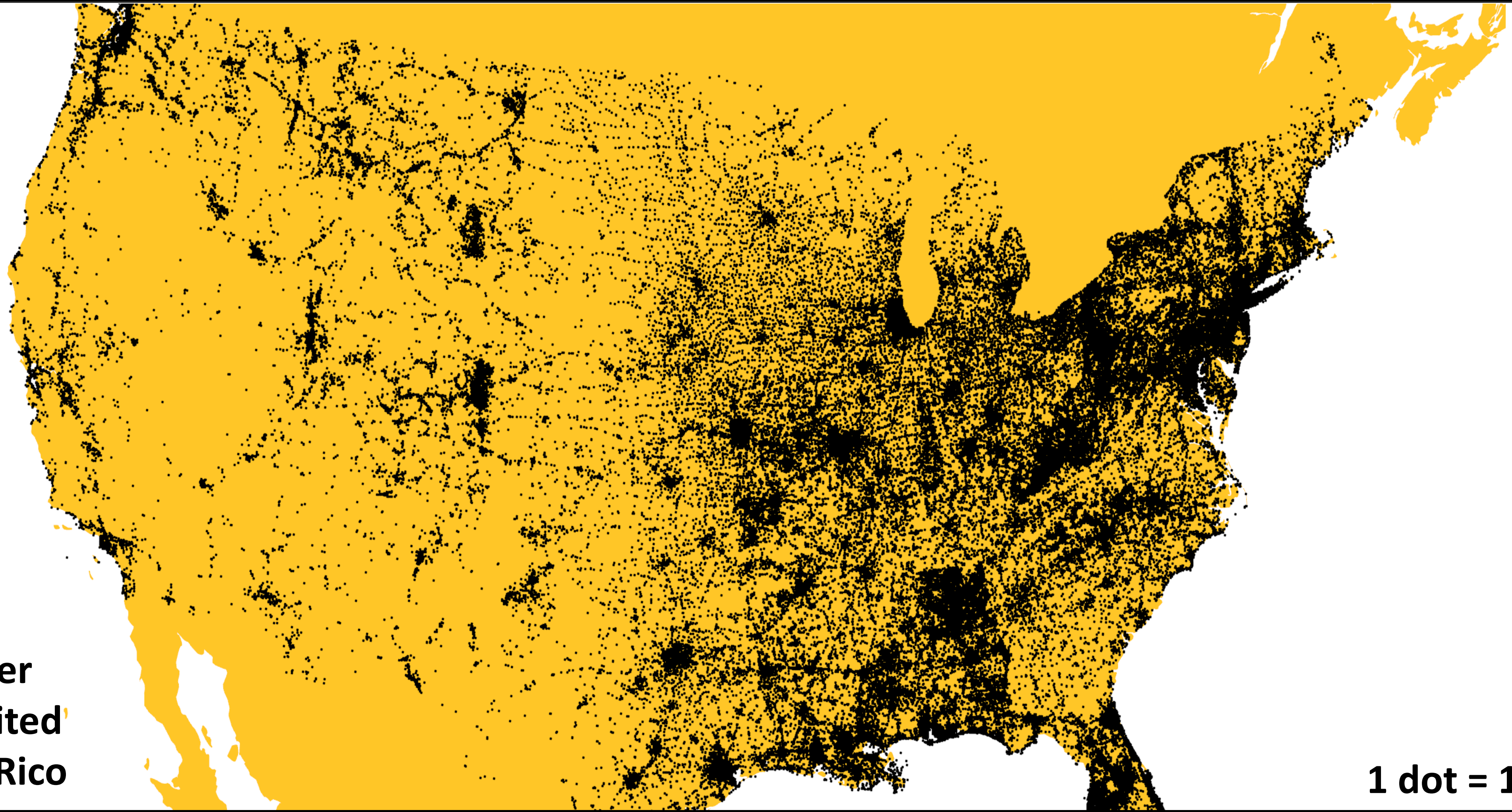
Photo credit: Tom Archer

Project Motivation

Organic residuals like biosolids and manure offer a potentially **low-cost** alternative to inorganic fertilizers

Photo credit: Treehuggertidings

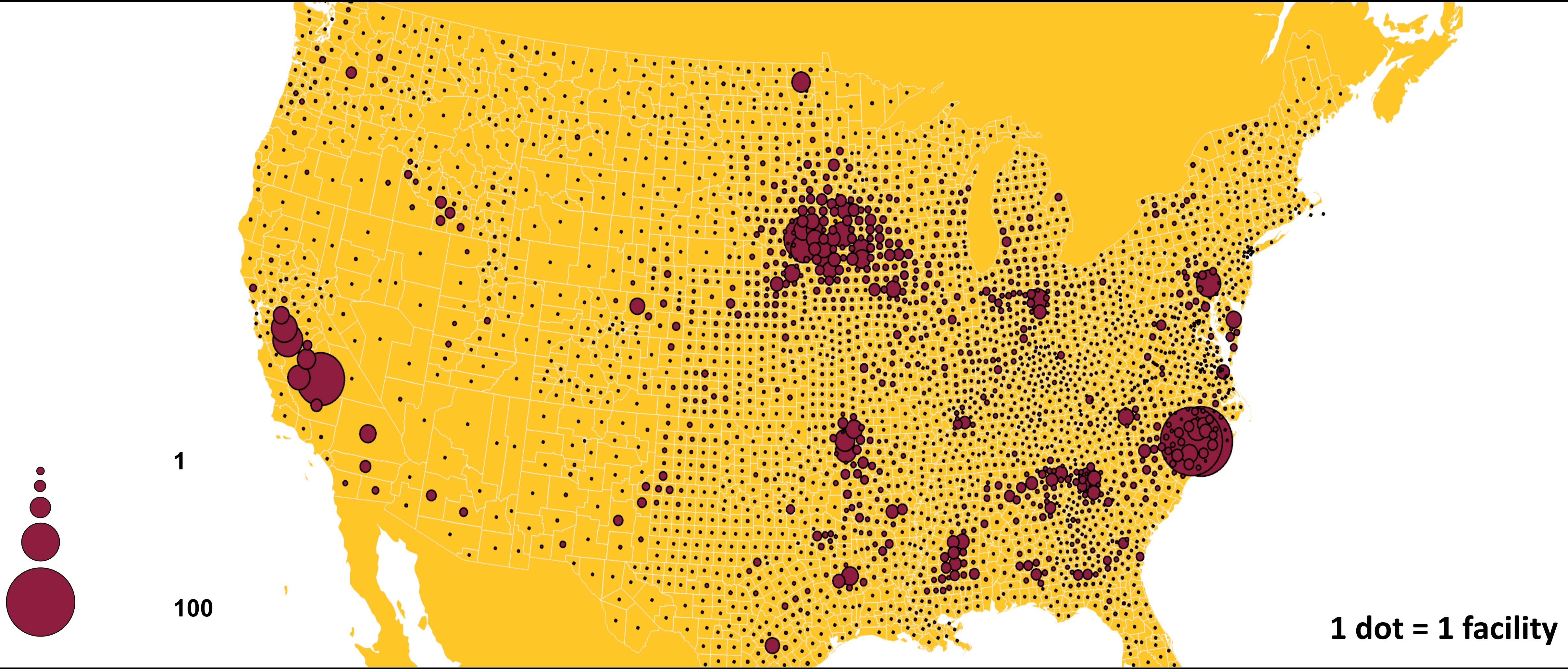
Wastewater Facilities in U.S.



There are almost 500,000 Wastewater Facilities in the United States and Puerto Rico

1 dot = 1 facility

CAFOs Per County



Sustainable Phosphorus Alliance

Project Motivation

Biosolids are federally regulated under 40 CFR Part 503, "Standards for the Use or Disposal of Sewage Sludge"

Concentrated Animal Feeding Operations (CAFO) are regulated under the National Pollutant Discharge Elimination System (NPDES) in 40 CFR Part 122 and 40 CFR Part 412

Project Motivation

The patchwork of state regulations are **cumbersome and confusing**

There is **little guidance** for states on developing regulations

This **impairs** the development of recycled fertilizer markets

Project Goal

The Biosolids and Manure Task Force work will let practitioners, agencies, and researchers easily study state and federal regulations on biosolids and manure by providing a user-friendly clearinghouse for land application regulations for industry, regulators, and others with vested interests.

Data Gathering

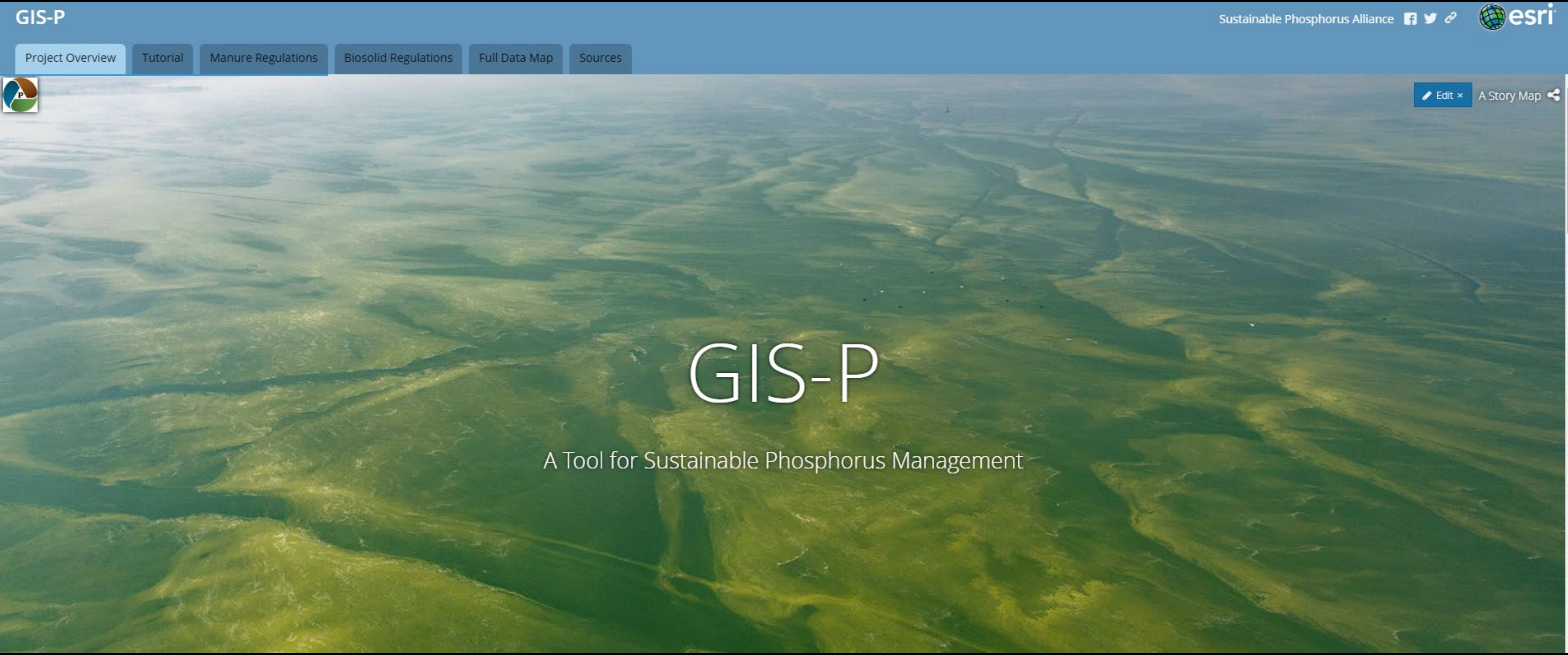
- May 2018-August 2018: Collect all state-level regulations governing the land application of biosolids and manures from CAFOs
- August 2018-March 2019: QA'd with state regulators

Tool Development

Translate Compendium information into a readable database

Column ID	Description	Data Type	Mappable
STATE_NAME	State name	Text	N
STATE_FIPS	Federal information processing standard (FIPS) state code	Integer	N
SUB_REGION	Subregion state belongs to	Text	N
STATE_ABBR	Alphabet code for state	Text	N
REG_AGEN	Name of regulatory agency	Text	N
REG_AGEN_CAT	Regulatory agency category: state epa, state ag, nat resour, health, combo, other	Text	Y
REG_LINKS	URL links to regulations	Text	N
DEL_ST	Is state delegated for biosolids? : yes, no	Text	Y
OTHER	Other important details to highlight	Text	N

GIS-P


GIS-P
Sustainable Phosphorus Alliance
esri
Project Overview
Tutorial
Manure Regulations
Biosolid Regulations
Full Data Map
Sources
Edit ×
A Story Map
GIS-P
A Tool for Sustainable Phosphorus Management

GIS-P

Sustainable Phosphorus Alliance

Project Overview | Tutorial | Manure Regulations | Biosolid Regulations | Full Data Map | Sources

Uses for GIS-P

- Scenario planning
- Comparisons across states
- Allows regulators to compare with nearby states
- Contextualization of regulations with related data

Data Collection Challenges

- Inconsistent Terminology & Approaches to Regulations
- “Gray” Areas of Regulations
- Some states still not QA’d

Requesting Your Feedback

States That Still Need QA

Biosolids
- California
- Connecticut
- Georgia
- Missouri
- Nebraska
- New Hampshire
- New Mexico
- Rhode Island
- Tennessee
- West Virginia
- Some California Regions

Manure
- Alaska
- Some California RWQBs
- Florida
- Hawaii
- Idaho
- Missouri
- Montana
- New Jersey
- North Carolina
- Rhode Island
- Tennessee
- Texas
- Vermont
- West Virginia
- Wisconsin

Also Consider…
- Other supplemental data you'd like to see
- Thoughts on "ease of use"

- Continuing to work on Canada

GIS-P

- We translated difficult to review/compare regulations into a user-friendly tool
- Makes comparison across states easy
- Allows for incorporation of other, related data sources for context
- Allows for multiple kinds of visualizations of complex data

ASU Arizona State University

For more information

Rebecca Muenich
(Rebecca.Muenich@asu.edu or muenichlab.com)

Matthew Scholz
(scholz@phosphorusalliance.org)

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